NARODOWE CENTRUM BADAŃ JĄDROWYCH

NATIONAL CENTRE FOR NUCLEAR RESEARCH

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CONTENTS

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MAIN RESEARCH ACTIVITIES

I. Astrophysics, Cosmic Rays & Elementary Particle Physics, Obserwational Astronomy

1. High-energy hadron-hadron interactions.
2. Elastic and inelastic μ and e interactions. Nucleon structure - theory and astronomy experiments.
3. Rare decays.
4. Baryon resonances and near threshold meson production.
5. Neutrino physics.
6. Astrophysics: optical detection of short bursts, large-scale structure, dark matter.
7. Cosmic ray physics.
8. Cosmology.
9. Theory of lepton and hadron interactions.
10. Theory of gravitational systems.

II. Nuclear physics

1. Relativistic ion collisions.
2. Nuclear reactions.
3. Nuclear structure.
4. Properties of heavy and superheavy nuclei (theory).
5. Theory of nuclear matter, hypernuclei & nuclear structure and dynamics.
6. Exotic nuclei.

III. Plasma physics and technology

1. Development of methods and tools for plasma diagnostics.
2. Physical phenomena in hot plasma and plasma interaction with solid targets.
3. Thin Nb and Pb film coating by means of arc discharges under ultra-high vacuum conditions.
4. Nonlinear effects in extended media & Bose-Einstein condensates (theory).
5. Fusion power reactors - modelling and calculations

IV. Accelerators, detectors & electronics

1. R&D of linear accelerators for high-energy electrons.
2. Optimization of TiN coating processes for accelerating structures.
3. New detection methods and their application in physics experiments, nuclear medicine and homeland security.
4. Electronics and detectors for large-scale experiments.
5. Systems for nuclear radiation spectrometry.
6. R&D of special silicon detectors for physics experiments and environmental protection.

V. Solid state physics, physics & engineering of materials; applications

1. Materials structure studies by nuclear methods.
2. Ion/plasma material modyfication; synthesis of new materials.
3. Diffusion processes in solids.
4. Arheometry: material studies of archeological objects using physical methods.

VI. Reactor physics, nuclear technology in energy generation, modelling & calculations

1. Physics, technology and safety of nuclear reactors.
2. Nuclear power energy generation.
3. Management of spent nuclear fuel and radioactive waste. Nucelar transmutation.

4. New reactors for non-electric applications (HTGR, VHTR, DFR).

VII. Nuclear technology in health and enviromental protection, management of hazards

1. Development of new radiopharmaceuticals for diagnostics and radionuclide therapy.
2. Dosimetry and nano-dosimetry.
3. Computer modelling of radiation sources, transport of radiation through matter and radiation dose calculations.
4. X-ray sources for medicine and industry.
5. New methods for obtaining radioactive isotopes; radioactivity standards.
6. Methods of assessment and forecasting of environmental threats from nuclear and industrial facilities.
7. Air monitoring.

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47.	Piazza L.	Italy	30 - 31.0 5 5.07	Polatom
48.	Pino F.	Padova University, Italy		TJ3
49.	Podowski M.	Center for Multiphase Research, Rensselaer Polytechnic Institute , Troy, NY, USA	13.10	UZ3
50.	Rigamonti D.	Universita di Milano-Bicocca, Mediolan, Italy	16 - 20.01 13 - 17.02	TJ4
51.	Rocha A.M.	Tecnico, Portugal	30.03.	Polatom
52.	Saas L.	CEA, Cadarache	15.05	UZ3
53.	Sacchi D.	ORTEC, Italy	07.06	Polatom

54.	Safarikova V.	UJV Rez, a. s., Cadarache	15.05	UZ3
55.	Serge D.	Hit Tech Relay	03.04	UZ3
56.	Shams A.	NRG, Petten	15.05 08 -10.02	UZ3
57.	Solberg S.	Gexcon, Bergen	21.03	UZ3
58.	Stevanato L.	Padova University, Italy		TJ3
59.	Streng R.	Eckert & Ziegler, Germany	06.09	Polatom
60.	Suthanthiran K.	Best Medical International, Inc. USA	19.06	Polatom
61.	Takeuchi T.	Nagoya University, Japan	04 - 08.06	DBP
62.	Tardocchi M.	Instituto di Fisica del Plasma, Mediolan, Italy	16 - 20.01 13 - 17.02	TJ4
63.	Thomas R.	European Southern Observatory (ESO)	4.05 - 26.06	DBP
64.	Topolnytskyi K.	Italy	21.06	Polatom
65.	Tritscher T.	TSI Europa, Germany	06.11	TJ4
66.	TsaiYue-Lin Sming	Physics Division, National Center	18 27.05	BP2
67.	Venneri F.G.V.	USNC	03.04	UZ3
68.	Vyskocil L.	UJV Rez a.s., Husinec	15.05	UZ3

FOREIGN INTERNSHIPS

1.	Klamra W.	Department of Physics Institut of Technology AlbaNova, Stoskholm, Sweden		TJ3
2.	Chewpraditkul W.	KMUTT, King Mongkut`s University of Technology Thonburi, Bangkok, Thailand		TJ3
3.	Sakthong O.	KMUTT, King Mongkut`s University of Technology Thonburi, Bangkok, Thailand		TJ3
4.	Chewpraditkul W.	KMUTT, King Mongkut`s University of Technology Thonburi, Bangkok, Thailand		TJ3
5.	Małek K.	Laboratoire d`Astrophisique de Marseille, Marseille, France	01.01 - 31.12.	BP4
6.	Zadrożny A.	University of Texas Rio Grande Vallery, Brownsville, USA	28.08.17 - 1.08.19	BP4
7.	Plebaniak Z.	APC - Astro Particle and Cosmology at University Paris, France	23.10 - 30.10	BP4
8.	Carrington M.	Brandon University, Canada	2.06 - 14.07	BP3
9.	Jakubowski M.	Institute of Plasma Physics AS CR, Praque, Czech Republic	12-23.06; 2.11-30.11	TJ5
10.	Kozioł K.	Northeastern University of Argentina, Corrients, Argentina	1.07.17 - 30.06.18	TJ5
11.	Kwiatkowski R.	Institute of Plasma Physics AS CR, Praque, Czech Republic	12-16.06	TJ5
12.	Rabiński M.	Institute of Plasma Physics AS CR, Praque, Czech Republic	19-23.06	TJ5
13.	Załoga D.	Institute of Plasma Physics AS CR, Praque, Czech Republic	20-30.11.	TJ5
14.	Koszuk Ł.	Oak Ridge National Laboratory, USA	26.10.16 - 10.03.17	UZ3
15.	Spirzewski M.	CEA, Saclay, France	13.03 - 14.04	UZ3
16.	Wróblewska M.	CEA Cadarache, France	01.04.17 - 31.01.18	UZ3
17.	Sikora A.	Portugal	14.05. - 14.06.	Polatom

PROJECTS

Research Projects Implemented with the Funds for Science

National Science Centre

1. Studies of CPT symmetry violation
   Principal Investigator: W. Krzemień, PhD
   No. 2014/12/S/ST2/00459; 2014-2017
   (FUGA 3)

2. Search for a new exotic boson in light meson decays
   Principal Investigator: D. Pszczel
   No. 2014/15/N/ST2/03179; 2015-2017
   (PRELUDIUM 8)

3. Study of polarization of gamma photons from gamma-ray bursts based on computer simulation of the photon detection in space-borne polarimeter POLAR
   Principal Investigator: A. Zwolińska
   NO. 2015/17/N/ST9/03556; 2016-2017
   (PRELUDIUM 9)

4. Cosmological models testing with deep galaxy surveys
   Principal Investigator: Assoc Prof. Agnieszka Pollo
   No. 2012/07/B/ST9/04425; 2014-2018
   (OPUS 4)

5. Investigation of the CP and CPT symmetries and the structure and decays of mesons at low energies in experiments KLOE/KLOE-2
   Principal Investigator: Prof. W. Wiślicki
   No. 2013/08/M/ST2/00323; 2013-2017
   (HARMONIA 4)

6. Badanie wpływu parametrów modeli oddziaływań wielkich energii na rozwój WPA i możliwości pomiarowe eksperymentu JEM-EUSO
   Principal Investigator: Z. Plebaniak
   No. 2016/20/T/ST9/00589; 2016-2018
   (ETIUDA 4)

7. Classification and clustering analysis of infrared-selected galaxies
   Principal Investigator: A. Solarz, PhD
   No. 2015/16/S/ST9/00438; 2015-2018
   (FUGA 4)

8. Participation of Poland in the Advanced Virgo project
   Principal Investigator: Prof. A. Królak (Leader: Institute of Mathematics Polish Academy of Sciences)
   No. 2014/14/M/ST9/00707; 2015-2018
   (HARMONIA 6)

9. T2K - the second generation neutrino experiment
   Principal Investigator: Prof. E. Rondio (Leader: The Henryk Niewodniczański Institute of nuclear Physocs Polish Academy of Sciences)

No. 2014/14/M/ST2/00850;2015-2018
(HARMONIA 6)

10. Study of proton-proton, hadron-nucleus and nucleus-nucleus relatyvistic collisions in the NA61/SHINE experiment at the CERN SPS - second stage
Principal Investigtaor: Prof. J. Stepaniak (Leader: Jagiellonian University)
No. 2015/18/M/ST2/00125; 2016-2019
(HARMONIA 7)

11. Study of electroweak procesess involving heavy quarks and participation in LHCb detector maintenance: Prof.. W.Wiślicki (Leader: The Henryk Niewodniczański Institute of Nucelar Physics Polish Academy of Sciences)
No. 2015/18/M/ST2/00123; 2016-2018
(HARMONIA 7)

12. Nuclear studies with radioactive beams at the CERN-ISOLDE laboratory
Principal Investigator: Prof. Z. Patyk (Leader: Warsaw University)
No. 2015/18/M/ST2/00523; 2016-2019
(HARMONIA 7)

13. Experiment COMPASS - study of the three-dimensional and spin structure of the nucleon
Principal Investigator: Prof. A. Sandacz (Leader: National Centre for Nuclear Researche)
No. 2015/18/M/ST2/00550; 2016-2018
(HARMONIA 7)

14. Polish contribution to preparation and implementation of the research program for CTA project in its first phase of operation prof.. L.Roszkowski (Leader: Jagiellonian University
No. 2016/22/M/ST9/00583; 2017-2020
(HARMONIA 8)

15. Research of fundamental properties of nuclear matter in the ALICE experiment at the Large Hadron Collider LHC at CERN: Prof. T.Siemiarczuk (Leader: The Henryk Niewodniczański Institute of Nucelar Physics Polish Academy of Sciences)
No. 2016/22/M/ST2/00176; 2017-2020
(HARMONIA 8)

16. Dark matter: theoretical models, particle candidates and prospects for their experimental discovery
Principal Investigator: Prof. L. Roszkowski
No. 2015/18/A/ST2/00748; 2016-2021
(MAESTRO 7)

17. Decays onto tau leptons - a tool to probe properties of a Higgs boson with the CMS experiment at LHC
Principal Investigator: M Bluj, PhD
No. 2014/13/B/ST2/02543; 2014-2018
(OPUS 7)

18. The synthesis and characterization of copper nitride coatings deposited by use of plasma surface engineering methods
Principal Investigator: K. Nowakowska-Langier, PhD;
No. 2014/15/B/ST8/01692; 2015-2018
(OPUS 8)

19. A search for long-lived massive charged particles using the CMS detector at the LHC operating at proton-proton collisions energy of 13 TeV
Principal Investigator: Assoc. Prof. P. Zalewski
No. 2014/15/B/ST2/03998; 2015-2018
(OPUS 8)

20. Dynamics of Yang-Mills plasma
Principal Investigator: Prof. M. Spaliński
No. 2015/19/B/ST2/02824; 2016-2018
(OPUS 10)

21. In vitro and in vivo preclinical studies of NaA nanozeolite functionalized with antibodies anti-PSMA and labeled with radium radioizotope for targeted prostate cancer therapy
Principal Investigator: Assoc. Prof.. R. Mikołajczak (Leader: Institute of nuclear Chemistry and Technology)
No. 2015/19/B/NZ7/02166; 2016-2019
(OPUS 10)

22. Investigation of correlated nucleon pairs in neutrino interactions
Principal Investigator: J. Zalipska PhD (Leader: University of Wrocław)
No. 2016/21/B/ST2/01092; 2017-2020
(OPUS 11)

23. Determination of Charge Parity symmetry (CP) breaking in the B meson decay channel B0s->J/Psi Phi
Principal Investigator: V.Batozskaya
No. 2015/17/N/ST2/04056; 2016-2018
(PRELUDIUM 9)

24. Indirect search for dark matter with the Super-Kamiokande detector
Principal Investigtaor: K. Frankiewicz
No. 2015/17/N/ST2/04064; 2016-2018
(PRELUDIUM 9)

25. Experiment EUSO-TA - detector calibration and Ultra High Energy Cosmic Rays measurements of cosmic rays in coincidence with Telescope Array experiment
Principal Investigator: Z. Plebaniak
No. 2015/19/N/ST9/03708; 2016-2019
(PRELUDIUM 10)

26. New source of knowledge about Early Piast history. Technological study on slavic jewelry
Prinicipal Investigator: E. Miśta
No. 2016/23/N/HS3/03160; 2017-2020
(PRELUDIUM 12)

27. Evolution and star formation history in red passive galaxies
Principal Investigator: M. Siudek
No. 2016/23/N/ST9/02963; 2017-2019
(PRELUDIUM 12)

28. Zastosowanie teorii indeksów Sobola do Globalnej Analizy Niepewności i Wrażliwości procesów zachodzących w reaktorach jądrowych
DEC-2017/01/X/ST8/01605; 2018-2018
(MINIATURA 1)

29. Classification if z~1
Principal Investigator: K. Małek, PhD
No. 2013/09/D/ST9/04030; 2014-2018
(SONATA 5)

30. The nitride semiconductor stuctures for long-lived betavoltaic nuclear batteries on galium nitride substrates with reduced of dislocations
Principal Investigator: P. Laskowski (Leader: Institute of High Pressure Physics of the Polish Academy of Sciences)
No. 2014/15/D/ST7/05288; 2015-2018
(SONATA 8)

31. Properties of galaxy clustering in the early stages of universe evolution
Principal Investigator: A. Durkalec, PhD
No. 2015/17/D/ST9/02121; 2016-2019
(SONATA 9)

32. Indirect search for dark matter with water neutrino detectors
Principal Investigator: P. Mijakowski, PhD
No. 2015/18/E/ST2/00758;2016-2020
(SONATA BIS 5)

Ministry of Science and Higher Education

1. **GBAR** - Opracowanie i wykonanie akceleratora liniowego wysokiej częstotliwości dla eksperymentu GBAR
Principal Investigator: S. Wronka, PhD
Nr3399/GBAR/2015/0 (2015-2019)

2. **MOB Trojanowski** - Mobilnośc Plus – IV edycja programu
Principal Investigator: S. Trojanowski, PhD
Umowa nr 1309/MOB/IV/20185/0 (2016-2018)

3. **BENICE -** Modelowanie zatruć w berylu powstających podczas eksploatacji oraz eksperymentalna walidacja w reaktorach doświadczalnych na przykładzie reaktorów MARIA i JHR
Principal Investigator: Z. Marcinkowska, PhD
Nr W60/JHR CEA/2015 (2015-2018)"

4. **C-BORD -** Wydajny system do inspekcji kontenerów na przejściach granicznych
Nr 328682/PnH/2016 (2016-2018)

5. **JENNIFER -** Japońsko-europejska sieć dla eksperymentalnego badania neutrin i wysokich intensywności
328686/PnH/2016 (2016-2019)

6. **JENNIFER -** Japońsko-europejska sieć dla eksperymentalnego badania neutrin i wysokich intensywności
nr 3813/H2020/2017/2 (2017-2019)

7. **SKPLUS -** Suoper-Kamiokande plus
Nr 328780/PnH/2016 (2016-2018)

8. **VINCO -** Inicjatywa Wyszehradzka Współpracy Jądrowej
Nr 328538/PnH/2016 (2016-2018)

9. **IVMR -** Retencja stopionego rdzenia w zbiorniku reaktora - strategia zarządzania awariami ciężkimi dla istniejących i przyszłych elektrowni jądrowych
Nr 328610/PnH/2016 (2016-2019)

10. **IVMR -** Retencja stopionego rdzenia w zbiorniku reaktora - strategia zarządzania awariami ciężkimi dla istniejących i przyszłych elektrowni jądrowych
Nr 3555/H2020-EURATOM/2016/2 (2016-2019)

11. **EUROfusion_NCBJ-JET4 -** Udział NCBJ w budowie detektorów we Wspólnym Europejskim Programie Wspólnoty EURATOM powołanym decyzją Rady UE Nr 1314/2013 z dnia 16 grudnia 2013, uzupelniającym program Horyzont 2020
Nr 3212/H2020-Euratom/2014/2 (2014-2018)

12. **EUROfusion -** Wdrożenie zadań przedstawionych na Mapie Drogowej Fuzji w projekcie "Horyzont 2020" w ramach wspólnego programu realizowanego przez członków Konsorcjum EUROfusion
Nr 329717/PnH/2016 (2016-2018)

13. **QUACO -** Korektor kwadrupolowy
Nr 328598/PnH/2016 (2016-2020)

14. **BRILLIANT -** Bałtycka Inicjatywa na Rzecz Zrównoważonych Technologii Jądrowych
Nr 328540/PnH/2016 (2016-2018)

15. **ESS-ENV -** Zaawansowane symulacje Monte-Carlo dotyczące zagadnień ochrony radilogicznej otoczenia akceleratora liniowego ESS
Nr 3735/ESS/2017/0 (2017)

16. **ESS ERIC -** Projektowanie oraz instalacja systemów sterowania LLRF dla sekcji M-Beta i H-Beta akceleratora European Spallation Source (ESS)
Decyzja nr DIR/WK/2016/03 (2016-2021)

17. **ESS ERIC -** ESS ERIC - European Spallation Source ERIC.Finansowanie kosztów wkładu krajowego wnoszonego na rzecz udziału we wspólnym międzynarodowym przedsięwzięciu
Decyzja nr DIR/WK/2016/04 (2016-2018)

18. **CEPTA -** Porównanie własności fosforku galu implantowanego tytanem po wygrzewaniu termicznym i po impulsie elektronowym
Umowa nr 3770/SPIRIT/2017/0 (2017-2018)

19. **XFEL -** Budowa i funkcjonowanie Europejskiego Ośrodka Badań Laserem Rentgenowskim na Swobodnych Elektronach - XFEL
Decyzja nr 6109/IA/621/2010
Decyzja nr 6109/IA/621/2010/2011
Decyzja nr 6109/IA/621/2010/2011/2014
Decyzja nr 6109/IA/621/2010/2011/2014/2016 (2010-2017)

20. **ALICE-PL -** Eksperyment ALICE przy akceleratorze LHC w CERN
Decyzja nr DIR/WK/2016/17 (2017-2021)

21. **SCAND-I-CO -** Dotacja na innowacyjne metody otrzymywania 47Sc i 67Cu w reaktorze jądrowym i cyklotronie
Nr 3639//FAO/IAEA/16/2017/0 (2017-2018)

22. **NEUTRINA-T2K -** Eksperyment T2K (Tokai-toKamioka)
Decyzja nr DIR/WK/2017/05 (2017-2022)

23. **XFEEL NADZÓR -** Europejski Ośrodek Badań Laserem Rentgenowskim na Swobodnych Elektronach
Decyzja nr DIR/WK/2017/11 (2017-2021)"

24. **EUROfusion -** Wspólny Program Fuzji Jądrowej
nr 3816/H2020-Euratom/2017/2 (2017)

25. **POLFEL -** Budowa zimnego źródła, jako pierwszego etapu konstrukcji Polskiego Lasera na Swobodnych Elektronach
Decyzja Nr 212727/E-78/S/2017-1 (2017-2018)

National Centre for Research and Development

1. **ZNOLUM -** Light emitting photonic structures based on ZnO implanted with rare earth elementsApplied Research Programme – programme path A
No PBS2/A5/34/2013 (2013-2017)

2. **ATOMSHIELD -** Trwałość i skuteczność betonowych osłon przed promieniowaniem jonizującym w obiektach energetyki jądrowej
Applied Research Programme – programme path A
No PBS2/A2/15/2014 (2014-2017)

3. **PET-SKAND -** Otrzymywanie radiofarmaceutyków opartych na radionuklidach skandu dla pozytywnej tomografii emisyjnej
Applied Research Programme – programme path A
No PBS3/A9/28/2015 (2015-2018)"

4. **GRAN-T-MTC** - Phase I clinical trial using a novel CCK-2/gastrin receptor-localizing radiolabelled peptide probe for personalized diagnosis and therapy of patiens with prograssive or metastatic medullary thyroid carcinoma
ERA NET TRANSCAN No ERA-NET-TRANSCAN/01/2013 (2013-2018)

5. **MCAS -** Universal, multichannel control and data acquisition system
TANGO No TANGO1/267932/NCBR/2015 (2015-2018)

6. **GRAFEL -** Zaawansowane uszczelnienia połączeń ruchomych na baize kompozytów elastromerowo-grafenowych (leader – National Centre for Nuclear Research) "Applied Research Programme – programme path B
No PBS2/B2/11/2013 (2015-2018)"

7. **EVARIS -** Program do oceny ryzyka wystapienia awarii w obiektach przemysłowych stwarzających zagrożenie poza swoim terenem
Program na rzecz Obronności i Bezpieczeństwa Państwa
Nr DOB-BIO7/09/03/2015 (2015-2018)

8. **BIOTECHNET -** Nowatorski generator technetu (99Mo/99mTc) z mikroporowatym sorbentem na bazie chitozanu, wykorzystujący molibden 99Mo, do zastosowań w diagnostyce izotopowej
STRATEGMED2/269080/8/NCBR/2015 (2015-2018)

9. **PANDA2 -** Centrum Informatyczne w Świerku: infrastruktura i usługi dla energetyki
PANDA2/1/2016 (2016-2020)

10. **CYBERSECIDENT -** Narodowa Platforma Cyberbezpieczeństwa
CYBERSECIDENT/369195/I/NCBR/2017 (2017-2020)

Research Projects granted byforeign institutions

1. **CERN**
   GBAR - The development and construction of an Electron Linear Accelerator for the GBAR Experiment
   Principal Investigator: S. Wronka, PhD
   2545/DG (2014-2019)
2. **ESS**
   ESS-ENV - Comprehensive Monte-Carlo studies of the nearest environment of the ESS linac during operation
   ESS-0092240 (2017)
3. **IAEA**
   Nanosized Delivery Systems for Radiopharmaceuticals.
   Principal Investigator: M. Maurin, MSc.
   No. 18475/R0 (2014-2017)
4. **IAEA**
   Sharing and Developing Protocols to Further Minimize Radioactive Gaseous Releases to the Environment in the Manufacture of Medical Radioisotopes, as Good Manufacturing Practice.
   Principal Investigator: M. Konior, PhD
   IAEA No 18869 (2015 – 2018)
5. **IAEA**
   SCAND-I-CO - Therapeutic Radiopharmaceuticals Labelled with New Emerging Radionuclides (67Cu, 186Re, 47Sc) in Poland.
   Principal Investigator: R. Mikołajczak, PhD
   IAEA No 20496 (2016 – 2019)
6. **CEA**
   BENICE - Beryllium poisoning model development and experimental validation in research reactors with exploitation in MARIA and Jules Horowitz Reactor.
   Principal Investigator: Z.Marcinkowska, PhD
   BENICE 15PPLA000350 (2015-2018)
7. **CERN**
   Contract KE3291/00 01-10-2016.
   Principal Investigator: D. Stefan, PhD
   CERN KE3291/RCS (2016-2019)
8. **IAEA**
   Active testing of PLCs used in nuclear installations by Bug Fuzzing Search for Cyber Vulnerabilities.
   Principal Investigator: J.Gajewski , PhD
   IAEA No. 20576 (2016 – 2019)
9. **COST**
   GLISTEN: GPCR – Ligand Interactions, Structures and Transmembrane Signalling: a European Research Network.
   COST CM1207 (2015-2017)
10. **COST**
    Native Mass Spectrometry and Related Methods for Structural Biology
    COST BM1403 (2014-2018)
11. **COST**
    Cosmology and Astrophysics Network for Theoretical Advances and training Actions
    CANTATA:CA15117, oc-2015-1-19562
12. **AXA**
    AXA - Development of methodology to assess the risk of states in which grid does not operate under the "normal" conditions and to support the process of taking remedial actions by Transmission Systems Operators
    (2016-2018)

13. **HZDR**
CEPTA - Porównanie własności fosforku galu implantowanego tytanem po wygrzewaniu termicznym i po impulsie elektronowym
ST 17000973 (2017-2018)

Research Projects co-financed by 7th Framework Programme and Horizont 2020

1. **EuCARD-2** - Enhanced European Coordination for Accelerator Research & Development
(7PR) Contract No. 312453 (2013-2017)
2. **ESNII plus** - Preparing ESNII for HORIZON 2020
(7PR) Contract No. 605172 (2013-2017)
3. **OPERRA** - Open Project for the European Radiation Research Area
(7PR) Contract No. 604984 (2013-2017)
4. **JENNIFER** - Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research
(H2020) Contract No. 644294 (2015-2019)
5. **SKPLUS** - Super-Kamiokande plus
(H2020) Contract No. 641540 (2014-2018)
6. **C-BORD** - Effective Container inspection at BORDer control points
(H2020) Contract No. 653323 (2015-2018)
7. **VINCO -** Visegrad Initiative for Nuclear Cooperation
(H2020) Contract No. 662136 (2015-2018)
8. **BRILLIANT -** Baltic Region Initiative for Long Lasting Innovative Nuclear Technologies
(H2020) Contract No. 662167 (2015-2018)
9. **EUROfusion -** Implementation of activities described in the Roadmap to Fusion during Horizon 2020 through a Joint programme of the members of the EUROfusion consortium
(H2020) Contract No. 633053 (2014-2018)
10. **IVMR -** In-Vessel Melt Retention Severe Accident Management Strategy for Existing and Future NPPs
(H2020) Contract No. 604984 (2015-2019)
11. **QUACO -** QUAdrupoleCOrrector
(H2020) Contract No. 689359 (2016-2020)
12. **GEMMA** - GEneration iv Materials Maturity
(H2020) Contract No. 755269 (2017-2021)
13. **FOREvER** - Fuel fOR REsEarch Reactors
(H2020) Contract No. 754378 (2017-2021)
14. **GEMINI Plus** Research and Development in support of the GEMINI Initiative
(H2020) Contract No. 755478 (2017-2020)
15. **M4F -** Multiscale Modelling For Fusion And Fission Materials
(H2020) Contract No. 755039 (2017-2021)
16. **NARSIS** - New Approach to Reactor Safety Improvements
H2020) Contract No. 755439 (2017-2021)
17. **NOMATEN -** Centre of Excellence in Multifunctional Materials for Industrial and Medical Applications"
(H2020) Contract No. 763604 (2017-2018)

18. **EU-SysFlex** - Pan-European system with an efficient coordinated use of flexibilities for the integration of a large share of RES
(H2020) Contract No. 773505 (2017-2021)

PARTICIPATION IN NATIONAL CONSORTIA

	NATIONAL CONSORTIA:	Institute representative:
1.*	Nuclear Science Center	G. Wrochna
2.*	National Consortium 'XFEL-POLAND' for collaboration with the European X-ray Free Electron Laser - Project XFEL	G. Wrochna/Z. Gołębiewski
3.	National Consortium 'High Temperature Nuclear Reactor in Poland'	G. Wrochna/M. Pawłowski
4.	National Consortium 'FEMTOFIZYKA' for collaboration with the FAIR project in GSI Darmstadt	B. Zwięgliński
5.	National Consortium 'COPIN' for scientific collaboration with France (IN2P3 Institute)	L. Szymanowski
6.	National Consortium for Hadron Radiotherapy (NCRH)	G. Wrochna/A. Wysocka-Rabin
7.	National Consortium of scientific Network 'Polish calculation system for experiments at LHC-POLTIER'	W. Wiślicki
8	Polish Synchrotron Consortium	R. Nietubyć
9.	Consotrium EAGLE	A. Syntfeld-Każuch
10	National Consortium 'PL-TIARA'	S. Wronka
11*	National Consortium 'COMPASS-PL'	A. Sandacz
12.*	National Consortium 'NEUTRINA-T2K'	E. Rondio
13.	National Consortium 'HADRONY-NA61/SHINE'	J. Stepaniak
14.	Polis Consortium VIRGO	A. Królak
15.	Consortium "Polish Particle Physics"	E. Rondio
16.	Polish Consortium ALICE-PL	T. Siemiarczuk
17.	Consortium ELA-MAT Polska	K. Kurek
18.	Consortium CMS-Polska	P. Zalewski
19.	Consortium Polska@ISOLDE	Z. Patyk
20.	Consortium "LHCb – PL" and "LHCb-PL-Upgrade"	W. Wiślicki
21.	Consortium "ELI-Polska"	A. Malinowska
22.	Consortium on "Cherenkov Telescope Array" Project	L. Roszkowski
23.	Scientific-Industrial Centre New Energetic Technologies	J. Rzadkiewicz, J. Żebrowski

* Coordinator: NCBJ

DEGREES

Habilitation

Justyna Łagoda (National Centre for Nuclear Research) (
"Improving neutrino oscillation analysis with near detector measurements in T2K experiment"

Łukasz Świderski (National Centre for Nuclear Research)
„Rozwój technik detekcyjnych w celu badania relacji pomiędzy nieproporcjonalnością odpowiedzi, energetyczną zdolnością rozdzielczą scyntylatorów oraz czasem zaniku scyntylacji"
"The development of detection techniques to study the relationship between the disproportionality of the response, the energetic resolving power of the scintillators and the scintillation time "

PhD Thesis

Wojciech Dziewiecki (National Centre for Nuclear Research)
"Cyfrowy detector radiograficzny wysokiej rozdzielczości z zastosowaniem płytek wielootworowych"

Przemysław Jóźwik (National Centre for Nuclear Research)
„Applications of ion channeling to the crystal deformation analysis"

DEPARTMENTS AND DIVISIONS OF THE INSTITUTE

NUCLEAR FACILITIES OPERATION DEPARTMENT

Director od Department	Michał Gryziński, PhD Eng
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MARIA REACTOR OPERATIONS DIVISION

Head of Division:	Ireneusz Owsianko, MSc Eng
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There are 59 employees (engineers and technicians) working in the Maria Reactor Operations Unit.

The main activity of this unit is carrying out safe operation of the MARIA research reactor.

In 2017 the reactor operated for 4933 hours at power levels from 18 MW to 25 MW.

The main activities carried out at the MARIA reactor were focused on:

- irradiation of target materials in the vertical channels and the rabbit system
- irradiation of uranium targets for ^{99}Mo production
- neutron scattering condensed matter studies with neutron beams from the reactor horizontal channel
- neutron radiography studies
- neutron modification of minerals
- training.

Irradiations of target materials such as: TeO_2, KCl, Lu_2O_3, $SmCl_2$, S, Co etc. were performed for the Radioisotope Centre Polatom and irradiation of uranium targets was performed for CURIUM (formerly Mallinckrodt Medical). In cooperation with the QUIREM company irradiation of targets containing holmium microspheres for radiotherapy treatment was also performed. The total activity of irradiated targets in 2017 was 1415 TBq.

The neutron irradiation service utilizing the MARIA reactor also includes the colouring of topaz minerals. The irradiation of minerals in special channels located outside the reactor core changes their clear natural state to shades of blue, thereby increasing the commercial value of the product. Blue topaz is released to the market as non-radioactive material, conforming to strict international criteria.

The commercial irradiation of uranium plate for ^{99}Mo production was carried out at the MARIA reactor in 2017 within 5 reactor operation cycles. Production of the ^{99}Mo radioisotope by irradiation of high-enriched uranium (HEU) and low enriched uranium (LEU) targets reached the level of 2337 TBq in 2017.

Ireneusz Owsianko

REPORTS

Topical Peer Review 2017 Ageing Management in the MARIA Reactor
B. Piwowarski, ... , **I. Owsianko**, **P. Nowakowski**, **E. Borek-Kruszewska**, **P. Szaforz**, **A. Niepokólczycka-Fenik**, **M. Kuć**, **M. Lipka**, **A. Burakowska**, **Ł. Murawski**, **Ł. Bartosik**, ... et al.
Narodowe Centrum Badań Jądrowych

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Incident of leakage from primary cooling system of research reactor Maria
A. Gołąb
Technical Meeting on Incident Reporting System for Research Reactors (Austria, Vienna, 2017-08-21 - 2017-08-25)

MARIA reactor safety improvements and research capacity uprate
M. Tarchalski, **M. Gryziński**, **G. Krzysztoszek**, **J. Jaroszewicz**, **K. Pytel**, **R. Prokopowicz**, **M. Lipka**
The 18th IGORR conference (Australia, Sydney, 2017-12-03 - 2017-12-07)

Fuel conversion overview of MARIA reactor
G. Krzysztoszek, C. Rontard, B. Stepnik-AREVA, I. Bolshinsky, D. Keiser-INL
International Meeting on Reduced Enrichment for Research and Test Reactors (USA, Chicago, 2017-11-13 - 2017-11-16)

Spent fuel removal from Poland - project close out
G. Krzysztoszek, A. Cholerzyński
The 11-th Technical Meeting on lessons Learned from the RRRFR Programme (Georgia, Tbilisi, 2017-06-19 - 2017-06-22)

MARIA reactor safety improvements and research capacity uprate
M. Tarchalski, **M. Gryziński**, **G. Krzysztoszek**, **J. Jaroszewicz**, **K. Pytel**, **R. Prokopowicz**, **M. Lipka**
The 18th IGORR conference (Australia, Sydney, 2017-12-03 - 2017-12-07)

MARIA reactor safety improvements and research capacity uprate
M. Tarchalski, **M.A. Gryziński**, **G. Krzysztoszek**, **J. Jaroszewicz**, **K. Pytel**, **R. Prokopowicz**, **M. Lipka**
The 18th IGORR conference (Australia, Sydney, 2017-12-03 - 2017-12-07)

Ageing Management Program and Reactor Modernization in MARIA research reactor
P. Nowakowski, **B. Piwowarski**
Technical Meeting on Research Reactor Ageing Management, Refurbishment and Modernization (Austria, Wiedeń, 2017-10-30 - 2017-11-03)

Obliczenia dużej mocy w Departamencie Badań Układów Złożonych NCBJ
A. Padee, **H. Giemza**, **M. Wójcik**, **K. Klimaszewski**, **W. Jaworski**, **M. Karpiarz**, **P. Kowalski**
Atmosphere Conference 2017 (Poland, Kraków, 2017-05-16 - 2017-05-17)

PERSONNEL

Technical and administrative staff

Marian Bąk
Regina Bąk
Sylwester Bąk
Zdzisław Bąk
Bolesław Broda
Cezary Dąbrowski
Wiesław Ćwiek
Jadwiga Dąbrowska
Andrzej Frydrysiak, MSc Eng
Marcin Gadoś
Andrzej Gołąb, MSc Eng
Mateusz Gorzała, MSc Eng
Kazimierz Grzenda
Magdalena Hajdacka
Ireneusz Hora
Jacek Idzikowski, MSc En.
Ireneusz Iwański, Eng.
Krzysztof Jezierski, MSc Eng
Rafał Kędziora
Dariusz Krawczyński
Waldemar Kultys
Edward Kurdej
Dariusz Kwiatkowski
Rober Laskus
Franciszek Lech
Jan Lechniak, MSc Eng
Konrad Lechnik, Eng
Krzysztof Lechnik
Mateusz Łysiak
Jan Macios
Krzysztof Majchrowski
Halina Majszczyk
Rober Marczak
Adrian Michalski
Dariusz Mucha
Przemysław Nawrocki, MSc Eng
Paweł Nowakowski, MSc Eng
Mariusz Ostanek
Ireneusz Owsianko, MSc Eng
Mariusz Pietrasik
Piotr Pytlarczyk
Dariusz Rudnicki
Krzysztof Sierański
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Stefan Skorupa
Mieczysław Skwarczyński
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Angelika Szmyd
Paweł Święch
Emil Wilczek, MSc Eng
Piotr Witkowski, Eng
Tomasz Witkowski, Eng
Paweł Wojtczuk
Marcin Wójcik
Karol Zduńczyk, Eng.
Jarosław Zienkiewicz, M Sc Eng
Krzysztof Żołądek

REACTOR RESEARCH AND TECHNOLOGIES DIVISION

Head of Division: Janusz Jaroszewicz, MSc Eng
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The Reactor Research and Technologies Division has 35 employees including researchers, 5 of whom have a PhD degree, engineers and technicians. The new organization of the Division was established in 2016 and includes 5 Groups. New activities require the establishment in the near future of an additional group dedicated to programmes for the exploitation of reactor probes and loops:

- Reactor Measurement and Analysis Group (DAP)
- Irradiation Technology Group (DTN)
- Reactor Technology and Design Group (DTK)
- Technical Group (DTE)
- Mechanical Workshop ((DTW).

The main activity of the Division is support of the MARIA Reactor Operations Division in operating the reactor and safety operations for the irradiation facilities. In 2017 the Division's activities were strongly related to the support of new programmes dedicated to full utilization of the MARIA reactor, mainly for irradiation of targets to produce radioactive sources used in nuclear medicine. The research and development conducted is primarily oriented towards applications leading to the implementation of innovative irradiation technologies. Recently the Division has launched new irradiation technology using different uranium targets for ^{99}Mo production, including the use of new LEU uranium targets composed of UO_2 microspheres. In cooperation with the Dutch company QUIREM Medical BV the Division developed techniques for the irradiation of Ho-PLLA microspheres in the MARIA reactor. The microspheres containing holmium are used in radioembolization procedures as an innovative form of radiotherapy for the treatment of liver cancer. The Division's activities cover safety analyses, numerical calculations, irradiation technology as well as construction of reactor facilities and manufactures.

The Division carries out intensive scientific cooperation with domestic scientific institutions and universities as well as collaborations with foreign institutions taking part in international projects and research programmes. Among these are such institutions as the CEA, ANL, CCFE, JAEA, etc.. Collaboration with academic institutions includes training organized and provided for students (Technical University of Warsaw).

The main activities carried out in the Division were focused on:

- safety analyses and numerical calculations supporting operation of the MARIA research reactor;
- reactor measurements: neutrons parameters (activation measurements, SPND), gamma heating / dose rate (calorimeters, ionization chambers), temperature measurements (thermocouples, etc.);
- application of numerical codes: Origen (fuel depletion, radionuclide composition, activity), MCNP6 (neutrons, gamma rays, charged particle transport), Ansys-Fluent (thermo-hydraulic calculations), etc.;
- operational measurements, e.g. reactivity measurements of control rods, temperature reactivity coefficient measurements;
- failed fuel detection system (control and data acquisition, processing);
- experiments and completion of monitoring software;
- design and manufacture of new elements and facilities for the reactor operation systems and for irradiation facilities including gamma sterilization;
- technology for irradiation of materials for radioisotope production in cooperation with the Radioisotope Centre POLATOM; production of ^{192}Ir seeds used for Intravascular Radiation Therapy and low activity ^{192}Ir source ribbon for oncology applications and neutron irradiation of ^{165}Ho-PLLA Microspheres (radioembolisation of the liver).

Janusz Jaroszewicz

REPORTS

Experimental characterization of neutron and gamma parameters in chosen irradiation location in the MARIA reactor core
M. Tarchalski, **G. Madejowski**, **R. Prokopowicz**, **K. Pytel**, **Z. Marcinkowska**
EuroFusion

Topical Peer Review 2017 Ageing Management in the MARIA Reactor
B. Piwowarski, ... , **I. Owsianko**, **P. Nowakowski**, **E. Borek-Kruszewska**, **P. Szaforz**, **A. Niepokólczycka-Fenik**, **M. Kuć**, **M. Lipka**, **A. Burakowska**, **Ł. Murawski**, **Ł. Bartosik**, ... et al.
Narodowe Centrum Badań Jądrowych

Round Robin neutron activation measurements in hydraulic rabbit system channel No 2, pos. No 1 and 2, in the MARIA reactor core.
G. Madejowski, **R. Prokopowicz**, **M. Dorosz**, **A. Kozieł**, **K. Pytel**
National Centre for Nuclear Research (Swierk) (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

MARIA reactor safety improvements and research capacity uprate
M. Tarchalski, **M. Gryziński**, **G. Krzysztoszek**, **J. Jaroszewicz**, **K. Pytel**, **R. Prokopowicz**, **M. Lipka**
The 18th IGORR conference (Australia, Sydney, 2017-12-03 - 2017-12-07)

MARIA reactor safety improvements and research capacity uprate
M. Tarchalski, **M. Gryziński**, **G. Krzysztoszek**, **J. Jaroszewicz**, **K. Pytel**, **R. Prokopowicz**, **M. Lipka**
The 18th IGORR conference (Australia, Sydney, 2017-12-03 - 2017-12-07)

MARIA reactor safety improvements and research capacity uprate
M. Tarchalski, **M.A. Gryziński**, **G. Krzysztoszek**, **J. Jaroszewicz**, **K. Pytel**, **R. Prokopowicz**, **M. Lipka**
The 18th IGORR conference (Australia, Sydney, 2017-12-03 - 2017-12-07)

Beryllium Poisoning Model For Research Reactors
M. Wróblewska, **A. Boettcher**, **Z. Marcinkowska**, **K. Pytel**, **J. Jagielski**, P. BLAISE, P. SIRÉTA
European Research Reactor Conference (Netherlands, Rotterdam, 2017-05-14 - 2017-05-18)

Experimental determination of delayed nuclear heating in MARIA reactor by using Karolina calorimeter and Gamma Thermometer
M. Tarchalski, **K. Pytel**, **R. Prokopowicz**, C. Reynard-Carette, J. Brun, A. Lyoussi, P. Sireta, **J. Jagielski**, D. Fourmentel, L. Barbot, **Z. Marcinkowska**, **M. Wróblewska**, A. Luks
ADVANCEMENTS in NUCLEAR INSTRUMENTATION MEASUREMENT METHODS and their APPLICATIONS (Belgium, Liege, 2017-06-19 - 2017-06-23)

The new nuclear heating calorimeter Karolina and dedicated experimental campaign in MARIA research reactor.
M. Tarchalski, **K. Pytel**, **R. Prokopowicz**, A. Luks
European Research Reactor Conference (Netherlands, Rotterdam, 2017-05-14 - 2017-05-18)

Oral Presentation

Measuring the axial profile of spent nuclear fuel burn-up by spontaneous-fission-neutrons
R. Prokopowicz, **K. Pytel**, B. Bieńkowska, **Z. Marcinkowska**, **M. Tarchalski**
European Research Reactor Conference (Netherlands, Rotterdam, 2017-05-14 - 2017-05-18)

Educational programmes in MARIA reactor
M. Lipka
European Research Reactor Conference (Netherlands, Rotterdam, 2017-05-14 - 2017-05-18)

Status and foreseen development of the RR Utilisation for Higher Education Programmes - POLAND
M. Lipka
Training Workshop on the Compendium on Research Reactor Utilization for Higher Education Programmes (Austria, Wiedeń, 2017-06-06 - 2017-06-09)

Novel model of trigeneration system generating hot, cold and desalinated water using low grade heat recovery from nuclear reactor set.
R. Zwierzchowski, M. Malicki, **M. Lipka**
International conference on advances in energy systems and environmental engineering (ASEE17) (Poland, Wrocław, 2017-07-02 - 2017-07-05)

Poster

Functional properties of poly(tetrafluoroethylene) (PTFE) gasket working in nuclear reactor conditions.
E. Wyszkowska, M. Leśniak, **Ł. Kurpaska**, **R. Prokopowicz**, **I. Jóźwik**, I. Jozwik, M. Sitarz, **J. Jagielski**
International Conference on Molecular Spectroscopy (ICMS) is an important biennial meeting of spectroscopists ICMS2017 (Poland, Białka Tatrzańska, 2017-09-03 - 2017-09-07)
J. Mol. Struct. Vol. 1157 (2018) 306

Possible Shifts in MARIA Reactor Reactivity and Power Changes caused by the Seismic Event
M. Lipka
The 18th IGORR conference (Australia, Sydney, 2017-12-03 - 2017-12-07)

DIDACTIC ACTIVITY

M. Dorosz - Exercise of the neutron flux measurements for the students of the Institute of Heat Engineering, Warsaw University of Technology, 20 I 2017

M. Lipka - Classes from the Theory of the Heat Machines on the Warsaw University of Technology, The Faculty of Power and Aeronautical Engineering.

R. Prokopowicz - Auxiliary supervising
Calculation scheme for determining prompt and delayed nuclear heating in MARIA reactor core,
Gaweł Madejowski, Eng.,
Faculty of Power and Aeronautical Engineering, Warsaw University of Technology

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

J. Jaroszewicz
National Centre for Nuclear Research, Member of Scientific Council

Z. Marcinkowska
NCBJ Scientific Council

M. Tarchalski
Member
National Centre for Nuclear Research

PERSONNEL

Research scientists
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Krzysztof Pytel, PhD
Rafał Prokopowicz, PhD

Research-technical Staff
Elżbieta Borek-Kruszewska, PhD
Janusz Jaroszewicz, MSc Eng
Mikołaj Tarchalski, PhD
Małgorzata Wierzchnicka, MSc Eng

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Danuta Kaczyńska
Robert Keler
Alina Kozieł, MSc (retired)
Jadwiga Kurdej
Maciej Lipka, MSc Eng
Tomasz Machtyl, MSc Eng
Gaweł Madejowski, MSc Eng
Adam Małkiewicz, Eng
Marek Migdal, MSc Eng
Jerzy Polak, MSc Eng (retired)
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Bogdan Święch
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Janusz Wilczek
Konrad Wilczek
Wiesław Wróbel
Mieczysław Wójcik
Antoni Zawadka
Zbigniew Zduńczyk
Maciej Ziemba
Adam Żurawski

RADIATION PROTECTION MEASUREMENTS LABORATORY

Head of Laboratory: Tomasz Pliszczynski, MSc Eng
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The activities of the Radiation Protection Measurements Laboratory are focused on environmental monitoring and the assessment of the radiation exposure of personel. Scientific interests mostly concern methods of mixed radiation dosimetry and internal dosimetry.

The main tasks of the Laboratory include:

- Radiation monitoring of the Świerk Centre and Różan (KSOP) sites,
- Surveillance of radiation safety,
- Radioactive waste control (especially liquid waste),
- Preparedness for radiation protection in emergency conditions,
- Development of radiation protection measurements and methods,
- Calibration of radiation protection monitoring instruments,
- Personal dosimetry,
- Sewage and drainage water activity measurements,
- Environmental radiation monitoring,
- Implementation of the Integrated Management System for NCBJ;
- Research in dosimetry (described below 1^{o})
- Setting up a neutron station at the MARIA reactor (described below 2^{o}) – internal project "Neutrony H2".

In 2017 the Radiation Protection Measurements Laboratory continued successfully its activities concerning the improvement of measuring procedures within two domains of the Laboratory which are accredited by the Polish Centre for Accreditation (PCA), namely:

- The determination of internal body contamination (whole body counter, thyroid counter and radiological analysis of excretions) – Accreditation No. AB 567.

- Calibration of dosimetric instruments – in reference gamma and neutron radiation fields and surface contamination monitors – Accreditation No. AP 070.

The Radiation Protection Measurement Laboratory realized a project "Child and Adult Thyroid Monitoring After Reactor Accident CAThyMARA" in the framework of the Open Project for the European Radiation Research Area OPERRA 2014.

One of the members of the Radiation Protection Measurement Laboratory staff, Katarzyna Rzemek, defended a doctoral thesis "The assessment of the exposure to alpha emitters (actinides) of nuclear and isotopic facilities staff at Nuclear Centre Świerk" at Warsaw University, Faculty of Chemistry.

The scientific activities of the Radiation Protection Measurements Laboratory are performed mostly by the Laboratory of Mixed Radiation Dosimetry (head of laboratory and "Neutrony H2" leader Aleksandra Niepokólczycka-Fenik M.Sc. Eng. – contact by e-mail Aleksandra.Niepokolczycka@ncbj.gov.pl or by phone: +48 22 2731057). The research group consists of seven PhDs, nine MScs and three BScs.

1. Main research topics:

- Development of methods for the determination of operational dosimetric quantities and dose distribution vs. LET in mixed radiation fields, using high-pressure ionisation chambers;
- Design and construction of recombination ionisation chambers and dosimeters;
- Investigation of processes of ionisation and recombination of ions in gases;
- Metrology of mixed radiation fields including pulsed and high energy fields;
- Neutron dosimetry in a wide energy spectrum;
- Verification of installed dosimetry systems for medical applications;
- High sensitivity gamma spectroscopy of radionuclide concentrations in ambient air, spectroscopy of radioactive sources and neutron activated materials – environmental monitoring network;
- Radiological measurements of soils from polar regions;
- Radiological survey of meteorites;
- Absorbed dose distribution assessment for SIRT therapy;
- Passive dosimetry based on TLD detectors.

2. A research-training facility at the MARIA reactor:

- Constructing a uranium neutron converter for a dense neutron beam;
- Thermo-hydraulic analyses (CFD) of the neutron converter, aimed to optimise and enable safe output of the epithermal neutron beam;
- Adapting a research room at the MARIA reactor (horizontal channel no. 2);
- Development of Beam Shaping Assembly and room shielding;
- Development of dosimetry methods for hadron therapy, with particular emphasis on boron-neutron capture therapy (BNCT) and investigation of radiation fields near radiation therapy facilities;
- Forming a framework for the new Laboratory for Biomedical Research based on international collaboration.

Tomasz Pliszczyński

REPORTS

CAThyMARA report: Report of WP4 about inter-comparison results for non-trained responders
M. Isaksson, P. Fojtík, J.F. Navarro, **J. Ośko**, B. Perez
OPERRA Deliverable D5.26 CAThyMARA: Child and Adult Thyroid Monitoring After Reactor Accident (OPERRA Project number 604984)

CAThyMARA report: Report ofWP2 about existing plans andmeans, including comparison with internationalrecommendations
O. MonteiroGil, ... , **J. Ośko**, ... et al.
OPERRA Deliverable D5.24

CAThyMARA report: Technical guidelines for radioiodine in thyroid monitoring
G. Etherington, ... , **J. Ośko**, ... et al.
OPERRA Deliverable D5.31 CAThyMARA: Child and Adult Thyroid Monitoring After Reactor Accident (OPERRA Project number 604984)

Topical Peer Review 2017 Ageing Management in the MARIA Reactor
B. Piwowarski, ... , **I. Owsianko**, **P. Nowakowski**, **E. Borek-Kruszewska**, **P. Szaforz**, **A. Niepokólczycka-Fenik**, **M. Kuć**, **M. Lipka**, **A. Burakowska**, **Ł. Murawski**, **Ł. Bartosik**, ... et al.
Narodowe Centrum Badań Jądrowych

Uncertainties in internal dose assessment: Lifetime dose assessment for three example workers occupationally exposed to uranium - Analysing the intercomparison results
E. Davesne, ... , **J. Ośko**, ... et al.
European Radiation Dosimetry Group e.V. EURADOS Report 2017-03 Neuherberg, October 2017

ENS-2.1.5.0-T25-08: Tritiated waste generation and management
K. Szewczak, **M. Maciak**, **S. Domański**, **A. Burakowska**, **I. Petrenko**
Eurofusion, WPENS (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Quantification of uncertainty on lifetime dose assessment for workersoccupationally exposed to uranium intakes through a EURADOS intercomparison
E. Davesne, R. Bull, J. Anderson, D. Bingham, A. Birchall, C.-M. Castellani, C. Challeton-Devathaire, M. Luzfernandez, M. Froning, A. Giomi, A.L. Lebacq, T. Pazmandi, J**. Ośko**, I. Gomezparada, A. Pantya, A. Rojas, A. Rojo, M. Takahashi, K. Tani, E. Blanchardon
ICRP 4th International Symposium on the System of Radiological Protection & 2nd European Radiation Protection Research Week (France, Paris, 2017-10-10 - 2017-10-12)

Child and adult thyroid monitoring after reactor accident: recommendations from European specialists
D. Broggio, S. Baudé, A. Belchior, V. Berkovskyy, I. Bonchuck, J. Dewoghélaëre, G. Etherington, P. Fojtik, D. Franck, J-M. Gómez-Ros, D. Gregoratto, J. Helebrant, G. HériardDubreuil, J. Hulka, M. Isaksson, A. Kocsonya, A-LLebacq, I. Likhtariov, P. Lombardo, M-A. Lopez, I. Malatova, J. Marsh, I. Mitu, O. MonteiroGil, M. Moraleda, J-F. Navarro, **J. Ośko**, A. Pántya, T. Pázmándi, B. Perez, V. Pospisil, G. Ratia, M-A. Saizu, P. Szántó, P. Teles, **K. Tymińska**, F. Vanhavere, P. Vaz, T. Vrba, I. Vu, M. Youngman, P. Zagyvai
ICRP 4th International Symposium on the System of Radiological Protection & 2nd European Radiation Protection Research Week (France, Paris, 2017-10-10 - 2017-10-12)

Najczęstsze błędy pomiarowe w dozymetrii
J. Ośko, **M. Feczko**, **T. Pliszczyński**
XV Konferencja Naukowo-Szkoleniowa HAZMAT i CBRNE (Poland, Smardzewice, 2017-11-16 - 2017-11-17)

Neutrony H2 - Stanowisko BNCT przy reaktorze Maria
G. Wojtania, **Ł. Krzemiński**
IV warsztaty BNCT w Świerku - Perspektywy współpracy naukowej (Poland, Otwock-Świerk, 2017-10-10 - 2017-10-10)

Interdyscyplinary approach to the boron neutron capture therapy at MARIA research reactor (Poland)
E. Michaś, **K. Tymińska**, **Ł. Murawski**, **G. Wojtania**, **Ł. Krzemiński**
The 9th Young Researchers BNCT Meeting (Japan, Kyoto, 2017-11-13 - 2017-11-15)

Ageing Management Program and Reactor Modernization in MARIA research reactor
P. Nowakowski, **B. Piwowarski**
Technical Meeting on Research Reactor Ageing Management, Refurbishment and Modernization (Austria, Wiedeń, 2017-10-30 - 2017-11-03)

Oral Presentation

Monitoring indywidualny zagrożeń związanych ze skażeniami wewnętrznymi susbtancjami promieniotwórczymi
J. Ośko, **M. Dymecka**, **M. Prusińska**, **T. Pliszczyński**
I Ogólnopolska Konferencja NaukowaPraktyczne działania w przypadku zagrożeń chenicznych, biologicznych, radiologicznych i nuklearnych (CBRN) (Poland, Warszawa, 2017-09-07 - 2017-09-08)

Poster

Reference neutron fields in calibration laboratory – simple dosimetric parameters and their changes in time
S. Domański, **P. Tulik**, **B. Boimski**
Neutron and Ion Dosimetry Symposium (NEUDOS-13) (Poland, Kraków, 2017-05-14 - 2017-05-19)

Determination of Sr-90 in environmental samples - comparison of two methods
M. Dymecka, **K. Rzemek**, **T. Pliszczyński**, **J. Ośko**
Fifth International Conference on Radiation and Applications in Various Fields of Research, RAD 2017, Montenegro (, Budva, 2017-06-12 - 2017-06-16)

Measurements of iodine activity in thyroid after medicaladministration
J. Ośko, **R. Sosnowiec**, **T. Pliszczyński**
ICRP 4th International Symposium on the System of Radiological Protection & 2nd European Radiation Protection Research Week (France, Paris, 2017-10-10 - 2017-10-12)

Thyroid monitoring with non-spectrometric instruments - Results from an intercomparison exercise within the OPERRA/CAThyMARA project
M. Isaksson, D. Broggio, P. Fojtik, A.L. Lebacq, J.F. NavarroAmaro, **J. Ośko**, B.P. Lopez, I. Vu
ICRP 4th International Symposium on the System of Radiological Protection & 2nd European Radiation Protection Research Week (France, Paris, 2017-10-10 - 2017-10-12)

Determination of polonium (^{210}Po) in urine samples
M. Prusińska, **K. Rzemek**, **M. Dymecka**, **T. Pliszczyński**
Fifth International Conference on Radiation and Applications in Various Fields of Researche (, Budva, 2017-06-12 - 2017-06-16)

BNCT research beam in MARIA reactor (NCBJ, Poland)
K. Tymińska, **Ł. Krzemiński**, **E. Michaś**, **Ł. Murawski**, **G. Wojtania**
The 9th Young Researchers BNCT Meeting (Japan, Kyoto, 2017-11-13 - 2017-11-15)

INTERNAL SEMINARS

Tryt[a]
Z. Haratym
Otwock, National Centre for Nuclear Research Radiation Protection Measurements Laboratory, 2017-05-16

a) in Polish

DIDACTIC ACTIVITY

B. Boimski - Prowadzenie wykładów z zakresu bezpieczeństwa jądrowego i ochrony radiologicznej. Kurs typu A, POLATOM 19 czerwca 2017

M. Dymecka - Leading the workshop on radiation protection: 'Radiochemistry-in-vitro and environmental monitoring', 9th International School on Nuclear Power, 14th-17th November 2017

A. Niepokólczycka-Fenik - Training on recruitment. "How to get new candidates for work and how to choose the right people" The training concerned the sources of new candidates and the way of conducting an interview. co-author Stefan Bulaszewski

J. Ośko - 9th International School of Nuclear Power (14-17.11.2017) - workshop - ionizing radiation dosimetry

J. Ośko - Auxiliary supervisor.
Katarzyna Rzemek, MSc
The assessment of the exposure to alpha emitters (actinides) of nuclear and isotopic facilities staff at Nuclear Centre Świerk
PhD thesis was realized at Warsaw University, Faculty of Chemistry

J. Ośko - Radiation Protection training courses for NCBJ staff

J. Ośko - Radiation protection training for PGE KWB Bełchatów staff, Rogowiec 27-28.04.2017.
T. Pliszczyński - Prowadzenie szkoleń z zakresu ochrony radiologicznej dla pracowników NCBJ.

T. Pliszczyński - Radiation protection training for PGE KWB Bełchatów staff, Rogowiec 27-28.04.2017.

R. Sosnowiec - IX Międzynarodowa Szkoła Energeytki Jądrowej, Warszawa-Świerk-Różan (14-17.11.2017 r.) - Prowadzenie ćwiczeń z ochrony radiologicznej.

M. Umaniec - IX Międzynarodowa Szkoła Energetyki Jądrowej, Warszawa-Świerk-Różan (14-17.11.2017 r.) - Prowadzenie ćwiczeń z ochrony radiologicznej.

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

Z. Haratym
Association for the Promotion of Quality in Radiotoxicological Analysis (France)

E.A. Jakubowska
Secretary of Polish Society for Medical Physics - Warsaw Division

A. Niepokólczycka-Fenik
Member of Organizing Committee on Nowe oblicze terapii BNCT in Białystok, Poland

J. Ośko
Polish Society of Medical Physics
full member EURADOS WG7 - Internal Dosimetry

B. Piwowarski
Member of Polish Association of Medical Physics

T. Pliszczyński
Association for the Promotion of Quality in Radiotoxicological Analysis (France)

Research scientist
Burakowska Agnieszka, PhD
Haratym Zbigniew, PhD
Ośko Jakub, PhD Eng
Tulik Piotr, PhD Eng
Tymińska Katarzyna, PhD
Wielgosz Monika, PhD Eng
Rzemek Katarzyna, PhD Eng

Technical research
Domański Szymon, MSc
Dymecka Małgorzata, MSc Eng
Pliszczyński Tomasz, MSc Eng

Technical and administrative staff
Araszkiewicz Agnieszka, MSc
Bartosik Łukasz, PhD Eng
Boimski Błażej, Eng.
Budzińska Milena, Eng
Ejsmont Ryszard
Feczko Maciej
Karpińska Barbara
Knake Natalia, MSc Eng
Korab Marzena, MSc
Król Krystian, PhD Eng
Kuć Michał, MSc
Kurdej Alicja
Leszko Aneta
Maciak Maciej, MSc Eng
Madejowski Gaweł, Eng
Mądry Magdalena, MSc
Michaś Edyta, Msc Eng
Murawski Łukasz, Eng.
Niepokólczycka-Fenik Aleksandra, MSc Eng
Okniński Piotr, Eng
Osiecka Katarzyna, MSc Eng
Pawełczuk Andrzej, Eng
Piotrkowicz Barbara
Piotrowski Michał, MSc
Piwowarski Bartłomiej, Eng
Prusińska Maria, MSc Eng
Sosnowiec Renata, Tech.
Szewczak Kamil, PhD
Śniegoń-Reterska Wiesława, MSc Eng
Talarowska Anna, Eng
Umaniec Marianna
Wiliński Maciej, Eng
Wiśniewska Kazimiera
Wojdowska Katarzyna, MSc
Wojtania Grzegorz, MSc Eng
Krzemiński Łukasz, MSc Eng
Worch Zofia
Zagórski Grzegorz
Zielińska Danuta

MATERIALS PHYSICS DEPARTMENT

Director of Department: Professor Jacek Jagielski
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e-mail: jacek.jagielski@ncbj.gov.pl

In 2017 the Materials Physics Department was composed of three divisions: the Materials Research Laboratory (LBM) headed by Dr Łukasz Kurpaska, the Nuclear Methods in Solid State Physics Division (FM1) headed by Dr Jacek Milczarek and the Plasma/Ion Beam Technology Division (FM2) headed by Dr Katarzyna Nowakowska Langier (who replaced Dr Cezary Pochrybniak in May 2017). The Department staff is composed of 66 persons, among them 26 with Ph.D. or D.Sc.degrees, which constitutes a slight increase compared to 2016.

In 2017 the priorities of the Materials Physics Department were focused on three axes: preparing to participate in the Polish Nuclear Energy Programme, modernization of the thermal neutron beams laboratory of the MARIA reactor and fundamental and applied research on materials with special emphasis on nuclear techniques used for modification and/or analysis. MPD participated in 6 European projects: VINCO, BRILLIANT, NOMATEN, GEMMA, M4F and EuCard2. Two of them (VINCO and NOMATEN) were coordinated by MPD staff. Main research topics were:

- Molecular dynamics simulations of defect transformations in irradiated materials.
- Nanomechanical analysis of irradiated materials.
- Development of ion implantation doping of zinc oxide for luminescence applications.
- Studies of copper nitride synthesis via the plasma surface engineering technique.
- Archeometry: materials studies of archeological objects using physical methods.
- Neutron scattering physics in solid state analysis.
- Modification of materials using ion beam and plasma pulses.

Among the main achievements of the MPD in 2017 one may list the acquisition of four neutron spectrometers from HZB Berlin the first device has already been received by NCBJ, successful realization of six EU projects; and realization of three externally financed national grants. Department scientists published 49 papers in refereed international journals and participated in 36 conferences.

Continuous development of MPD's capabilities in studies of materials for nuclear applications allowed the preparation of the European Teaming project called NOMATEN; the proposal for the first phase was accepted in 2017 by the European Commission (project NOMATEN), and a proposal to the Foundation for Polish Science for matching funds (in the framework of the MAB Plus programme) was prepared and submitted. The MAB Plus proposal was accepted by the Foundation in 2018.

Research and organizational activities of MPD have been carried out in numerous international collaboration programme, among them particularly close relations are with French organizations (CEA and CNRS), Oak Ridge National Laboratory (project related to irradiation and damage accumulation in Single Phased Consentrated Solution Alloys), German laboratories (HZDR and HZB) and the Joint Project Nuclear Materials of the European Energy Research Alliance. MPD staff have also been involved in EuroFUSION activities.

Apart from research activities MPD carried out actions related to accreditation and certification of the MRL Laboratory and regular technical analyses of the MARIA reactor, e.g. non-destructive testing of the MARIA cooling system was continued in 2017. Commercial services, e.g. assessment of mechanical parameters of cast steel for railway system were also carried out.

MPD plans for the immediate future include continuation of European projects, modernization of the neutron beam laboratory and further development of nuclear materials, from atomistic scale simulations made with Molecular Dynamics and Monte Carlo methods to measurement of functional properties. A strong emphasis will be given to rejuvenation of the research staff.

Jacek Jagielski

NUCLEAR METHODS IN SOLID STATE PHYSICS DIVISION

Head of Division: Jacek J. Milczarek, PhD
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The Department is involved in research into the microscopic structure and dynamics of condensed matter systems. The techniques employed permit studies to be performed from the atomistic level to macroscopic phenomena. Methods based on the interaction of radiation with matter comprise X-rays (XRD and synchrotron radiation) and thermal neutrons (neutron scattering and neutron radiography). Six thermal neutron beams of the MARIA nuclear research reactor are used in our research. Some specialized techniques such as high pressure systems, rapid quenching and the sol-gel method are also used. A few theoretical and computational studies on the properties of fluorescence have also been carried out.

The Department has been involved in a major refurbishment of the experimental hall of the MARIA nuclear reactor. The aim is the deployment of the thermal neutron diffractometers from the Ber-II reactor of the Helmholtz-Zentrum Berlin. The instruments to be transferred to MARIA are equipped with two-dimensional detector systems and special systems for settings changes based on air-cushions.

In 2017 the Department comprised two laboratories:

- The Regional Laboratory of Neutronography,
- The X-ray Diffraction Laboratory,

There were 15 employees with two full professors, 6 researchers with PhD degrees, two with MSc degrees, 2 electronics engineers and 3 technicians.

The main work performed in 2017 dealt with:

- X-ray diffraction studies on active pharmaceutical compounds.
- The effect of phase decomposition on the phonon spectra and short range magnetic order in $Mn_{0.3}Ni_{0.3}Cu_{0.4}$ pseudo-binary alloy.
- Spontaneous drying of skeletal and inorganic systems containing collagen.
- Application of neutron imaging in cultural heritage and paleontological research.
- Preparation of the MARIA reactor experimental hall for the installation of the neutron diffractometers from the Ber-II reactor of the Helmholtz-Zentrum Berlin.

Jacek J. Milczarek

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Oral Presentation

Migracja wody w quasi dwuwymiarowych układach porowatych
I. Fijał-Kirejczyk, M. Rogante, **J.J. Milczarek**, **J. Żołądek**, **J. Żołądek-Nowak**, **Z. Jurkowski**
X Jubileuszowa Ogólnopolska Konferencja (Poland, Chlewiska, 2017-06-04 - 2017-06-08)

Wpływ rozpadu fazowego na relację dyspersji fononów i na fluktuacje magnetyczne w stopie $Mn_{0.3}Ni_{0.3}Cu_{0.4}$ badany metodą rozpraszania neutronów
J. Jankowska-Kisielińska, **J. Żołądek**, **Z. Jurkowski**
X Jubileuszowa Ogólnopolska Konferencja (Poland, Chlewiska, 2017-06-04 - 2017-06-08)

Dyfraktometry Helmholtz Zentrum Berlin w reaktorze MARIA NCBJ
J.J. Milczarek, **J. Jankowska-Kisielińska**, **J. Żołądek-Nowak**
X Jubileuszowa Ogólnopolska Konferencja (Poland, Chlewiska, 2017-06-04 - 2017-06-08)

Poster

Neutron characterization of ancient and modern textiles
M. Rogante, A. Len, **J.J. Milczarek**, L. Rosta
2nd International Conference on Neutron Imaging and Neutron Methods in Archaeology and Cultural Heritage (NINMACH) 2017 (Hungary, Budapest, 2017-10-11 - 2017-10-13)

DIDACTIC ACTIVITY

J. J. Milczarek - 15 lectures on "Neutrons in research and technology of materials" for 3rd year students of Faculty of Materials Science and Engineering of Warsaw University of Technology

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

J. Jankowska-Kisielińska
member Polish Society of Neutron Scattering

J.J. Milczarek
Polish Neutron Scattering Society
Polish Physical Society

Research staff
Jacek J.Milczarek, PhD
Armand Budzianowski, PhD
Izabela Fijał-Kirejczyk, PhD
Joanna Jankowska-Kisielińska, PhD
Jan Maurin, Associate Professor
Dariusz Rusinek, PhD
Kamila Stefańska-Skrobas, PhD
Karolina Świderska, MSc
Joanna Żołądek-Nowak, MSc

Technical and administrative staff
Bartosz Rajczak
Tadeusz Wójcik
Jan Żołądek

PLASMA/ION BEAM TECHNOLOGY DIVISION

Head of the Division Katarzyna Nowakowska-Langier , PhD
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The Plasma/Ion Beam Technology Division (FM2) is located in buildings 7 - 8, and 84 of the National Centre for Nuclear Research (NCBJ). FM2 is part of the laboratories included in the Materials Physics Department (MPD).

The scientific activity of the Plasma/Ion Beam Technology Division (FM2) includes different aspects of research related to materials engineering, surface engineering, functional properties characterizations and also material synthesis and modification. Plasma and plasma related techniques are the main tools used by FM2 groups. Plasma surface engineering as a scientific field is being expanded in our laboratory, and allows us to improve, modernize and develop modern and unique methods of material synthesis. Our investigations also include research related to plasma diagnostics which is an important and indispensable part of the work conducted by the FM2 group. Basic features of these phenomena as well as the specificity of plasma generation in various systems (experimental and technological) are studied. The last very important tools used in our research are ion and electron beams produced by implantation techniques. They are considered as a promising technique for the modification of material structure and synthesis of non-equilibrium structures.

The Plasma/Ion Beam Technology Division is divided into specialized laboratories:

Nuclear Microanalysis Laboratory

In 2017, the investigations of the nuclear microanalysis group were mainly focused on structural changes of materials upon implantation, development and validation of *McChasy* – a computer simulation tool for Rutherford Backscattering Spectrometry in the channelling direction and analysis of archeological relics. The project objectives were implemented in close collaboration with UW (Poland), IF PAN (Poland), HZDR (Germany), Paris-Sud University (France), CNRS (France), ORNL (Oak Ridge National Laboratory, USA) and several other national and foreign institutions.

In the past year our group was stable in number of employees. In 2017, the FM2 group realized five main scientific projects. Some of them were finished and some are still ongoing. The work rcarried out esulted in thirteen papers published/accepted plus five submitted/under the initial review process. Most of the papers were published in internationally recognized journals. The total predicted impact factor for all publications is 26.83 (18.49 – published/accepted, 8.34 – submitted).

Short summary of a chosen, realized project (accomplished)

Light emitting photonic structures basing on ZnO implanted with rare earth elements (projects ZnOLum and ZnOTrans) *Financial support from: The National Centre for Research and Development (PBS2/A5/34/). NCBJ in collaboration with IF PAN (leader) and ITME and The Polish Ministry of Science and Higher Education from the Science Funds for the 2015–2016 fiscal years for execution of co-financed international projects (3418/SPIRIT/2015/0), respectively.*

The aim of the project was to optimize the annealing process of ZnO single crystals and ZnO epitaxial layers implanted with RE ions which can be used as light emitters. High-quality wurtzite ZnO deposited by the Atomic Layer Deposition (ALD) method on a GaN/Al_2O_3 substrate and commercial single crystals (MaTecK) implanted at room temperature with different RE ions: Yb, Eu, Er, Pr, Dy to fluencies ranging from $5x10^{14}$ to $2x10^{15}$ions/cm^2 were investigated. After ion implantation two different types of annealing were used: rapid thermal annealing (RTA) and flash lamp annealing (FLA). The structural changes in the layers modified by ion implantation and subsequent annealing were characterized by means of the RBS/c technique and other complementary methods such as HRXRD and TEM. Subsequently, photoluminescence (PL) studies were performed. It is expected that the control of the crystalline quality, damage recovery, RE-atom lattice site location and optical efficiency after FLA annealing will lead to important progress in ZnO optical applications.

Ion/Plasma Materials Modification Laboratory

Research on materials modification covers issues related to the modification of the surfaces of materials by ion/electron beams or plasma stream interactions. These studies focus on the synthesis of non-equilibrium structures of materials and their influence on the properties as well as the synthesis of new materials. 4 main projects related to these issues have been realized.

One of the results of our investigations is an improvement of the durability of WC-Co tools used in the treatment of wood materials after surface modification by electron beam pulses and plasma stream. The work was realized in cooperation with the Faculty of Wood Technology of Warsaw University of Life Sciences - SGGW.

Currently, in the field of plasma surface engineering research is focused on the issues of pulse energy and masses which are delivered to the system during plasma processes. In addition, much research is carried out in the domain of the synthesis and characterizations of the layers of a variety materials. Studies performed by this group are also focused on the development of plasma surface engineering techniques.

Short summary of the implemented project in the field of plasma surface engineering

The synthesis and characterization of copper nitride coatings deposited by use of plasma surface engineering methods - This work was financially supported by the National Science Centre within the project 2014/15/B/ST8/01692.

The research problem addressed in this project concerns the use of unconventional synthesis conditions in order to obtain a material which is very difficult to synthesize (due to the narrow range of its thermodynamic stability). Therefore, the utilization of synthesis methods using non-equilibrium plasma allows us to control the process by other parameters than those which come from thermal activation. Synthesis of materials by plasma engineering methods plays an important role in the modification of their functional properties. Implementation of the project opens opportunities to extend our knowledge in the area of synthesis mechanisms from the point of unconventional synthesis, especially in narrow ranges of thermodynamic stability which are very important for materials science.

The results of these studies were published in 4 papers and were the subject of an engineering & master's thesis and a doctoral dissertation. The most important technical and technological achievements include: design, construction and commissioning of a modern facility for the synthesis of layers using the GIMS method (Gas Injection Magnetron Sputtering). Research in the field of Plasma surface engineering, was carried out in close cooperation with the Faculty of Materials Science and Engineering, Warsaw University of Technology.

The main equipment in FM2 includes:

experimental and technological

- Pulse Magnetron Sputtering (PMS)
- Gas Injection Magnetron Sputtering (GIMS)
- Flat cathode arc UHV set-up
- Vacuum sputtering
- MEVVA high current metallic ion implanter
- Semi-industrial implanter of gaseous ions
- Electron gun
- RPI-type plasma gun

materials characterisation

- Scanning microscope with EDS probe
- Ball-disc tribotester
- UHV set-up for testing quantum yield of photocathodes

Summarizing, in 2017, researchers from the FM2 group published 39 journal papers and participated in 32 international conferences and symposia. At the same time 16 projects were ongoing. Detailed descriptions of the outstanding achievements can be found in the thematic issues prepared by task leaders.

In 2017, FM2 employed 28 peoples of whom 10 were in scientific positions, 5 in research positions and 13 were employed as engineers.

Katarzyna Nowakowska-Langier

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Experimental determination of delayed nuclear heating in MARIA reactor by using Karolina calorimeter and Gamma Thermometer
M. Tarchalski, **K. Pytel**, **R. Prokopowicz**, C. Reynard-Carette, J. Brun, A. Lyoussi, P. Sireta, **J. Jagielski**, D. Fourmentel, L. Barbot, **Z. Marcinkowska**, **M. Wróblewska**, A. Luks
Advancements in nuclear instrumentation measurement methods and their applications (Belgium, Liege, 2017-06-19 - 2017-06-23)

Wpływ częstotliwości modulującej na syntezę cienkich warstw metodą PMS
G. Strzelecki, **K. Nowakowska-Langier**, R. Chodun, S. Okrasa, B. Wicher, K. Zdunek
XLV Szkoła Inżynierii Materiałowej (Poland, Rytro, 2017-09-26 - 2017-09-29)

Archaeological face of the surface non-invasive analysis
A. Gójska, **E. Miśta**, **P. Sibczyński**
International Conference Silver in Early Medieval Central Europe (Poland, Warsaw, 2017-11-30 - 2017-12-01)

Proposal of metallization method for a ceramic chamber of a dipole magnetic kicker
J. Lorkiewicz, **R. Nietubyć**, **R. Mirowski**
XL-th IEEE-SPIE Joint Symposium Wilga 2017 (Poland, Wilga, 2017-05-29 - 2017-06-04)

Damage accumulation studies in ion-irradiated oxides: Current status and new perspectives
J. Jagielski, L. Thomé, A. Chartier, **O. Dorosh**, **C. Mieszczyński**, I. Jozwik
19th International Conference on Radiation Effects in Insulators (REI-19) (France, Versailles, 2017-07-02 - 2017-07-07)
Nucl. Instr. and Meth. B (in press)

Beryllium Poisoning Model For Research Reactors
M. Wróblewska, **A. Boettcher**, **Z. Marcinkowska**, **K. Pytel**, **J. Jagielski**, P. Blaise, P. Siréta
European Research Reactor Conference (Netherlands, Rotterdam, 2017-05-14 - 2017-05-18)

Mechanism of damage buildup in ZnO
A. Turos
European Materials Research Society Fall Meeting 2017 (E-MRS 2017) (Poland, Warszawa, 2017-09-18 - 2017-09-21)

Evaluation of consolidation method on mechanical and structural properties of ODS RAF steel
M. Frelek-Kozak, **Ł. Kurpaska**, **E. Wyszkowska**, **W. Pawlak**, **J. Jagielski**, **I. Jóźwik**, I. Jóźwik, M. Chmielewski
Nanosmat Conference 2017 (France, Paryż, 2017-09-11 - 2017-09-13)
Appl. Surf. Sci. Vol. 01 (2018) 163

Analytical methods for studies of irradiated materials
A. Turos
VINCO Technical Meeting (Poland, Warsaw, 2017-11-17 - 2017-11-17)

Oral Presentation

Materials surface damage and modification under high power plasma exposures
I. Garkusha, V. Maklaj, O. Byrka, V. Taran, S. Herashchenko, S. Malykhin, **K. Nowakowska-Langier**, **M.J. Sadowski**, **E. Składnik-Sadowska**
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Influence of electron pulses on roughness and wettability of beech wood surface
M. Barlak, J. Wilkowski, P. Boruszewski, **J. Zagórski**, **Z. Werner**
3rd International Conference on Wood Composites Modification and Machining (Poland, Kiry, 2017-09-06 -

2017-09-08)

Modification of the surfaces of wood cutting tools using CO_2 laser - SEM analysis
P. Kołodziejczak, J. Wilkowski, **M. Barlak**, P. Czarniak, **Z. Werner**, **J. Zagórski**, **B. Staszkiewicz**
3rd International Conference on Wood Composites Modification and Machining (Poland, Kiry, 2017-09-06 - 2017-09-08)

Ion-irradiated elastomers reinforced with graphene filler
J. Jagielski
Elastomery 2017 (Poland, Warsaw, 2017-11-21 - 2017-11-23)

The studies on zirconium alloys surface layer properties modifications for the enhancement of high temperature oxidation resistance
W. Starosta, **M. Barlak**, A. Kochmańska, P. Kołodziejczak, M. Miłkowska, M. Rydzewski, B. Sartowska, J. Smolik, P. Tomassi, L. Waliś
NUTECH-2017 Conference on Development and Application of Nuclear Technologies (Poland, Kraków , 2017-09-10 - 2017-09-13)

Contribution of the Yb4f states to the electronic structure of ZnO estimated by Resonant Photoemission Spectroscopy
I.N. Demchenko, Y. Melikhov, P. Konstantynov, **R. Ratajczak**, **A. Turos**, E. Guziewicz
OMEE 2017: International Conference on Oxide Materials for Electronic Engineering – fabrication, properties and application (Ukraine, Lviv, 2017-05-29 - 2017-06-02)
Acta Phys. Pol. A (in press)

Phase composition of copper nitride coatings examined by the use of X-ray diffraction and Raman spectroscopy
K. Nowakowska-Langier, R. Chodun, **Ł. Kurpaska**, S. Okrasa, **G. Strzelecki**, K. Zdunek
International Conference on Molecular Spectroscopy (ICMS) is an important biennial meeting of spectroscopists ICMS2017 (Poland, Białka Tatrzańska, 2017-09-03 - 2017-09-07)

Study of applicability of non-destructive analyses methods in archaeology
A. Gójska, **E. Miśta**, **P. Sibczyński**
TECHNART 2017Non-destructive and microanalytical techniques in art and cultural heritage (Spain, Bilbao, 2017-05-02 - 2017-05-06)

Non-invasive studies on technological provenance of medieval silver jewelry from Baltic sea region
R. CzechBłońska, **E. Miśta**, W. Duczko, **A. Gójska**, P. Ciepielewski, J. Gaca
TECHNART 2017Non-destructive and microanalytical techniques in art and cultural heritage (Spain, Bilbao, 2017-05-02 - 2017-05-06)

Hydrogen-Free Dlc Coatings Deposited by HiP GIMS
K. Zdunek, R. Chodun, B. Wicher, **K. Nowakowska-Langier**, S. Okrasa
10-th Symposium on Vacuum based Science and Technology (Poland, Kołobrzeg, 2017-11-27 - 2017-11-30)

Study of Properties of Copper Nitride Layers Obtained By Pulsed Magnetron Sputtering
K. Nowakowska-Langier, S. Okrasa, R. Chodun, **G. Strzelecki**, **K. Król**, R. Minikayev, K. Zdunek,
10-th Symposium on Vacuum based Science and Technology (Poland, Kołobrzeg, 2017-11-27 - 2017-11-30)

Valence-change-induced Fano resonance" RPES of Yb implanted ZnO
I.N. Demchenko, Y. Melikhov, P. Konstantynov, **R. Ratajczak**, **A. Turos**, E. Guziewicz
E-MRS 2017 Fall Meeting (Poland, Warsaw, 2017-09-18 - 2017-10-21)

Cathodoluminescence analysis of damage build-up in irradiated spinel mono- and polycrystals
I. Jozwik, M. Zielinski, A. Azarov, **R. Ratajczak**, **C. Mieszczyński**, **A. Stonert**, **J. Jagielski**
19th International Conference on Radiation Effects in Insulators (REI-19) (France, Versailles, 2017-07-02 - 2017-07-07)
Nucl. Instr. and Meth. B (in press)

Mechanism of damage buildup in ion bombarded ZnO
A. Turos
20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2017) (Portugal, Lisbon, 2017-07-09 - 2017-07-14)

Preliminary Results of Fast Electrons Measurements by Means of a Cherenkov-type Three-channel Detector
M. Rabiński, **L. Jakubowski**, **M.J. Jakubowski**, **K. Malinowski**, **M.J. Sadowski**, **J. Żebrowski**, **R. Mirowski**, V. Weinzettl, O. Ficker, J. Mlynar, R. Panek, R. Paprok, M. Vlainic, COMPASSteam
Mini-conference on Run-Away Electrons (Czech Republic, Prague, 2017-02-14 - 2017-02-14)

Optymalizacja parametrów cewki napędowej urządzenia miotającego typu Inductance Coil Gun
A. Horodeński, **C. Pochrybniak**, **K. Namyślak**
XXI Międzynarodowa Konferencja Naukowo–Techniczna UZBROJENIE 2017 (Poland, Jachranka, 2017-06-19 - 2017-06-22)
Materiały konferencyjne (2017)

Studies of runaway electrons via Cherenkov effect in tokamaks
J. Żebrowski, **M. Rabiński**, **L. Jakubowski**, **M.J. Sadowski**, **M.J. Jakubowski**, **R. Kwiatkowski**, **K. Malinowski**, **R. Mirowski**, J. Mlynar, V. Weinzettl, F. Causa, COMPASSandFTUTeams
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Koncepcja magnetohydrodynamicznego zapłonnika plazmowego do inicjowania zapłonu małowrażliwych materiałów wybuchowych
C. Pochrybniak, Z. Leciejewski, Z. Surma, J. Michalski, **A. Horodeński**, **K. Namyślak**,
XXI Międzynarodowa Konferencja Naukowo–Techniczna UZBROJENIE 2017 (Poland, Jachranka, 2017-06-19 - 2017-06-22)
Problemy Techniki Uzbrojenia (in press)

Popularyzacja tematyki energetycznej w działaniach Centrum Nauki Kopernik
L. Nowicki
Wymiana Doświadczeń Edukacyjnych Polski i Francji dotyczących Energetyki Jądrowej (Poland, Warszawa, 2017-05-16 - 2017-05-16)

Najnowsze wyniki archeometrycznych badań nietypowych paciorków z siarczku arsenu znalezionych na wczesnośredniowiecznym cmentarzysku w Bodz k. Włocławka
R. Czech-Błońska, **E. Miśta**
Analiza Chemiczna w Ochronie Zabytków (Poland, Warszawa, 2017-12-07 - 2017-12-08)

Poster

Ion-irradiated butadiene acrylonitrile rubber reinforced with graphene filler
J. Jagielski
19th International Conference on Radiation Effects in Insulators (REI-19) (France, Versailles, 2017-07-02 - 2017-07-07)

White light luminescence from annealed thin ALD-ZnO films implanted with Dy
R. Ratajczak, **C. Mieszczyński**, E. Guziewicz, S. Prucnal, M. Stachowicz, D. Snigurenko, K. Kopalko, B.S. Witkowski, T.A. Krajewski, W. Skorupa, **A. Turos**
19th International Conference on Radiation Effects in Insulators (REI-19) (France, Versailles, 2017-07-02 - 2017-07-07)

Surface analysis of steel samples irradiated by laser beams and pulsed plasma streams
K. Nowakowska-Langier, **E. Składnik-Sadowska**, M. Kubkowska, P. Gasior, **R. Kwiatkowski**, **M.J. Sadowski**, A.K. Marchenko
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Cap layer as a way of enhancement of photoluminescence intensity of ZnO films implanted with Rare Earth
E. Guziewicz, G. Łuka, **R. Ratajczak**, S. Prucnal, **A. Stonert**, D. Snigurenko, **A. Turos**
E-MRS 2017 Fall Meeting (Poland, Warsaw, 2017-09-18 - 2017-10-21)

Analysis of optical spectra from steel samples exposed to pulsed plasma streams
A.K. Marchenko, **E. Składnik-Sadowska**, **R. Kwiatkowski**, **K. Nowakowska-Langier**, **M.J. Sadowski**, M. Kubkowska, I.E. Garkusha, V.A. Makhlai
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Measuring the protons participating in the $^{11}B(p, \alpha)2\alpha$ nuclear-fusion reaction using CR-39 TASTRAK
A. Malinowska, A. Szydłowski, **R. Kwiatkowski**, M. Paduch, R. Miklaszewski, **K. Malinowski**, E. Zielińska, **M. Jaskóła**, **A. Korman**, **M. Kuk**
27th ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

Optical properties of epitaxial ZnO-ALD films implanted with Rare Earth
E. Guziewicz, **R. Ratajczak**, M. Stachowicz, T.A. Krajewski, D. Snigurenko, **A. Turos**
OMEE 2017: International Conference on Oxide Materials for Electronic Engineering – fabrication, properties and application (Ukraine, Lviv, 2017-05-29 - 2017-06-02)

Alpha-particle spectroscopy by the use of polyallyl-diglycol-carbonate (PADC) detectors
A. Malinowska, **A. Szydłowski**, **R. Kwiatkowski**, K. Malinowski, **M. Jaskóła**, **A. Korman**, **M. Kuk**
27th ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

The luminescence in visible region from annealedthin ALD-ZnO films implanted with different RareEarth ions
R. Ratajczak, **C. Mieszczyński**, E. Guziewicz, S. Prucnal, M. Stachowicz, G. Łuka, D. Snigurenko, K. Kopalko, R. Böttger, R. Heller, W. Skorupa, J.V. Borany, **A. Turos**
E-MRS 2017 Fall Meeting (Poland, Warsaw, 2017-09-18 - 2017-10-21)

Channeling investigations of damage buildup in Er-implanted epitaxial and single crystal ZnO
C. Mieszczyński, **R. Ratajczak**, E. Guziewicz, **A. Turos**
E-MRS 2017 Fall Meeting (Poland, Warsaw, 2017-09-18 - 2017-10-21)
Phys. Status Solidi A (2018) 1700889

Ion irradiation - induced mechanical and structural changes of ODS RAF steel
M. Frelek-Kozak, **Ł. Kurpaska**, M. LEŚNIAK, **J. Jagielski**
European XFEL Users Meeting 2017 (Germany, Hamburg, 2017-01-25 - 2017-01-27)

Polish In-Kind Contribution to European XFEL: Status in Summer 2017
J. Lorkiewicz, **K. Chmielewski**, Z. Gołębiewski, **W. Grabowski**, **K. Kosiński**, **K. Kostrzewa**, **P. Krawczyk**, **I.M. Kudła**, **P. Markowski**, K. Meissner, **E. Pławski**, **M. Sitek**, **J. Szewiński**, **M. Wojciechowski**, **Z. Wojciechowski**, **G. Wrochna**, **J. Sekutowicz**, J. Fydrych, M. Duda, M. Jeżabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Stodulski, M. Wiencek, J. Świerblewski, P. Grzegory, G. Michalski, P. Borowiec, M. Chorowski, P. Duda, A. Iluk, K. Malcher, J. Poliński, E. Rusiński, J. Głowinkowski, M. Winkowski, P. Wilk
38th International Free-Electron Laser Conference (FEL2017) (USA, Santa Fe, 2017-08-20 - 2017-08-25)
Kip Bishopsberger (LNL), Volker RW Schaa (GSI) (Santa Fe, NM, USA) No. (2017)

Characteristic State of Substrate and Coatings Interface Formed by Impulse Plasma Deposition Method
R. Chodun, **K. Nowakowska-Langier**, P. Konarski, S. Okrasa, K. Zdunek,
10-th Symposium on Vacuum based Science and Technology (Poland, Kołobrzeg, 2017-11-27 - 2017-11-30)

Preliminary Results of the Dark Current Modelling for the Polfel Superconducting Lead Photocathode
K. Szymczyk, **J. Lorkiewicz**, **R. Nietubyć**, **J. Sekutowicz**
38th Interational Free Electron Laser Conference (FEL2017) (USA, Santa Fe, 2017-08-20 - 2017-08-25)
Kip Bishopsberger, Volker RW Schaa (Santa Fe, NM, USA) No. (2017)

Optical properties of epitaxial ZnO-ALD films implanted with Rare Earth
E. Guziewicz, **R. Ratajczak**, M. Stachowicz, S. Prucnal, T.A. Krajewski, D. Snigurenko, K. Goscinski, **A. Turos**
"Jaszowiec 2017", 46th International School & Conference on the Physics of Semiconductors (Poland, Szczyrk, 2017-06-17 - 2017-06-23)

Częstotliwość modulująca w procesach impulsowego rozpylania magnetronowego
G. Strzelecki, **K. Nowakowska-Langier**, R. Chodun, S. Okrasa, B. Wicher, K. Zdunek
Sympozjum Engineering of nano coatings - solutions for modern electronics (Poland, Warszawa, 2017-12-04 - 2017-12-05)

Development of a Cherenkov-type diagnostic system to study runaway electrons within the COMPASS tokamak
M. Rabiński, **L. Jakubowski**, **K. Malinowski**, **M.J. Sadowski**, **J. Żebrowski**, **M.J. Jakubowski**, **R. Mirowski**, V. Weinzettl, O. Ficker, J. Mlynar, R. Panek, R. Paprok, M. Vlainic
2nd European Conference on Plasma Diagnostics (France, Bordeaux, 2017-04-18 - 2017-04-21)

Influence of Ar-ion implantation on the structural and mechanical properties of zirconia as studied by Raman spectroscopy and nanoindentation techniques
Ł. Kurpaska, J. Jasinski, **E. Wyszkowska**, **K. Nowakowska-Langier**, M. Sitarz
International Conference on Molecular Spectroscopy (ICMS) is an important biennial meeting of spectroscopists ICMS2017 (Poland, Białka Tatrzańska, 2017-09-03 - 2017-09-07)
SPECTROCHIM ACTA A (2018)

Functional properties of poly(tetrafluoroethylene) (PTFE) gasket working in nuclear reactor conditions.
E. Wyszkowska, M. Leśniak, **Ł. Kurpaska**, **R. Prokopowicz**, **I. Jóźwik**, I. Jozwik, M. Sitarz, **J. Jagielski**
International Conference on Molecular Spectroscopy (ICMS) is an important biennial meeting of spectroscopists ICMS2017 (Poland, Białka Tatrzańska, 2017-09-03 - 2017-09-07)
J. Mol. Struct. Vol. 1157 (2018) 306

Influence of the various frequency modulation of plasma generation on structure and properties of the nitrides layers obtained by Pulsed Magnetron Sputtering.
K. Nowakowska-Langier, R. Chodun, R. Minikayev, S. Okrasa, **G. Strzelecki**, K. Zdunek
European XFEL Users Meeting 2017 (Germany, Hamburg, 2017-01-25 - 2017-01-27)

Functional properties of Ar-ion modified single-crystals of YSZ grown in [100], [110] and [111] crystallographic orientations
Ł. Kurpaska, M. Sitarz, **J. Jagielski**
20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2017) (Portugal, Lisbon, 2017-07-09 - 2017-07-14)
Surf. Coat. Technol. (2017)

Channeling study of defects accumulation in Er-implanted ZnO
C. Mieszczyński, **R. Ratajczak**, E. Guziewicz, **A. Turos**
19th International Conference on Radiation Effects in Insulators (REI-19) (France, Versailles, 2017-07-02 - 2017-07-07)

LECTURES, COURSES AND EXTERNAL SEMINARS

Technology of electromagnetic acceleration of macroscopic objects and its applicability for military use[a]
A. Horodeński
Warsaw, Military University of Technology, Faculty of Mechanical Engineering, 2017-01-17

Technology of electromgnetic acceleration of macroscopic objects[a]
A. Horodeński
Gliwice, Silesian University of Technology Institute of Engineering and Biomedical Materials, 2017-03-14

Ion beam modifications of compound semiconductors[b]
A. Turos

Warsaw, Institute of High Pressure PAS, 2017-04-20

Ion Implantation in Wide Band-gap Semiconductors[a]
A. Turos
Warsaw, Institute of Electron Technology, 2017-05-22

Computed Tomography CT[a]
E. Miśta
Wroclaw, Chemistry Department of Wroclaw University, 2017-06-20

.[a]
J. Jagielski
Warsaw, Warsaw University of Technology, 2017-12-01

a) in Polish
b) in English

INTERNAL SEMINARS

Inductance Coil Gun - numeric model and results of measurement [a]
A. Horodeński
Swierk, NCBJ, 2017-10-23

Mechanism of propagation of pulse ion-pasma beams[a]
A. Horodeński
Warszawa, Warszawa, 2017-12-07

a) in Polish

DIDACTIC ACTIVITY

M. Barlak - Consultation of Engineering Dissertations of Karolina Nitychoruk and Łukasz Żurawski - attendants of the 3-rd course of stationary study of first degree of Faculty of Wood Technology of Annals of Warsaw University of Life Sciences (SGGW) - Agreement between SGGW and NCBJ No CIiTT/95/2016

M. Barlak - Consultation of Engineering Dissertations of Konrad Ziółokowski, Filip Szkarłat and Krzysztof Ostrowski - attendants of the 3-rd course of stationary study of first degree of Faculty of Wood Technology of Annals of Warsaw University of Life Sciences (SGGW) - Agreement between SGGW and NCBJ No CIiTT/95/2016

A. Gójska - Preparing a PhD dissertation E.A.Miśta

R. Ratajczak - Damage buildup and structure recovery in RE-ion implanted ZnO

R. Ratajczak - Student practice

A. Turos - Przemysław Jóźwik -
"Application of Ion Channeling for the Analysis of Crystal Lattice Deformation"

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

M. Barlak
Session chairman on 3rd International Conference on Wood Composites Modification and Machining in Kiry, Poland

A. Gójska
Polish Physical Society

J. Jagielski
Boehmische Physical Society
Polish Physical Society
Member of the Scientific Council
Member of the SCientific Council of SLCJ
Institute of Electronic Materials Technology

E. Miśta
Vice-President, Polish Nuclear Society - Youth Forum
Member, European Nuclear Society - Young Generations (ENS YNG)
Member, Women in Nuclear
member, Inter-Society for Scientific Research and Protection of the World Cultural Heritage HUMANICA
NCNR representative person
European Infrastructure for Heritage Study - PL
Representative in the ERIHS Council

R. Nietubyć
Polish Synchrotron Radiation Society

K. Nowakowska-Langier
Polish Synchrotron Radiation Society (PSRS)

L. Nowicki
Session chairman on konferencja Interakcja-Integracja in Warszawa, Poland
Session chairman on konferencja Interakcja-Integracja in Warszawa, Poland

A. Turos
Member of the Materials Research Society
member of Boehmische Physical Society
Institute of Electronic Materials Technology
Institute of Eectronic Materials Technology, member

K. Zdunek
European Joint Committee on Plasma and Ion Surface Engineering (EJC PISE)
Faculty of Materials Science, Warsaw University of Technology

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Kamil Nawyślak, MSc Eng
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Renata Ratajczak, PhD
Andrzej Turos, Prof. PhD DSc
Zbigniew Werner, Associate Professor

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Anna Stonert, PhD
Grzegorz Strzelecki, MSc Eng
Andrzej Tremblicki
Andrzej Wiraszka
Jerzy Zagórski

MATERIALS RESEARCH LABORATORY

Head of the Division Łukasz Kurpaska, PhD
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The Materials Research Laboratory (MRL) is one of three laboratories included in the Department of Materials Physics (MPD) of the National Centre for Nuclear Research (NCBJ). MRL is engaged in research work covering all aspects of materials engineering. Investigations are carried out on structural materials and their welded joints including investigations performed on irradiated materials. The MRL Hot laboratory is the only facility in Poland able to handle and perform mechanical, structural and chemical investigations on material irradiated in nuclear reactors. All studies performed in the MRL are conducted according to a Quality Assurance Programme.

The main part of the Hot Laboratory is a set of 12 hot cells with lead shielding to enable handling of radioactive materials with activity levels up to 4 TBq related to ^{60}Co. Every cell is equipped with different devices providing flexibility for a wide nuclear research programme involving metallurgical, physical and chemical testing of irradiated structural materials. The main equipment installed in the MRL includes:

- Instron 8500 Dynamic Testing System with two 100 kN frames for testing tensile and compressive strength, low cycle fatigue resistance, fracture toughness, bend characteristics and crack growth resistance over the -150 ^{o}C to 1000 ^{o}C temperature range,
- Instrumented Wolpert Pendulum Impact Testing Machine PW 30/15 for dynamic tests of Charpy-V type specimens carried out over the -150 ^{o}C to 800 ^{o}C temperature range, for determination of significant force and deflection values, partial energy values and characteristic fracture mechanical values,
- DIA-TESTOR 7521 Wolpert Hardness Testing Machine for tests using Brinell, Vickers and Rockwell procedures,
- ROBOFIL 200 Spark Erosion Machine for specimen preparation
- ISOCS (In Situ Object Counting System) Shield System for in situ gamma spectroscopy with a germanium detector.

ARL 3460 Spectrometer for quantitative analyses of the chemical composition of metals.

The devices are fully automated, remotely operated and instrumented.

The remaining equipment of the hot cell complex allows:

- Cutting out of samples from irradiated reactor components
- Sample preparation for metallographic examinations
- Optical microscopy
- Thermal treatment and annealing
- Chemical analysis.

At the end of 1998 the laboratory for non-destructive testing of materials was put into operation in the MRL. The non-destructive laboratory is equipped with state of the art equipment and uses four different non-destructive methods of investigation: visual inspection, liquid penetration inspection, ultrasonic examination, radiographic inspection and structure investigation. The NDT division of MRL is strongly involved in the study of the technical condition of the MARIA Research Reactor. Several different ND tests were performed in 2017. Among many one can name periodic investigation of the cladding material, complex analysis of the secondary circuit of the MARIA research reactor and preparation of a working plan related to the assessment of the reactor aging, the “WENRA report”.

MRL holds the Accreditation Certificate of Testing Laboratory No AB 025 which confirms fulfillment of the ISO/IEC 17025:2001 criteria and since 1995 holds the Certificate of Testing Laboratory 2nd Degree Approval No LB-038/27 granted to the MRL by the Office of Technical Inspection. This indicates that MRL fulfils the criteria of the standard PN-EN IOS/IEC 17025:2005. It should be emphasized that MRL is the only laboratory in Poland which is able to provide accredited measurements in the field of fracture mechanics of materials according to ASTM E399-09, ISO 12108, BS 6835-1: 1998 and BS EN ISO 12737: 2011 standards. Such competences ensure that all the work performed in the MRL is in accordance with international standards widely used by research laboratories worldwide.

Currently, besides projects funded by the European Commission in 2015: VINCO and BRILLIANT new projects are being opened. The MRL performs nanomechanical investigations of materials and is involved in R&D projects funded by the EC– GEMMA (*Generation IV Materials MAturity*) and M4F (*Multiscale modelling for fusion and fission materials*). Both projects are aimed at developing materials for IV Generation Nuclear Reactors and will last till 2021.

In 2017 the main areas of research were: zirconium oxidation, investigation of the mechanical properties of ion implanted nickel based alloys, aluminum alloys and fabrication and mechanical properties of ODS RAF steels and Al_2O_3 coatings. Among these tests, special attention was given to nanomechanical investigations of ion implanted layers. In 2017 MRL researchers published 10 high impact journal papers and participated in 4 international conferences and symposia.

Among a number of scientific articles prepared by MRL personnel, one should name two which deserve attention:

- M. Frelek-Kozak, L. Kurpaska, M. Lesniak, I. Jozwik, J. Jagielski, *Mechanical and structural properties of ODS RAF steels submitted to low energy ions irradiation*, Fusion Engineering and Design 127 (2018) 54-59 (I.F 1.3)
- E. Wyszkowska, M. Lesniak, L. Kurpaska, R. Prokopowicz, I. Jozwik, M. Sitarz, J. Jagielski, *Functional properties of poly(tetrafluoroethylene) (PTFE) gasket working in nuclear reactor conditions*, Journal of Molecular Structure 1157 (2018) 306-311 (I.F 1.7)
-

Finally one should mention the collaboration programme with the Ministry of Energy and the preparation of guidelines entitled "Nondestructive (NDT) and destructive (DT) tests in nuclear power facilities". In addition, work has been carried out for industrial partners i.e. NDT tests, chemical composition analysis and fracture mechanics investigations.

The most important national and international collaboration programme were performed with ITME Institute of Electronic Materials Technology, AGH University of Science and Technology and Warsaw University of Technology, the French Alternative Energies and Atomic Energy Commission (CEA) and the University of Tennessee. One person from the MRL staff participated in a 1 month internship in France (November 2017, Université d'Amiens) funded by the French Embassy in Poland. In 2017, no foreign guest visited the MRL facilities.

As of December 2017, MRL employed 20 people of whom 3 were working in scientific positions, 1 in a research position and 16 in engineering positions. Due to the reorganization of the laboratory staff, starting from 2016, MRL has been undergoing a major reorganization process.

Łukasz Kurpaska

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Badania materiałów i elementów techniki jadrowej przez Laboratorium Badań Materiałowych NCBJ
B. Zając, **Ł. Kurpaska**
Krajowa Konferencja Badań Nieniszczących (Poland, Starachowice, 2017-10-17 - 2017-10-19)
Przegląd Spawalnictwa Vol. 89 No 11 (2017) 50

Evaluation of consolidation method on mechanical and structural properties of ODS RAF steel
M. Frelek-Kozak, **Ł. Kurpaska**, **E. Wyszkowska**, **W. Pawlak**, **J. Jagielski**, **I. Jóźwik**, I. Jóźwik, M. Chmielewski
Nanosmat Conference 2017 (France, Paryż, 2017-09-11 - 2017-09-13)
Appl. Surf. Sci. Vol. 01 (2018) 163

Oral Presentation

Phase composition of copper nitride coatings examined by the use of X-ray diffraction and Raman spectroscopy
K. Nowakowska-Langier, R. Chodun, **Ł. Kurpaska**, S. Okrasa, **G. Strzelecki**, K. Zdunek
International Conference on Molecular Spectroscopy (ICMS) is an important biennial meeting of spectroscopists ICMS2017 (Poland, Białka Tatrzańska, 2017-09-03 - 2017-09-07)

Effect of the real interface roughness on the stress distribution and crack propagation in thermal barrier coating using finite element method
T. Bolek, **I. Cieślik**, R. Sitek
Nanosmat Conference 2017 (France, Paryż, 2017-09-11 - 2017-09-13)

Poster

Potassium gadolinium tungstate doped RE ions as potential nano-sized material for medical imaging
I. Cieślik, **T. Bolek**, A. Majchrowski, M. Płocińśka, S. Hirano
Nanosmat Conference 2017 (France, Paryż, 2017-09-11 - 2017-09-13)

Ion irradiation - induced mechanical and structural changes of ODS RAF steel
M. Frelek-Kozak, **Ł. Kurpaska**, M. Leśniak, **J. Jagielski**
European XFEL Users Meeting 2017 (Germany, Hamburg, 2017-01-25 - 2017-01-27)

Functional properties of poly(tetrafluoroethylene) (PTFE) gasket working in nuclear reactor conditions.
E. Wyszkowska, M. Leśniak, **Ł. Kurpaska**, **R. Prokopowicz**, **I. Jóźwik**, I. Jozwik, M. Sitarz, **J. Jagielski**
International Conference on Molecular Spectroscopy (ICMS) is an important biennial meeting of spectroscopists ICMS2017 (Poland, Białka Tatrzańska, 2017-09-03 - 2017-09-07)
J. Mol. Struct. Vol. 1157 (2018) 306

Structural properties of zirconia – in-situ high temperature XRD characterization
Ł. Kurpaska
International Conference on Molecular Spectroscopy (ICMS) is an important biennial meeting of spectroscopists ICMS2017 (Poland, Białka Tatrzańska, 2017-09-03 - 2017-09-07)
J. Mol. Struct. (2018)

Functional properties of Ar-ion modified single-crystals of YSZ grown in [100], [110] and [111] crystallographic orientations
Ł. Kurpaska, M. Sitarz, **J. Jagielski**
20th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2017) (Portugal, Lisbon, 2017-07-09 - 2017-07-14)
Surf. Coat. Technol. (2017)

Influence of Ar-ion implantation on the structural and mechanical properties of zirconia as studied by Raman spectroscopy and nanoindentation techniques

Ł. Kurpaska, J. Jasinski, **E. Wyszkowska**, **K. Nowakowska-Langier**, M. Sitarz
International Conference on Molecular Spectroscopy (ICMS) is an important biennial meeting of spectroscopists ICMS2017 (Poland, Białka Tatrzańska, 2017-09-03 - 2017-09-07)
Spectrochim Acta A (2018)

Oxidation resistance of aluminide layers formed on the Ni-based superalloy
T. Bolek, **I. Cieślik**, R. Sitek, K.J. Kurzydłowski
XIV Warszawskie Seminarium Doktorantów Chemików - ChemSession 17 (Poland, Warszawa, 2017-06-09 - 2017-06-09)
ChemSession\'17 No. (2017) p. 50

Potassium gadolinium tungstate doped rare earth ions to medical diagnostic
I. Cieślik, **T. Bolek**, A. Majchrowski, M. Płocińska, S. Hirano
XIV Warszawskie Seminarium Doktorantów Chemików - ChemSession 17 (Poland, Warszawa, 2017-06-09 - 2017-06-09)
ChemSession\\\'17 No. (2017)

Impact of the real interface roughness on residual stress state in Thermal Barrier Coatings using FEM
T. Bolek, **I. Cieślik**, R. Sitek, K.J. Kurzydłowski
European XFEL Users Meeting 2017 (Germany, Hamburg, 2017-01-25 - 2017-01-27)

Toxicity study and spectroscopy characteristic of potassium gadolinium tungstate nanocrystals (KGW)
I. Cieślik, **T. Bolek**, A. Majchrowski, J. Sołtysiak, S. Hirano
European XFEL Users Meeting 2017 (Germany, Hamburg, 2017-01-25 - 2017-01-27)

LECTURES, COURSES AND EXTERNAL SEMINARS

Electrical part of a nuclear power plant in the light of international requirements - guidelines for Polish industry[a]
B. Zając
Warsaw, Ministry of Energy, 2017-11-29

Technical requirements, guidelines and recommendations for the Polish industry in the field of non-destructive and destructive testing in nuclear power facilities[a]
B. Zając
Otwock, National Center for Nuclear Research, 2017-11-30

a) in Polish

INTERNAL SEMINARS

Research on the possibilities of improving the adhesion of Pb layers deposited on the Nb substrate[a]
B. Zając
Otwock, National Center for Nuclear Research, 2017-02-06

LAMMPS as a tool of molecular dynamics. An example of modeling interlayer potential in graphene structures.[a]
Z. Kozioł
Świerk, NCBJ National Center for Nuclear Research, 2017-04-05

LAMMPS as a Tool in Molecular Dynamicson the Example of Modeling of the International Potentialin Graphic Structures[a]
B. Zając
Otwock, National Center for Nuclear Research, 2017-04-05

a) in Polish

DIDACTIC ACTIVITY

I. Cieślik - Trainee student supervising
Marii Curie Skłodowska University

B. Zając - Magnetic particle test course, level 2 according to PN-EN ISO 9712 for the Center of Personnel Development "INTERPROFESJA" 06-10.03.2017.

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

Z. Kozioł
Journal of Nanoscience with Advanced Technology, Verizona Open Access (JNAT-Journal)

Ł. Kurpaska
Corrosion Science, Springer
Mechanics of Materials, Elsevir
Journal of Molecular Structure, Elsevir
Surface Coatings and Technology, Elsevir

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DEPARTMENT OF FUNDAMENTAL RESEARCH

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The activity of the department in 2017 is presented in some detail in the sections devoted to its four Divisions: the Nuclear Physics Division (BP1), Theoretical Physics Division (BP2), High Energy Physics Division (BP3) and Astrophysics Division (BP4). Here there only the three main achievements of the department in 2017.

Insight into nuclear chirality In an odd-odd nucleus, such as ^{128}Cs, the three angular momenta of the proton, the neutron, and the even-even core span a three-dimensional space giving the possibility of two distinct orientations – different chiralities. The first measurement of the g-factor of the isomeric state in ^{128}Cs, which was performed by E. Grodner and collaborators, indicates nonchiral geometry, that is the three angular momentum vectors are located nearly in one plane.

Sivers asymmetry If a nucleon`s spin is oriented orthogonally to its motion, the momentum distribution of the partons (quarks or gluons) which form the nucleon is not left-right symmetric with respect to the plane defined by the direction of nucleon spin and momentum. This is called the Sivers asymmetry which was measured for the first time for gluons in the COMPASS experiment. The group led by A. Sandacz played a key role in the measurement.

Colliding neutron stars The LIGO/VIRGO Collaboration discovered the first ever event (GW170817) observed in both gravitational and electromagnetic waves. The event, which was interpreted as resulting from the collision of two neutron stars, marks the beginning of an new era of multi-messenger astronomy. The POLGRAW group lead by A. Królak contributed to the discovery with in the framework of the VIRGO Collaboration

Stanisław Mrówczyński

NUCLEAR PHYSICS DIVISION

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Our scientific activities in 2017 concentrated mainly on two subjects: low energy nuclear physics and medium energy physics.

Activities of the low-energy direct reactions group in 2017 resulted in a total of nine articles, eight in Phys. Rev. C and one in Eur. Phys. J. A, describing work performed in collaboration with colleagues from Poland and abroad. An invited talk was presented at the Fourth Workshop of the Hellenic Institute of Nuclear Physics, held at the University of Ioannina, Greece, entitled: "Light Charged Particle Production in Reactions Induced by Weakly-bound Projectiles: Still an Open Question." The REX-ISOLDE facility at CERN was visited to participate in experiment IS619, "Effects of the neutron halo in ^{15}C scattering at energies around the Coulomb barrier," the first experiment to use the newly-developed ^{15}C beam at ISOLDE /N. Keeley/.

As a result of a nuclear reaction, ^{128}Cs nuclei were produced at the Heavy Ion Laboratory of Warsaw University. Employing the fast timing technique, the half-life for the 10+ excited state state was experimentally studied. The data are being evaluated. /O. Czerviakova, T. Cap, E. Grodner/

The occurrence of octupolar shapes in the Ba isotopic chain was recently established experimentally up to $N = 90$. To extend further the systematics, the evolution of the shape in the most neutron-rich members of the $Z = 56$ isotopic chain accessible at present, ^{148,150}Ba, has been studied via β decay at the ISOLDE Decay Station (CERN). The positive- and negative-parity low-spin excited states of ^{150}Ba were measured for the first time and the β-decay scheme of ^{148}Cs extended. Employing the fast timing technique, half-lives for the 2+ level in both nuclei have been determined, resulting in $T_{1/2} = 1.51(1)$ ns for ^{148}Ba and $T_{1/2} = 3.4(2)$ ns for ^{150}Ba. The systematics of low-spin states, together with the experimental determination of the $B(E2 : 2+ \rightarrow 0+)$ transition probabilities, indicate an increasing collectivity in $^{148–150}$Ba, towards prolate deformed shapes. The experimental data are compared to symmetry conserving configuration mixing (SCCM) calculations, confirming the evolution of increasingly quadrupole deformed shapes with a definite octupolar character. The results were published in Phys. Rev. C **97**, 024305 (2018) /O. Czerviakova, Z. Patyk/.

The Intermediate Mass Fragments production probability in semi-peripheral reactions was measured in collisions of ^{124}Xe projectiles with two different targets of ^{64}Ni and ^{64}Zn at a laboratory energy of 35 A MeV. The two colliding systems although, having the same size (isobaric), differ in the target N/Z ratio. An enhancement of Intermediate Mass Fragment production for the neutron rich ^{64}Ni target is found. In the case of one Intermediate Mass Fragment (IMF) emission, the contributions from dynamical and statistical emissions have been evaluated, revealing that the observed enhancement is related to an increase of the dynamical emission probability for the neutron rich target, especially for heavy IMFs (Z >=7). When comparing the Xe+Ni, Zn results with the previously studied Sn+Ni systems, the dynamical emission probability clearly increases with the N/Z of the investigated system. A high sensitivity of the prompt-dynamical emission of the primary PLF* to the entrance channel N/Z ratio of the composite systems is distinctly seen.

A novel application of the IMFIMF correlation function was made to the physical case of binary massive projectile-like (PLF) splitting for dynamical and statistical breakup/fission in heavy ion collisions at the Fermi energy. Theoretical simulations are also shown for comparisons with the data. These preliminary results have been obtained for the inverse kinematics ^{124}Sn+ ^{64}Ni reaction at 35A MeV, studied using the forward part of the CHIMERA detector. In this reaction strong competition between dynamical and statistical components and its evolution with the charge asymmetry of the binary break up has already been shown. We show that the IMF-IMF correlation function can be used to pin down the timescale of fragment production in binary fission-like phenomena. We also made simulations with the CoMDII model in order to compare to the experimental IMF-IMF correlation function. In future we plan to extend these studies to different reaction mechanisms and nuclear systems and to compare with different theoretical transport simulations. /T. Cap/.

Our efforts were was concentrated on the exclusive vector mesons (VM) obtained in the reaction mu +p → VM+ mu' +p or simply virtual gamma* →VM. The main goal of the data analysis was the Spin Density Matrix Elements (SDME's). The SDME describes the spin relation between a virtual photon and the vector meson. Additional experimental data were obtained by the COMPASS COLLABORATION. We studied three kinds of vector mesons -

omega, rho and phi. However, the analysis of the omega and rho (with a recoil detector) has reached advanced levels. (W. Augustyniak and B. Mariański)

The group is engaged in the large-scale international collaboration PANDA (anti Proton ANnihilations at DArmstadt) at FAIR and in 2017 worked on legal and administrative issues have raised by the Shareholder (JU-Cracow) and the host laboratory (FAIR GmbH). The work terminated with an Addendum to the Tripartite Contract signed by representatives of the FAIR and NCBJ administrations, which opens the way towards funding the project. The group published one paper in a refereed journal - Phys. Rev. D95 (2017) 032003 /B. Zwieglinski, A. Trzcinski, G. Kęsik/.

Zygmunt Patyk

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Light charged particle production in reactions induced by weakly-bound projectiles: Still an open question
N. Keeley
Fourth Workshop of the Hellenic Institute of Nuclear Physics on New Aspects and New Perspectives in Nuclear Physics (HINPW4). (Greece, Ioannina, 2017-05-05 - 2017-06-06)

Non-chiral to chiral phase transition in ^{128}Cs based on magnetic moment measurements.
E. Grodner
XXIV Nuclear Physics Workshop (Poland, Kaziemierz Dln., 2017-09-20 - 2017-09-24)

Search for the nuclear chirality - 10 minutes manual for experimenters
E. Grodner
Shapes and Symmetries in Nuclei: from Experiment to Theory (SSNET 17 Conference) (France, Paris, 2017-11-06 - 2017-11-10)

Oral Presentation

Transverse target spin asymetries in exclusive ω muoproduction at COMPASS
B. Mariański
XVII Workshop on High Energy Spin Physics DSPIN-17 (Russia, Dubna, 2017-09-11 - 2017-09-15)
Journal of Modern Physics, Conference Series Vol. 938 (2017) 012010

Dynamical and statistical emission of heavyfragments in ^{197}Au + ^{197}Au collisionsat 23A MeV
T. Cap, **J. Wilczyński**
XXXV Mazurian Lakes Conference on Physics (Poland, Piaski, 2017-09-04 - 2017-09-09)

Poster

Measuring the protons participating in the ^{11}B(p, α)2α nuclear-fusion reaction using CR-39 TASTRAK
A. Malinowska, A. Szydłowski, **R. Kwiatkowski**, M. Paduch, R. Miklaszewski, **K. Malinowski**, E. Zielińska, **M. Jaskóła**, **A. Korman**, **M. Kuk**
27th ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

Alpha-particle spectroscopy by the use of polyallyl-diglycol-carbonate (PADC) detectors
A. Malinowska, **A. Szydłowski**, **R. Kwiatkowski**, K. Malinowski, **M. Jaskóła**, **A. Korman**, **M. Kuk**
27th ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

Dawka lokalna i jej rola w biologicznej odpowiedzi linii komórkowych ssaków in vitro
U. Kaźmierczak, D. Banaś, J. Braziewicz, J. Czub, **M. Jaskóła**, **A. Korman**, M. Kruszewski, A. Lankoff, H. Lisowska, **A. Malinowska**, T. Stępkowski, Z. Szefliński, M. Wojewódzka
44. Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-09-15)

Effect of irradiation of CHO-K1 cells by mixed beam containing carbon and oxygen ions
J. Czub, D. Banaś, J. Braziewicz, **M. Jaskóła**, U. Kaźmierczak, **A. Korman**, A. Lankoff, H. Lisowska, Z. Szefliński, A. Wójcik
RAD 2017 Fifth International Conference on Radiation and Applications in various fields of research (Montenegro, Budva, 2017-06-12 - 2017-06-16)

Dynamical and statistical emission of heavyfragments in ^{197}Au + ^{197}Au collisionsat 23A MeV
T. Cap, **J. Wilczyński**
XXXV Mazurian Lakes Conference on Physics (Poland, Piaski, 2017-09-03 - 2017-09-09)

Two identical pion correlations at small relative momenta in collisions of Al+Al and Ni+Ni at 1.9A GeV
V. Charviakova, K. Piasecki, T. Matulewic
XXXV Mazurian Lakes Conference on Physics (Poland, Piaski, 2017-09-04 - 2017-09-09)

LECTURES, COURSES AND EXTERNAL SEMINARS

Light charged particle production in reactions induced by weakly-bound projectiles: Still an open question.[b]
N. Keeley
Warsaw, University of Warsaw, 2017-04-20

Habilitation Seminar of dr M. Balcerzyk[a]
B. Zwięgliński
Gdańsk, Gdańsk Technical University, 2017-11-17

SDMEs in exclusive rho0 meson production from 2012 data[b]
W. Augustyniak
Genewa, CERN, 2017-02-20

Systematic studies on SDMEs in exclusive omega meson from 2012 data[b]
B. Mariański
Genewa, CERN, 2017-02-20

SDMEs in exclusive rho0 meson production from 2012 data[b]
W. Augustyniak
Genewa, CERN, 2017-03-06

Systematic studies on SDMEs in exclusive omega meson from 2012 data[b]
B. Mariański
Genewa, CERN, 2017-03-22

SDMEs of exclusive ω meson production[b]
B. Mariański
Genewa, CERN, 2017-03-23

SDMEs for rho0: COMPASS results with CAMERA for 2012 data[b]
W. Augustyniak
Genewa, CERN, 2017-12-06

SDMEs of exclusive ω meson production (DUCS 2012 data) status report[b]
B. Mariański
Genewa, CERN, 2017-12-06

SDMEs of exclusive ω meson production (DUCS 2012 data) status report[b]
B. Mariański
Genewa, CERN, 2017-12-07

a) in Polish
b) in English

DIDACTIC ACTIVITY

T. Cap - Open physics classes for school students (ground school, lower secondary school, high school) and preschoolers organized by Polish Physics Society and the Faculty of Physics at the University of Warsaw.

B. Mariański - Lectures on ekonometry in WSZ-SW

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

V. Charviakova
FOPI colaboration, GSI Darmstadt. Study the characteristics of heavy ion reactions, to reconstruct the properties of the hot and dense reaction zone and investigate particle production at the SIS beam energies.
ISOLDE, CERN. Experiments in the fields of nuclear and atomic physics, solid-state physics, materials science and life sciences.

N. Keeley
Fellow of the Institute of Physics
Council member. National Centre for Nuclear Research

P. Żuprański
Member of the Scientific Council of the HERMES Collaboration at DESY

B. Zwięgliński
Coordination Board of the PANDA Detector activities, SINS representative
representative of NCBJ, National Consortium FEMTOPHYSICS

Research scientists
Witold Augustyniak, PhD*
Volha Charviakova, MSc
Tomasz Cap, MSc
Ernest Grodner, PhD
Nicholas Keeley, Associate Professor
Andrzej Korman, PhD*
Bohdan Mariański, PhD*
Zygmunt Patyk, Professor
Andrzej Trzciński, PhD
Bogusław Zwięgliński, Professor*
Paweł Żuprański, Associate Professor*

Technical and administrative staff
Dorota Dobrowolska
Grażyna Kęsik, Eng

*part-time employee

THEORETICAL PHYSICS DIVISION

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The Theoretical Physics Department consists of 30 physicists and 3 PhD students working on different aspects of low and high energy physics, plasma and nonlinear phenomena as well as on the general problems of quantization of particle dynamics, astrophysics, string theory and cosmology, "new physics" models beyond the Standard Model and the dark matter problem.

The results of our scientific activity in 2017 were presented in 170 publications in total, of which were 43 with number of co-authors less than 5. We gave 21 invited lectures at international conferences and workshops.

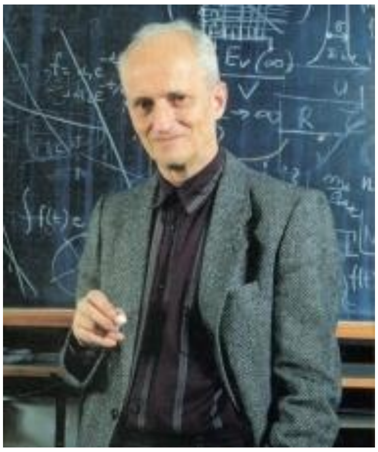
Our research effort was mainly concentrated on the following topics:

- properties of heavy and superheavy nuclei;
- properties of nuclear matter, nuclear collisions and exotic atoms;
- phenomenology of collisions of hadrons and leptons;
- dark matter;
- "new physics" models beyond the Standard Model;
- supersymmetric models
- theoretical cosmology;
- string theory;
- nonlinear effects in extended media.

Collaborations with several universities and institutes have been maintained (e.g. the Universities of Warsaw, Kielce, UMCS, Paris, Liege, London and Scientific Institutes like: PAN, CERN, GANIL,GSI, JINR, RIKEN).

It is with great regret that we note the deaths of our two excellent colleagues in 2017. Both of them throughout their scientific life were very closely related to our theoretical department at Hoża; supporting and co-creating it.

Professor Janusz Dąbrowski passed away on January 13, 2017, He was one of the most outstanding nuclear physicists in Poland. He was co-founder and Head of the Atomic Nucleus Theory Division in the former Institute for Nuclear Research. He was a great man of a very optimistic attitude and inexhaustible sense of humour.



Professor Adam Sobiczewski passed away on October 20, 2017. He was a world-class expert in theoretical nuclear physics, in particular, the structure and properties of heavy and superheavy nuclei. Prof. Sobiczewski's played a vital role in building the strong position of the physics of heavy and super-heavy nuclei, both at NCBJ and in Poland.

Michał Kowal

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Dark matter, on and off the beaten track
L. Darme
Astrofizyka Cząstek w Polsce (Poland, Kraków, 2017-09-20 - 2017-09-22)

Quantum dynamics of the general Bianchi IX model
W. Piechocki
The 4th Conference of the Polish Society on Relativity (Poland, Kazimierz Dolny, 2017-09-24 - 2017-09-28)

Search for Deeply Bound Kaonic Nuclear States inThe AMADEUS Experiment
M. Skurzok, **S. Wycech**
XXXV Mazurian Lakes Conference on Physics (Poland, Piaski, 2017-09-04 - 2017-09-09)
Acta Phys. Pol. B Vol. 49 (2018) 705

Quark-quark Correlations in the CGC
T. Altinoluk, T. Altinoluk, N. Armesto, G. Beuf, A. Kovner, M. Lublinsky
International Conference on the Initial Stages of High-Energy Nuclear Collisions (IS 2017) (Poland, Krakow, 2017-09-18 - 2017-12-22)

Interplay of nonextensivity and dynamics in the description of QCD matter
J. Rożynek, **G. Wilk**
XL Brazilian Meeting on Nuclear Physics (Brazil, Campos do Jordã, 2017-09-03 - 2017-09-07)

Internal clock formulation of quantum mechanics
P. Małkiewicz
The 4th Conference of the Polish Society on Relativity (Poland, Kazimierz Dolny, 2017-09-24 - 2017-09-28)

Two-particle correlations in the CGC
T. Altinoluk, T. Altinoluk, N. Armesto, G. Beuf, A. Kovner, M. Lublinsky
IV. Spanish-Russian Congress on Particle, Nuclear, Astroparticle Physics and Cosmology (Russia, Dubna, 2017-09-04 - 2017-09-08)

Adiabatic fission barriers and High-K states in superhevy nuclei.
P. Jachimowicz, **M. Kowal**, **J. Skalski**
First Physics with the Super SeparatorSpectrometer S3 (France, CEA Saclay, 2017-03-27 - 2017-03-30)

The nucleon properties inside dense nuclear matter.
J. Rożynek
XL Brazilian Meeting on Nuclear Physics (Brazil, Campos do Jordã, 2017-09-03 - 2017-09-07)

Production of a photon and two jets in the hybrid factorization
T. Altinoluk, T. Altinoluk, N. Armesto, A. Kovner, M. Lublinsky, E. Petreska
2017 Low x Workshop (Italy, Bari, 2017-06-12 - 2017-06-18)

Candidates for Extra Stables High-K Ground States in Super-heavy Nuclei
P. Jachimowicz, **M. Kowal**, **J. Skalski**
2017 KFFTP-BLTP Joint Workshop on Physics of Strong Interaction (China, Shen-Shen, 2017-11-26 - 2017-12-01)

Properties of actinides nuclei within macroscopic-microscopicWarsaw model
P. Jachimowicz, **M. Kowal**, **J. Skalski**
Recommended Input Parameter Library for Fission Cross Section Calculation (RIPL), Vienna, Austria (Austria, Vienna, 2017-06-06 - 2017-06-09)

On neutrino production of a charmed meson
B. Pire, **L. Szymanowski**, **J. Wagner**
25th International Workshop on Deep Inelastic Scattering and Related Topics (DIS 2017) (United Kingdom, Birmingham, 2017-04-03 - 2017-04-07)

Problem of IIId minimum in light actinides nuclei
P. Jachimowicz, **M. Kowal**, **J. Skalski**
Recommended Input Parameter Library for Fission Cross Section Calculation (RIPL), Vienna, Austria (Austria, Vienna, 2017-06-06 - 2017-06-09)

NLO exclusive diffractive processes with saturation
R. Boussarie, A.V. Grabovsky, D.Yu. Ivanov, **L. Szymanowski**, S.Wallon.
25th International Workshop on Deep Inelastic Scattering and Related Topics (DIS 2017) (United Kingdom, Birmingham, 2017-04-03 - 2017-04-07)

Exploring GPDs through the photoproduction of a gamma rho pair
R. Boussarie, B. Pire, **L. Szymanowski**, S. Wallon
25th International Workshop on Deep Inelastic Scattering and Related Topics (DIS 2017) (United Kingdom, Birmingham, 2017-04-03 - 2017-04-07)

Structure of ground and excited states in SHE from deformed Woods-Saxon.
P. Jachimowicz, **M. Kowal**, **J. Skalski**
3rd International Symposium on Super-Heavy Elements "Challenges in the studies of super-heavy nuclei and atoms". SHE 2017 (Poland, Kazimierz Dolny, 2017-09-09 - 2017-09-14)

QCD resummation effects in forward J/ψ and very backward jet inclusive production at the LHC
R. Boussarie, B. Ducloué, **L. Szymanowski**, S. Wallon
25th International Workshop on Deep Inelastic Scattering and Related Topics (DIS 2017) (United Kingdom, Birmingham, 2017-04-03 - 2017-04-07)

Search for the effects of tetrahedral symmetry in the heaviest nuclei
P. Jachimowicz, **M. Kowal**, **J. Skalski**
3rd International Symposium on Super-Heavy Elements "Challenges in the studies of super-heavy nuclei and atoms". SHE 2017 (Poland, Kazimierz Dolny, 2017-09-09 - 2017-09-14)

Fission of SHN & its hindrance: odd-particle systems & isomers
W. Brodziński, P. Jachimowicz, **M. Kowal**, **J. Skalski**
3rd International Symposium on Super-Heavy Elements "Challenges in the studies of super-heavy nuclei and atoms". SHE 2017 (Poland, Kazimierz Dolny, 2017-09-09 - 2017-09-14)

Structure and decay properties of the high-K ground and isomeric states in heaviest elements
P. Jachimowicz, **M. Kowal**, **J. Skalski**
COPIGAL Meeting on recent results and future projects involving PARIS, AGATA, NEDA, and FAZIA detectors (Poland, Krakow, 2017-12-13 - 2017-12-15)

On Gamov states of Sigma+ Hyperons
S. Wycech, K. Pisciccia
2-nd Jagiellonian Symposium on Fundamental and Applied Subatomic Physics (Poland, Krakow, 2017-06-03 - 2017-06-11)
Acta Phys. Pol. B Vol. 48 (2017) 1861

Space-time near a cosmological singularity
S. Parnovsky, **W. Piechocki**
International Conference "Astronomy and Space Physics in Kyiv University " (Ukraine, Kuiv, 2017-05-23 - 2017-05-26)

Oral Presentation

Stability of nonliear waves and solitons described by the Zakharov-Kuznetsov equation
P. Goldstein, **E. Infeld**
Nonlinearity & Geometry. SYMposium (dedicated to prof. A. Sym on the occasion of his 70th birthday) (Poland, Warszawa, 2017-01-20 - 2017-01-23)

Stability of ion acoustic nonlinear waves and solitons in low β plasmas
P. Goldstein, **E. Infeld**
PLASMA 2017. International Conference on Research and Applications of Plasmas (Poland, Warszawa, 2017-09-18 - 2017-09-22)

New exclusive processes and the PARTONs project
J. Wagner
NT Program INT-17-3, Tomography of Hadrons and Nuclei at Jefferson Lab (USA, Seattle, 2017-08-28 - 2017-09-27)

An instanton - motivated approach to the spontaneous fission of odd nuclei
W. Brodziński, **J. Skalski**
3rd International Symposium on Super-Heavy Elements "Challenges in the studies of super-heavy nuclei and atoms". SHE 2017 (Poland, Kazimierz Dolny, 2017-09-09 - 2017-09-14)

Reconstructing WIMP DM properties through an interplay of signal measurements in direct detection, Fermi-LAT, and CTA searches for dark matter
L. Roszkowski, **E. Sessolo**, **S. Trojanowski**, K. Turzyński, **A.J. Williams**
Cosmic Rays, Pulsars & Dark Matter (USA, Santa Fe, 2017-03-01 - 2017-03-03)

Towards understanding thermal history of the Universe through direct and indirect detection of dark matter
L. Roszkowski, **S. Trojanowski**, K. Turzyński
PLANCK 2017: 20th International Conference from the Planck Scale to the Electroweak Scale (Poland, Warsaw, 2017-05-21 - 2017-05-27)

Inhibited and/or enhanced alpha transitions from high-K (super)heavy isomers.
P. Jachimowicz, **M. Kowal**, **J. Skalski**
XXXV Mazurian Lakes Conference on Physics (Poland, Piaski, 2017-09-04 - 2017-09-09)

Muon g-2 (and related pheno) in vector-like extensions of the MSSM
A. Choudhury, **L. Darme**, **L. Roszkowski**, E. Sessolo, **S. Trojanowski**
PLANCK 2017 (Poland, Warszawa, 2017-05-22 - 2017-05-27)

Expectations for the muon g-2 in simplified models with dark matter
K. Kowalska, **E. Sessolo**
EPS-HEP 2017 (Italy, Venice, 2017-07-05 - 2017-07-12)

Hard photoproduction of a diphoton with a large invariant mass
A. Pędrak, B. Pire, **L. Szymanowski**, **J. Wagner**
GDR QCD 2017 (France, Saclay, Paris, 2017-12-04 - 2017-12-06)

Game of frames: Jordan vs. Einstein - dynamical systems approach
O. Hrycyna
The 4th Conference of the Polish Society on Relativity (Poland, Kazimierz Dolny, 2017-09-24 - 2017-09-28)

Sound waves in hadronic matter
G. Wilk, Z. Włodarczyk
XLVI International Symposium on Multiparticle Dynamics (Mexico, Tlaxcala City, 2017-09-11 - 2017-09-15)
EPJ Web Conf. Vol. 172 (2018) 01002

Chiral symetries and partner groups
A. Góźdź, **A. Pędrak**, A. Gosev, S. Vinicky

XXIV Nuclear Physics Workshop (Poland, Kazimierz Dolny, 2017-09-20 - 2017-09-24)

Fission hindrance for odd-particle systems & isomers in SH nuclei
W. Brodziński, P. Jachimowicz, **M. Kowal**, **J. Skalski**
XXXV Mazurian Lakes Conference on Physics (Poland, Piaski, 2017-09-04 - 2017-09-09)
Search for Deeply Bound Kaonic Nuclear States with AMADEUS
M. Skurzok, **S. Wycech**
8th Nuclear Physics in Astrophysics (NPA8) (Italy, Catania, 2017-06-18 - 2017-06-25)
European Physical Journal Web of Conferences Vol. 165 (2017) 01046

The fate of the oscillating false vaccum
L. Darme
PLANCK 2017: 20th International Conference from the Planck Scale to the Electroweak Scale (Poland, Warsaw, 2017-05-21 - 2017-05-27)

Dark matter and the high-intensity frontier
L. Darme
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)

Formation of Sigma Pi pairs in nuclear capture of K- mesons
R. DelGrande, K. Piscicchia, **S. Wycech**
2-nd Jagiellonian Symposium on Fundamental and Applied Subatomic Physics (Poland, Krakow, 2017-06-03 - 2017-06-11)
Acta Phys. Pol. B Vol. 48 (2017) 1881

Poster

Towards understanding thermal history of the Universe through direct and indirect detection of dark matter
L. Roszkowski, **S. Trojanowski**, K. Turzyński
DM@LHC 2017 (USA, Irvine, CA, 2017-04-03 - 2017-04-05)

LECTURES, COURSES AND EXTERNAL SEMINARS

High-K states in Superehevy nuclei[a]
M. Kowal
Krakow, IFJ, 2017-04-22

Quantum dynamics of Hamiltonian constraint systems[b]
P. Małkiewicz
Warsaw, Theoretical Physics Institute, Physics Department, Warsaw University, 2017-05-26

Relaxing the eikonal approximation: Finite width target corrections in the CGC [b]
T. Altinoluk
Krakow, Jagiellonian University, 2017-05-30

New superheavy elements[a]
M. Kowal
Lublin, UMCS, 2017-10-19

Hard photoproduction of a diphoton with large invariant mass[a]
A. Pędrak
Lublin, Uniwersytet Marii Curie-Skłodowskiej, Katedra Fizyki Teoretycznej, 2017-11-07

Renormalization in cold gases: calculation of the Lee-Huang-Yang Correction[b]
P. Ziń
Warsaw, Center For Theoretical Physics, 2017-11-22

Expectations for the muon g-2 in simplified models with dark matter[b]
E. Sessolo
Warsaw, University of Warsaw, 2017-12-14

Stability of ion acoustic nonlinear waves and solitons and solitons in low β plasmas[b]
P. Goldstein
Edmonton, Alberta, Canada, University of Alberta, 2017-06-16

Internal clock formulation of quantum mechanics[b]
P. Małkiewicz
Paris, France, APC, Universite Paris Diderot, 2017-09-29

Cross sections predictions and some structure efects in syperehavy nuclei.[b]
M. Kowal
Beijing , Institute of Theoretical Physics Chinese Academy of Sciences, 2017-11-22

a) in Polish
b) in English

INTERNAL SEMINARS

How\'s SUSY doin\' - A brief assessment of the state of supersymmetry[b]
E. Sessolo
Dortmund, TU Dortmund, 2017-05-09

Hard photoproduction of a diphoton with a large invariant mass[b]
A. Pędrak
Warsaw, National Centre For Nuclear Research, 2017-12-13

b) in English

DIDACTIC ACTIVITY

W. Piechocki - Co-promoter of Nick Kwidzynski (Institute for Theoretical Physics, Cologne University, Germany) in his studies to obtain his doctor degree in theoretical physics.

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

E. Czuchry
member of Polish Society of Relativity

J. Dąbrowski
Fellow of the American Physical Society
Acta Physica Polonica B, Member of the International Editorial Council of Acta Physica Polonica B

P. Goldstein
Polish Physical Society
American Mathematical Society

O. Hrycyna
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Fellow of the Institute of Physics, London, UK
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Journal of Technical Physics, Member of the Editorial Board of Journal of Technical Physics Institute of Fundamental Technical Research, Polish Academy of Sciences

M. Kowal
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P. Małkiewicz
Polish Society on Relativity

J. Mielczarek
Polish Society on Relativity

W. Piechocki
Member of the Polish Relativistic Society
Member of the Polish Physical Society
Member of NCBJ Scientific Council
PhD Proceedings Admission Committee Member of the NCBJ Scientific Council

L. Roszkowski
Reports on Progress in Physics, Reports on Progress in Physics, Institute of Physics Publishing
Reports on Progress in Physics, Reports on Progress in Physics Institute of Physics

J. Skalski
member of the Scientific Council of the National Centre for Nuclear Research

A. Sobiczewski
Corresponding Member of the Polish Academy of Sciences
Corresponding Member of Polish Academy of Learning
full member, Polish Academy of Sciences
full member, Polish Academy of Arts and Sciences
Warsaw Scientific Society, full member
Postępy Fizyki, Honorary editor of "Postępy Fizyki" (Advances in Physics)
Nuclear Physics and Atomic Energy, Editor: Kiev Insitute for Nuclear Research of the National Academy of Sciences of Ukraine
Member of the Scientific Council of the Heavy Ion Laboratory of Warsaw University
Member of the Programme Advisory Committee for Nuclear Physics, JINR, Dubna (Russia)
Nicolaus Copernicus Astronomical Center
Member of the Scientific Council, The Niewodniczański Institute for Nuclear Physics of the Polish Academy of Sciences (Cracow)
National Center for Nuclear Research: member

M. Spaliński
International Journal of Modern Physics A, Member of the Editorial Board, International Journal of Modern Physics A
member

L. Szymanowski
member of PANDA Theory Advisoty Group

S. Trojanowski
Member of Organizing Committee on WIN 2017: The 26th International Workshop on Weak Interactions and Neutrinos in Irvine, CA, USA

Research scientists
Tolga Altinoluk
Jan Błocki, Professor
Brodziński Wojciech, MSc
Ewa Czuchry, PhD
Luc Darmé, PhD
Piotr Goldstein, PhD
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Orest Hrycyna, PhD
Andrzej Hryczuk*, PhD
Eryk Infeld, Professor
Michał Kowal, Associate Professor
Kamila Kowalska*, PhD
Przemysław Małkiewicz, PhD
Aleksandra Pędrak, PhD
Włodzimierz Piechocki, Professor
Grzegorz Plewa, PhD
Maciej Pylak*, PhD
Soumya Rao, PhD
Leszek Roszkowski, Professor
Jacek Rożynek, PhD
Enrico Sessolo, PhD
Janusz Skalski, Associate Professor
Adam Sobiczewski, Professor
Michał Spaliński, Professor
Lech Szymanowski, Professor
Sebastian Trojanowski*, PhD
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Grzegorz Wilk, Professor
Sławomir Wycech, Professor
Paweł Ziń, PhD

PhD students
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Wojciech Brodziński, MSc
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Technical and administrative staff
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HIGH ENERGY PHYSICS DIVISION

Head of Division Justyna Łagoda, PhD DSc, prof. NCBJ
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The Division participates in various high energy physics experiments, covering the most interesting topics in the particle physics. These include experiments at the Large Hadron Collider, neutrino oscillations, searches for Dark Matter and accelerator experiments with fixed targets.

Among the LHC experiments, the Division takes part in three of them: CMS, ALICE and LHCb.

The CMS NCBJ group collaborates with Warsaw University and Warsaw University of Technology. The group continues work on the improvement of one of the muon triggering subsystems and performs data analysis. The main subjects of interest here are decays of the Higgs boson into a pair of τ leptons, in which the significance reached currently is 5σ, and the search for heavy stable charged particles predicted by some extensions of the Standard Model, for which no signal has yet been found and only the limits on cross section could be obtained.

The aim of the ALICE collaboration is to study the quark-gluon plasma, produced in collisions of heavy ions and light systems at high energies. The data are taken for lead-lead, proton-lead and proton-proton collisions. The NCBJ group is involved in the reconstruction of the neutral pion and η^o-meson spectra and the analysis of the prompt and thermal photon production, which allow the properties of the early stage of the interaction and the thermal properties of the plasma to be determined. The aim of the analysis of charged particle emission carried out by the group is to infer the degree of plasma thermalisation from the imprint left by it on the secondary charged particles leaving the interaction region. The group also took part in the construction and maintenance of the photon spectrometer and the software development for the ALICE experiment.

The LHCb experiment is dedicated to studies of heavy flavour production and the decays of particles containing *b* and *c* quarks. The NCBJ group participates in studies of the violation of the CP symmetry in the decays of B_s mesons, analysis of charmed hyperons and the search for exotic hadronic states. The activity of the group also includes detector maintenance and alignment as well as software development.

The NCBJ neutrino group is mainly involved in the T2K long-baseline experiment in Japan, which aims at a precise determination of the neutrino mixing parameters and the search for CP violation in the lepton sector by observing the neutrino oscillations in a muon neutrino beam. The group is activity concerns the analyses performed in the Near Detector, including those related to the measurements of the cross section for (anti)neutrino interactions, and the oscillation analyses, for which the Near Detector provides a reference measurement of the unoscillated beam. In cooperation with the University of Wrocław, the group also contributed to the improvement of the neutrino interaction simulation.

Some members of the neutrino group participate in indirect searches for Dark Matter by observation of neutrino events in the Super-Kamiokande detector. Recently, the group also joined the KM3Net project, aimed at the construction of a huge deep sea neutrino telescope.

Among the fixed-target experiment in which the Division is involved, the NA61/SHINE experiment at the CERN SPS accelerator has a connection with the neutrino group, as it provided the differential cross sections for hadron production in the collisions of a proton beam with carbon and the T2K replica target, which allowed the neutrino beam systematic error in the T2K experiment to be considerably reduced. NA61/SHINE also studied hadron production in proton-proton and π^--carbon collisions.

COMPASS is another CERN SPS experiment, is devoted to the study of the intrinsic three-dimensional and spin structure of the proton as well as hadron spectroscopy using high energy hadron and polarised muon beams scattering off polarised and unpolarised targets. Recently, the experiment provided the first measurement of the Sivers asymmetry for gluons from semi-inclusive deep inelastic scattering, in which the NCBJ group played the major role. This result appears particularly interesting in view of the gluon contribution to the proton spin, as the observed non-zero gluon Sivers asymmetry is a signature of gluon orbital momentum.

Two experiments located outside CERN in which the members of the Division participate are: KLOE, running on the DAΦNE e^+e^- storage ring, in which the NCBJ group looks for violation of T and CPT symmetry in neutral kaon pairs coming from Φ meson decays; and WASA at COSY, where the NCBJ group studies the rare decays of η mesons searching for possible deviations from the Standard Model.

Thanks to a wide and active involvement in international experiments, in 2017 members of the Division are (co-)authors of 284 peer-reviewed publications .

Justyna Łagoda

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Nuclear energy in Poland - perspectives
G. Wrochna
International conference on advances in energy systems and environmental engineering (ASEE17) (Poland, Wrocław, 2017-07-02 - 2017-07-05)

PARTONS project and fits to high precision DVCS data
P. Sznajder
25th International Workshop on Deep Inelastic Scattering and Related Topics (DIS 2017) (United Kingdom, Birmingham, 2017-04-03 - 2017-04-07)

Nuclear Cogeneration Industrial Initiative for SET plan
G. Wrochna
Workshop SET-Plan Implementation Plan on key action n.10 on Nuclear (Belgium, Brussels, 2017-07-12 - 2017-07-13)

PARTONS project and fits to high precision DVCS data
P. Sznajder
XVII International Conference on Hadron Spectroscopy and Structure (Hadron 2017) (Spain, Salamanca, 2017-09-25 - 2017-09-29)

Heavy Quarks in Turbulent QGP
St. Mrówczyński
Initial Stages 2017 (Poland, Kraków, 2017-09-18 - 2017-09-22)

Nuclear High-Temperature Heat for Industrial Processes: High Temperature Gas-cooled Reactors (HTGR) in Europe
G. Wrochna
61st IAEA General Conference (Austria, Vienna, 2017-09-18 - 2017-09-22)

Obliczenia dużej mocy w Departamencie Badań Układów Złożonych NCBJ
A. Padee, H. Giemza, M. Wójcik, K. Klimaszewski, W. Jaworski, M. Karpiarz, P. Kowalski
Atmosphere Conference 2017 (Poland, Kraków, 2017-05-16 - 2017-05-17)

Our interests in NICA
St. Mrówczyński
II NICA Days in Warsaw (Poland, Warsaw, 2017-11-06 - 2017-11-10)

Status and prospects of neutrino physics
J. Zalipska
Matter to the Deepest, XLI International Conference of Theoretical Physics (Poland, Podlesice, 2017-09-03 - 2017-09-08)
Acta Phys. Pol. B (2017)

COMPASS results on DVCS and exclusive π^0 production
A. Sandacz
XVII Workshop on High Energy Spin Physics DSPIN-17 (Russia, Dubna, 2017-09-11 - 2017-09-15)

Pion production at the nucleon level: resonances and continuum
M. Kabirnezhad
NuInt 17: 11th International Workshop on Neutrino-Nucleus Scattering in the Few-GeV Region (Canada, Toronto, 2017-06-25 - 2017-06-30)

Rare meson decays from WASA-at-COSY
J. Stepaniak
Workshop WASA at GSI/FAIR (Germany, Darmstadt, 2017-11-27 - 2017-11-28)

Searches for dark matter induced neutrinos at Super-Kamiokande
P. Mijakowski
Astrofizyka Cząstek w Polsce 2017 (Poland, Krakow, 2017-09-20 - 2017-09-22)

Status of the DUNE experiment
D. Stefan
International Workshop on Next Generation Nucleon Decay and Neutrino Detectors (NNN17) (United Kingdom, Warwick, 2017-10-26 - 2017-10-28)

Entanglement, fluctuations and discrete symmetries in∗particle decays
W. Wiślicki
2nd Jagiellonian Symposium on Fundamental and Applied Subatomic Physics (Poland, Kraków, 2017-06-04 - 2017-06-09)
Acta Phys. Pol. B Vol. B48 (2017) 1909

Dark Matter Searches at Super-Kamiokande
P. Mijakowski
TAUP 2017 — XV International Conference on Topics in Astroparticle and Underground Physics (Canada, Sudbury, 2017-07-24 - 2017-07-28)
J Phys Conf Ser (2017)

Entanglement in particle decays
W. Wiślicki
57 Cracow School of Theoretical Physics (Poland, Zakopane, 2017-06-19 - 2017-06-22)

The tracking system at LHCb in Run 2: hardware alignment systems, online calibration, radiation tolerance and 4D tracking with timing
A. Ukleja
International Conference on Technology and Instrumentation in Particle Physics (China, Beijing, 2017-05-22 - 2017-05-27)

Experimental anomalies as possible hints to new phenomena in flavour physics
W. Wiślicki
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)

Recent results on neutrino oscillations
J. Łagoda
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)

Studies of CP and CPT symmetries with LHCb
W. Krzemień
2nd Jagiellonian Symposium on Fundamental and Applied Subatomic PhysicsWorkshop on Discrete Symmetries and Entanglement (Poland, Cracow, 2017-06-04 - 2017-06-09)

T2K and other long baseline experiments
J. Łagoda
Astrofizyka Cząstek w Polsce (Poland, Kraków, 2017-09-20 - 2017-09-22)

The Hyper-Kamiokande project
J. Łagoda
FPCP 2017 - Flavor Physics & CP VIolation (Czech Republic, Prague, 2017-06-05 - 2017-06-09)
Proceedings of Science (PoS) Vol. FCPV2017 (2017) 24

CMS Overview. Physics highlights.
M. Kazana
6th International Conference on New Frontiers in Physics (ICNFP 2017) (Greece, Kolymbari, 2017-08-17 - 2017-08-29)
EPJ Web Conf. (2018)

Machine Learning approach to neutrino experiment track reconstruction
R. Sulej
Connecting The Dots / Intelligent Trackers (France, Orsay, 2017-03-06 - 2017-03-09)

Oral Presentation

Heavy flavour production at the LHC energies with CMS
B. Boimska
4th International Conference on the Initial Stages in High-Energy Nuclear Collisions (Poland, Cracow, 2017-09-18 - 2017-09-22)

The T2K Flux Prediction
K. Kowalik
NuInt 17: 11th International Workshop on Neutrino-Nucleus Scattering in the Few-GeV Region (Canada, Toronto, 2017-06-25 - 2017-06-30)

Search for physics beyond the SM in meson decays with WASA detector
D. Pszczel
EPS-HEP 2017 (Italy, Venice, 2017-07-05 - 2017-07-12)
Proceedings of Science (in press)

Exotic hadrons with heavy flavour
D. Melnychuk
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)

Message Queues in DIRAC
W. Krzemień
7th DIRAC Workshop (Poland, Warszawa, 2017-05-29 - 2017-05-31)

Mixing and CPV in charm hadrons at LHCb
W. Krzemień
The 21st Particles and Nuclei International Conference (PANIC) (China, Beijing, 2017-09-01 - 2017-09-05)

Opportunities for international collaboration on modular high temperature reactors
M. Richards, C. Hamilton, D. Hoffman, K. Kunitomi, M.-H. Kim, M.A. Fütterer, **G. Wrochna**
International Congress on Advances in Nuclear Power Plants, ICAPP 2017 - A New Paradigm in Nuclear Power Safety (Japan, Kyoto, 2017-04-24 - 2017-04-28)
International Congress on Advances in Nuclear Power Plants, ICAPP No. (2017)

Recent results from KLOE-2
W. Krzemień
The 21st Particles and Nuclei International Conference (PANIC) (China, Beijing, 2017-09-01 - 2017-09-05)

The ALLEGRO Experimental Gas Cooled Fast Reactor Project
L. Bělovský, J. Gadó, B. Hatala, A. Vasile, **G. Wrochna**
International Conference on Fast Reactors and Related Fuel Cycles: Next Generation Nuclear Systems for Sustainable Development (FR17) (Russia, Yekaterinburg, 2017-06-26 - 2017-06-29)
International Atomic Energy Agency No.IAEA-CN-245-96 (2017)

Plans for deployment of High Temperature Reactors in Poland
G. Wrochna
26th International Conference Nuclear Energy for New Europe (NENE 2017) (Slovenia, Bled, 2017-09-11 - 2017-09-14)

Poster

Simulation of the two- and three-photon events in the J-PET scanner
R. Masełek, W. Krzemień

VI Ogólnokrajowa Konferencja Młodzi Naukowcy w Polsce -- Badania i Rozwój (Poland, Warsaw, 2017-11-17 - 2017-11-17)

Polish In-Kind Contribution to European XFEL: Status in Summer 2017
J. Lorkiewicz, **K. Chmielewski**, Z. Gołębiewski, **W. Grabowski**, **K. Kosiński**, **K. Kostrzewa**, **P. Krawczyk**, **I.M. Kudła**, **P. Markowski**, K. Meissner, **E. Pławski**, **M. Sitek**, **J. Szewiński**, **M. Wojciechowski**, **Z. Wojciechowski**, **G. Wrochna**, **J. Sekutowicz**, J. Fydrych, M. Duda, M. Jeżabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Stodulski, M. Wiencek, J. Świerblewski, P. Grzegory, G. Michalski, P. Borowiec, M. Chorowski, P. Duda, A. Iluk, K. Malcher, J. Poliński, E. Rusiński, J. Głowinkowski, M. Winkowski, P. Wilk
38th International Free-Electron Laser Conference (FEL2017) (USA, Santa Fe, 2017-08-20 - 2017-08-25)
Kip Bishopsberger (LNL), Volker RW Schaa (GSI) (Santa Fe, NM, USA) No. (2017)

LECTURES, COURSES AND EXTERNAL SEMINARS

Elements of modern C++ and STL[b]
W. Krzemień
Cracow, Jagiellonian University, 2017-03-20

Search for a dark matter at the LHC[b]
P. Zalewski
Warsaw, University of Warsaw, Physics Department, 2017-04-11

Search for dark matter at the LHC[b]
P. Zalewski
Warsaw, University of Warsaw, Physics Department, 2017-04-21

OMTF Performance[b]
M. Kazana
Geneve, CERN, 2017-11-15

CMS Overview.[b]
M. Kazana
Warsaw, University of Warsaw, 2017-12-08

Search for the CP and CPT symmetry violation in the flavour neutral meson system at LHCb[b]
W. Krzemień
Cracow, Jagiellonian University, 2017-12-11

Analysis of the eta->eeg channel (pp 2012 data): dark photon and eta form factor[b]
D. Pszczel
Julich, Germany, Forschungzentrum, 2017-06-02

Study of eta-pi0e+e- and eta-e+e-[b]
J. Stepaniak
Julich, Germany, Forschungzentrum, 2017-06-02

How machine learning conquers reconstruction in neutrino experiments[b]
R. Sulej
Geneva, CERN, 2017-07-26

Nuclear Innovations 2050 Advisory Panel: Plans for HTGR deployment in Poland[b]
G. Wrochna
Paris, OECD Nuclear Energy Agency, 2017-09-25

Search for the CP and CPT symmetry violation in the flavour neutral meson s ystem at LHCb[b]
W. Krzemień
Uppsala, Uppsala University, 2017-10-05

Prismatic High-Temperature Gas-cooled Reactor (HTGR) for its Development and Deployment: Plans for HTGR deployment in Poland[b]

G. Wrochna
Vienna, Permanent Mission of Japan to the International Organizations in Vienna, 2017-10-31

eta -> e+e-g analysis, form factor extraction and dark photon search[b]
D. Pszczel
Munster, Germany, Institut fur Kernphysik, 2017-11-03

(LHCb)DIRAC Developments: MessageQueues[b]
W. Krzemień
Frascati,, INFN, 2017-11-21

Looking for CP asymmetry in prompt three-body charm baryon decays[b]
A. Ukleja
Geneva, CERN, 2017-11-29

From physics to medicine. Few words about distributed computing and network security[a]
W. Krzemień
Cracow, Jagiellonian University, 2017-01-11

a) in Polish
b) in English

INTERNAL SEMINARS

Nuclear enegy in Poland - Vanka-Vstanka or Schroedinger\'s cat?[a]
G. Wrochna
Warsaw, Warsaw University, Faculty of Physics, 2017-04-07

solar neutrinos and oscyllations in dense matter[a]
M. Szeptycka
warsaw, ncbj, neutrino group, 2017-04-12

From Pauli\'s hypothesis to T2K experiment[b]
J. Łagoda
Warsaw, NCBJ, 2017-04-24

core collapse supernova and neutrinos[a]
M. Szeptycka
warsaw, ncbj, neutrino group, 2017-04-28

Particle-Flow reconstruction and global event description with the CMS detector at LHC[b]
M. Bluj
Warsaw, University of Warsaw, 2017-05-19

Tau reconstruction and identification for CMS Phase-2 upgrade TDRs[b]
M. Bluj
Geneva, CERN, 2017-07-12

Do we lose reconstructing new (recovery) tau decay modes?[b]
M. Bluj
Geneva, CERN, 2017-09-04

Performance of tau reconstruction and identification with Pt(gamma)>1GeV and a new trainig of MVA-isolation for 2017[b]
M. Bluj
Geneva, CERN, 2017-10-23

[a] in Polish
[b] in English

DIDACTIC ACTIVITY

M. Bluj - Auxiliary supervisor of Ph.D. thesis of Michał Olszewski, a doctoral student at Physics Department of University of Warsaw

M. Bluj - Supervision of a traineeship of Mr. Jan Klamka a student at Physics Department of University of Warsaw

M. Bluj - Supervision of Andrzej Pyskir a doctoral student at Physics Department of University of Warsaw (with dr. hab. Artur Kalinowski)

J. Łagoda - Grzegorz Żarnecki, since March 2017

J. Łagoda - Supervising of student's laboratory: "Neutrino interactions outside of T2K near detector: sand muons" (Wawrzyniec Korzeń)

J. Łagoda - Why do we use a near detector in neutrino experiments (Kamil Skwarczyński)

E. Rondio - Katarzyna Frankiewicz

E. Rondio - Monireh.Kabirnezhad

A. Sandacz - Supervision of master's student Piotr Orpel from Physics Department of Warsaw University of Technology. The subject of his master degree thesis is related to the COMPASS experiment data.

T. Siemiarczuk - Charged particle production in pp, pPb and PbPb interactions at LHC energies in the ALICE experiment

T. Siemiarczuk - Photon production in pp interactions at LHC energies in the ALICE experiment

M. Szeptycka - continuation of work with Marcin Kasztelan

M. Szleper - Supervision of a summer student training project for a 4th year physics student, Mr. Krzysztof Jodłowiec.

W. Wiślicki - Coaching PhD

J. Zalipska - Open lecture presented during Festival of Science "Neutrino the ghost particle and traps for neutrinos".

J. Zalipska - Public lecture during Festival of Science "How to caugth ghost particles, so traps for neutrinos"

J. Zalipska - Supervising student during her specialized laboratory work in a summer semester of academic year 2016/2017

J. Zalipska - Supervising student during its laboratory work, academic year 2016/2017

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

H. Białkowska
Warsaw Scientific Society
Member of the Scientific Council of the Institute of Experimental Physics, Warsaw University

W. Krzemień
Member of Organizing Committee on 7th DIRAC Workshop in Warszawa, Poland

J. Łagoda
NCBJ, member, head of Doctorate Board

St. Mrówczyński
member of Committee of Physics of Polish Academy of Sciences

E. Rondio
Electron-Ion-Collider Advisory Committee
member of Scientific Advisory Committee Institute Cosmology and Physics of Americas (COFI)
Member of scientific Board
member of Scientific Board for Institute of Experimental Physics, Physics Faculty of Warsaw University

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Member of the Warsaw Scientific Society
Member of the European Physical Society
Full member of the Polish Academy of Sciences
Active member Polish Academy of Knowledge
Fellow European Physical Society
Uniwersity of Warsaw Heavy Ion Laboratory

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National Centre for Nuclear Research

W. Wiślicki
Pl-Grid National Consortium
Member of Steering Committee of the Scientific Board, National Centre for Nuclear Research
Member of the European Technology Platform for High Performance Computing
Board Member

G. Wrochna
Member of the Polish Nuclear Society
Member of the Physics Committee PAN
Societas Scientiarum Varsaviensis
Chairman of the Energy Minister's advisory committee to analyse and prepare conditions for the implementation of high-temperature nuclear reactors in Poland
Member of the Governing Board of European Sustainable Nuclear Energy Technology Platform (SNETP)
Chairman of Nuclear Cogeneration Industrial Initiative (NC2I)
Member of the Science Policy Committee, Minstry of Science and Higher Education
Committee for analysis of financing science and higher education
Member of the Governing Board of Polish Committee of World Energy Council
Chairman of European Atomic Energy Society
Expert of Euratom Program Committee
Member of Adisory Panel for Nuclear Innovations 2050, OECD Nuclear Energy Agency
Member of the Steering Committee of V4G4 Association (Visegrad-4 group for Generation-4 reactors)
Member of the European-XFEL Council
Member of Nuclear Science Committee of OECD's Nuclear Energy Agency
Member of Committee on the Safety of Nuclear Installations of OECD's Nuclear Energy Agency
Member of the panel of experts for the interim evaluation of the JRC's nuclear activities under the Euratom programme (2014-2018).
Member of the Scientific Council of the Institute of Plasma Physics and Laser Microfusion
Member of the Scientific Council of the Central Labortory for Radiological Protection
Member of the presidium of the scientific council of National Centre for Nuclear Research

P. Zalewski
Programme Committee Member, Finance/Economics Committee Member; National Centre for Nuclear Research

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Varvara Batozska, MSc
Helena Białkowska**, Professor
Marcin Berłowski*, PhD
Michał Bluj, PhD
Bożena Boimska, PhD
Maciej Górski, PhD
Julia Hoffman*, PhD
Monireh Kabirnezhad,
Małgorzata Kazana, PhD
Katarzyna Kowalik, PhD
Wojciech Krzemień, PhD
Andrzej Kupść*, Associate Professor
Podist Kurashvili, PhD
Justyna Łagoda, Associate Professor
Dmytro Melnychuk, PhD
Piotr Mijakowski, PhD
Stanisław Mrówczyński, Professor**
Adam Nawro**t, Eng
Damian Pszczel, MSc
Paweł Przewłocki, PhD
Andrzej Sandacz**, Professor
Teodor Siemiarczuk**, Professor
Ryszard Sosnowski, Professor
Joanna Stepaniak**, Professor
Dorota Stefan, PhD*
Marek Szczekowski, Associate Professor
Maria Szeptycka**, Professor
Michał Szleper, Associate Professor
Paweł Sznajder, PhD
Piotr Szymański*, Associate Professor
Piotr Traczyk, PhD*
Artur Ukleja, PhD
Grzegorz Wrochna, Professor
Piotr Zalewski, Associate Professor
Joanna Zalipska, PhD

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Katarzyna Frankiewicz, MSc
Piotr Kalczyński, MSc
Erik Kofoed, MSc
Oleksander Kovalenko, MSc
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Grzegorz Żarnecki, MSc

Technical and administrative staff
Tadeusz Marszał **
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ASTROPHYSICS DIVISION

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The Division of Astrophysics consists of two laboratories: the Laboratory of Cosmic Ray Physics in Łódź and the Laboratory of Astrophysics in Warsaw. The Laboratory of Astrophysics in Warsaw has an active research programme in observational cosmology, high-energy astrophysics, and the search for astrophysical transient sources of different origins – from gravitational wave sources to gamma ray bursts (GRBs).

Among the most important scientific events of 2017 the first place without doubt should be given to new discoveries in the field of gravitational waves, in particular the first ever event registered by gravitational wave detectors and at the same time seen in the electromagnetic range of the spectrum. This signal was attributed to the collision of two neutron stars. It is said to mark the beginning of an era of so called multi-messenger astronomy. These discoveries we made by the international LIGO/VIRGO consortium. The Polish POLGRAW belongs to the VIRGO Collaboration, and their members prof. Andrzej Królak (group leader), eng. Adam Kutynia and dr Adam Zadrożny work in our Division. We contribute both to the scientific and technological work of the LIGO/VIRGO consortium.

The cosmology group specializes in the statistics and evolution of the large scale structure of the Universe, galaxy evolution and methods of source classification in large astrophysical databases, including machine-learning based methods. It participates and/or actively uses data from the largest projects in the field: VIPERS, VUDS, AKARI and WISE. A significant achievement of 2017 was a series of scientific papers following the release of data by the VIPERS project analysing the properties of galaxies and large scale structure in the Universe when it was twice as young as it is today. We co-organized the 3rd International Cosmology Summer School “Introduction to Cosmology” in Kraków.

The Pi of the Sky experiment, aimed at the prompt detection of optical counterparts of GRBs, as well as other transient phenomena, continued its observational campaigns carried out by two observatories using in total five telescopes with 18 detectors operating at optical wavelengths. These observations were used, among other things, in the observational campaign following the binary neutron star merger detection by LIGO/VIRGO as a gravitational wave event. Pi of the Sky also detected a signal from an unusual three-episode gamma-ray burst GRB 160625B, which was subsequently described in an article published in Nature astronomy.

The Laboratory of Cosmic Ray Physics is continues its traditional line of research, concentrated on Cosmic Rays - energetic particles from outside the Solar System, and high-energy astrophysics. Energetic Cosmic Rays produce cascades of particles in the atmosphere, called Extensive Air Showers (EAS). Measuring EAS and their properties is the main means of experimental studies of very high energy Cosmic Rays.

In 2017 the main activity focused on participation in the space borne experiment EUSO. We participate in the JEM-EUSO Collaboration which is preparing a large space UV telescope to measure ultra high energy cosmic rays (with energies above 3E19 eV). With the expected statistics we should find directions to astrophysical sources of such particles (if such sources exist). In the Łódź laboratory we have developed and are producing the high voltage power supply units for the EUSO photomultipliers. Power supply units for a balloon experiment EUSO-SPB (EUSO Super Pressure Balloon) launched in 2017 were also produced in Łódź. EUSO-SPB was launched on April 24th from the NASA balloon launch site in Wanaka (New Zealand) and landed on the South Pacific Ocean on May 7th. Data analysis is in progress. In 2018, the Mini-EUSO experiment aimed at measurements of the Earth UV background is planned to be installed on the International Space Station.

Additionally, we participated in analysing data gathered by the POLAR experiment mounted on the Chinese Space Station TiangGong-2 and dedicated to measurements of polarisation of X-rays arriving from GRB.

We also started participation in a new project - the Baltic Sea Underground Innovation Network (BSUIN), which is a network of underground laboratories across the Baltic Sea region. We plan to use and develope our experience in measurements of neutron background in underground laboratories in the framework of this project.

KASCADE-Grande addresses experimentally the problems of mass composition and EAS development in the atmosphere in the energy range 1E15-1E18 eV. The LOPES Collaboration in KIT – Karlsruhe develops radio techniques for EAS measurements in Karlsruhe. These experiments, in which our group has participated from the beginning, have finished data taking, but we continue data analysis, publishing results in the top journals with high impact factors.

In the area of high energy particle physics our Division participates in the ZEUS experiment at DESY (Hamburg, Germany), and in the WASA @ COSY Collaboration in Juelich, Germany.

Agnieszka Pollo

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

First observations of gravitational wave signals
A. Królak
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)

Status of the Polgraw-Virgo group. Search for gravitational waves from rotating neutron stars in LIGO O1 data
A. Królak
The 4th Conference of the Polish Society on Relativity (Poland, Kazimierz Dolny, 2017-09-24 - 2017-09-28)

How to obtain the physical properties of a large, varied sample of galaxies
K. Małek, V. Buat, D. Burgarella, Y. Roehlly
Cosmic Censuses: exploiting large panchromatic surveys to understand extragalactic populations (United Kingdom, Sussex, 2017-10-09 - 2017-10-13)

Automatic classification of sources in large astronomical catalogues
A. Pollo, **A. Solarz**, **K. Małek**, **M. Bilicki**
The European Week of Astronomy and Space Science (EWASS 2017) (Czech Republic, Prague, 2017-06-25 - 2017-06-30)

Luminosity and stellar mass dependency of galaxy clustering at z~3
A. Durkalec
The growth of galaxies in the Early Universe - III (Italy, Sesto, 2017-01-18 - 2017-01-21)

Space and cyberspace: hidden patterns in astrophysical datasets
A. Solarz
The European Week of Astronomy and Space Science (EWASS 2017) (Czech Republic, Prague, 2017-06-25 - 2017-06-30)

How luminous galaxies trace the dark Universe
A. Pollo
XXXVIII Zjazd Polskiego Towarzystwa Astronomicznego (Poland, Zielona Góra, 2017-09-11 - 2017-09-14)
Proceedings of the Polish Astronomical Society (2017)

What matters for the Kilo-Degree Survey
M. Bilicki, KiDScollaboration
Tartu-Tuorla cosmology meeting 2017: What matters? (Estonia, Tõrve, 2017-09-27 - 2017-09-29)

Oral Presentation

Tests of the SIBYLL 2.3 high-energy hadronic interaction model using the KASCADE-Grande muon data
J.C. Arteaga-Velázquez, **P. Łuczak**, **J. Zabierowski**
XLVI International Symposium on Multiparticle Dynamics (Mexico, Tlaxcala City, 2017-09-11 - 2017-09-15)
EPJ Web Conf. (in press)

Cosmic Ray Air Shower Scintillating Detector
M. Kasztelan
Cosmic-Ray Extremely Distributed Observatory 2017: The Anniversary Symposium (Poland, Kraków, 2017-08-30 - 2017-08-30)

Baltic Sea Underground Innowation Network (BSUIN)
K. Jędrzejczak
Astrofizyka Cząstek w Polsce (Poland, Kraków, 2017-09-20 - 2017-09-22)

Accuracy of mass and radius determination of the neutron star in ATHENA and LOFT missions
A. Majczyna, J. Madej, A. Różańska, M. Należyty
Annual NewCompStar Conference 2017 (Poland, Warszawa, 2017-03-27 - 2017-03-31)

Pi of the Sky in LSC-Virgo\'s EM follow-up in O1 science run
A. Zadrożny, L. Mankiewicz, A.F. Żarnecki, **M. Sokołowski**
XL-th IEEE-SPIE Joint Symposium Wilga 2017 (Poland, Wilga, 2017-05-29 - 2017-06-04)

Practical SED Modelling using CIGALE
K. Małek, V. Buat, D. Burgarella, Y. Rohelly
Cosmic Censuses: exploiting large panchromatic surveys to understand extragalactic populations (United Kingdom, Sussex, 2017-10-09 - 2017-10-13)

Clustering of AKARI NEP galaxies: how dusty galaxies evolve in the cosmic web?
A. Pollo, **A. Solarz**
The Cosmic Wheel and the Legacy of the AKARI archive: from galaxies and stars to planets and life (Japan, Tokyo, 2017-10-17 - 2017-10-20)
JAXA Repository / AIREX (JAXA-SP series) (2017)

Extrapolation of nucleus-nucleus cross section to cosmic ray energies using geometrical model
Z. Plebaniak, **T. Wibig**
35th International Cosmic Ray Conference - ICRC2017 (Korea, Bexco, Busan, 2017-07-12 - 2017-07-20)
Proceedings of Science (in press)

Automatised novelty detection in the WISE survey with oneclass support vector machines
A. Solarz
Astronomical Data Analysis Software and Systems (Chile, Santiago, 2017-10-22 - 2017-10-26)
ASP Conference Series (2018)

Interferometric Radio Measurements of Air Showers with LOPES: Final Results
F.G. Schroeder, **P. Łuczak**, **J. Zabierowski**
35th International Cosmic Ray Conference - ICRC2017 (Korea, Bexco, Busan, 2017-07-12 - 2017-07-20)
Proceedings of Science Vol. ICRC2017 (2017) 458

Automatised novelty detection in the WISE survey
A. Solarz
XXXVIII Zjazd Polskiego Towarzystwa Astronomicznego (Poland, Zielona Góra, 2017-09-11 - 2017-09-14)

Mesurement of the muon content of EAS in KASCADE-Grande compared with SIBYLL 2.3 predictions
J.C. Arteaga-Valasquez, **P. Łuczak**, **J. Zabierowski**
35th International Cosmic Ray Conference - ICRC2017 (Korea, Bexco, Busan, 2017-07-12 - 2017-07-20)
Proceedings of Science Vol. ICRC2017 (2017) 316

Machine learning in astrophysics
T. Krakowski, **K. Małek**, **M. Bilicki**, M. Siudek, **A. Pollo**
XXXVIII Zjazd Polskiego Towarzystwa Astronomicznego (Poland, Zielona Góra, 2017-09-11 - 2017-09-14)
Proceedings of the Polish Astronomical Society (2017)

KiDS 4-band photo-z performance with different methods
M. Bilicki, KiDScollaboration
Photo-z Workshop for Large Surveys 2017 (Japan, Sendai, 2017-05-17 - 2017-05-19)

A new release of the KASCADE Cosmic Ray DataCentre (KCDC)
D. Kang, **P. Łuczak**, **J. Zabierowski**
35th International Cosmic Ray Conference - ICRC2017 (Korea, Bexco, Busan, 2017-07-12 - 2017-07-20)
Proceedings of Science Vol. ICRC2017 (2017) 452

A new analysis of the combined data from bothKASCADE and KASCADE-Grande
S. Schoo, D. Kang, **P. Łuczak**, **J. Zabierowski**
35th International Cosmic Ray Conference - ICRC2017 (Korea, Bexco, Busan, 2017-07-12 - 2017-07-20)
Proceedings of Science Vol. ICRC2017 (2017) 339
Connecting light and dark side of the universe. Relation between galaxy stellar and dark matter halo mass at z~3
A. Durkalec, **A. Pollo**
Astrofizyka Cząstek w Polsce 2017 (Poland, Krakow, 2017-09-20 - 2017-09-22)

Kilo-Degree Survey: a new era in observing the large-scale structure
M. Bilicki, KiDScollaboration
XXXVIII Zjazd Polskiego Towarzystwa Astronomicznego (Poland, Zielona Góra, 2017-09-11 - 2017-09-14)

Latest Results of KASCADE-Grande
A. Haungs, **P. Łuczak**, **J. Zabierowski**
35th International Cosmic Ray Conference - ICRC2017 (Korea, Bexco, Busan, 2017-07-12 - 2017-07-20)
Proceedings of Science Vol. ICRC2017 (2017) 545

GAMA as THE calibration sample for photometric redshifts
M. Bilicki
GAMA: Final data release, legacy, and future galaxy evolution surveys (Australia, Perth, 2017-11-06 - 2017-11-10)

Recent results from the KASCADE-Grande cosmic-ray experiment --- Test of hadronic interaction models with air-shower data
J.R. Hoerandel, **P. Łuczak**, **J. Zabierowski**
17 conference on Elastic and Diffractive Scattering (EDS17) (Czech Republic, Prague, 2017-06-26 - 2017-06-30)
EConf (in press)

Update on the Time Domain F-Statistic all-sky search
A. Królak
LIGO-Virgo conference (USA, Pasadena, 2017-03-13 - 2017-03-16)

Poster

HVPS system for ∗ – EUSO detectors
Z. Plebaniak, **J. Karczmarczyk**, **W. Marszał**, **J. Szabelski**, P. Gorodetzky, P. Prat, G. Prévôt
35th International Cosmic Ray Conference - ICRC2017 (Korea, Bexco, Busan, 2017-07-12 - 2017-07-20)
Proceedings of Science (in press)

Properties of symbiotic X-ray binary GX 1+4
M. Należyty, **A. Majczyna**, J. Madej, A. Udalski, A. Różańska
Annual NewCompStar Conference 2017 (Poland, Warszawa, 2017-03-27 - 2017-03-31)

Fuzzy logic svm based classification for large astronomical data sets
A. Poliszczuk, **A. Solarz**, **A. Pollo**
The European Week of Astronomy and Space Science (EWASS 2017) (Czech Republic, Prague, 2017-06-25 - 2017-06-30)

Model atmospheres of hot neutron stars
A. Majczyna, J. Madej, A. Różańska, M. Należyty
XXXVIII Zjazd Polskiego Towarzystwa Astronomicznego (Poland, Zielona Góra, 2017-09-11 - 2017-09-14)

Point Spread Function of EUSO-TA detector
Z. Plebaniak, **J. Szabelski**, **T. Wibig**, L. Piotrowski
35th International Cosmic Ray Conference - ICRC2017 (Korea, Bexco, Busan, 2017-07-12 - 2017-07-20)
Proceedings of Science (in press)

What makes [Ultra] Luminous Infrared Galaxies shine? Environments of ULIRGs from the ADF-S
M. Bankowicz, **A. Pollo**, **K. Małek**, T.T. Takeuchi, D. Burgarella, V. Buat, A. Herzig
The Cosmic Wheel and the Legacy of the AKARI archive: from galaxies and stars to planets and life (Japan, Tokyo, 2017-10-17 - 2017-10-20)
JAXA Repository / AIREX (JAXA-SP series) (2017)

Searching for the previously unknown classes of objects in the AKARI-NEP Deep data with fuzzy logic SVM algorithm
A. Poliszczuk, **A. Solarz**, **A. Pollo**
The Cosmic Wheel and the Legacy of the AKARI archive: from galaxies and stars to planets and life (Japan, Tokyo, 2017-10-17 - 2017-10-20)
JAXA Repository / AIREX (JAXA-SP series) (2017)

Search for periodic interferences in LIGO O1 data
O. Dorosh, **A. Królak**
LSC-Virgo August 2017 Meeting (Switzerland, Genewa, 2017-08-28 - 2017-09-01)

LECTURES, COURSES AND EXTERNAL SEMINARS

Cosmic Ray Laboratory in Lodz[a]
Z. Plebaniak
Lodz, Technical University of Lodz, 2017-03-09

VIPERS: the slice of the Universe at z~1[a]
A. Pollo
Warsaw, Warsaw University, 2017-03-28

Gravitational waves - a new window on the Universe[a]
A. Królak
Łódź, Uniwersytet Łódzki, 2017-05-17

Astrophysics Division in NCBJ - presentation[a]
A. Pollo
Warsaw, Warsaw Technical University , 2017-05-24

Searching for optical counterparts to gravitational waves detected by LIGO-Virgo detectors[a]
A. Zadrożny
Toruń, Center of Astronomy, UMK, 2017-06-05

Searching for optical counterparts to gravitational waves registered inLIGO-Virgo detectors network[b]
A. Zadrożny
Kraków, Astronomical Observatory, Jagiellonian University, 2017-07-14

Luminous galaxies in the (dark) cosmic web[a]
A. Pollo
Warsaw, Warsaw University, 2017-11-09

Observational cosmology with the largest sky surveys[a]
M. Bilicki
Wrocław, Institute of Astronomy, 2017-11-27

Observational cosmology with the largest sky surveys[a]
M. Bilicki
Zielona Góra, Janusz Gil Institute of Astronomy, 2017-11-28

Observational cosmology with the largest photometric surveys[a]
M. Bilicki
Warsaw, Astronomical Observatory, Warsaw University, 2017-12-19

All-sky galaxy catalogues in 3D and their applications[b]
M. Bilicki
Tõravere, Estonia, Tartu Observatory, 2017-02-22

Virgo - the third eye[a]
A. Królak
Baton Rouge, Louisiana State University, 2017-03-21
From space to cyberspace: automatic anomaly detection in AllWISE Sky Survey[b]
A. Solarz
Valparaiso, Chile, University of Valparaiso Instituto de Física y Astronomía, 2017-04-20

Recent wide-angle photometric redshift catalogues[b]
M. Bilicki
Kashiwa, Japan, Kavli Institute for the Physics and Mathematics of the Universe, 2017-05-25

SED fitting of a large, varied sample of galaxies; the analysis of main physical parameters across wide redshift range[b]
K. Małek
Sussex, University of Sussex, UK, 2017-07-24

Search for unusual objects in AllWISE Sky Survey[b]
A. Solarz
Santiago, European Space Observatory, 2017-10-27

Automatic search for peculiar objects in Sky Surveys[b]
A. Solarz
Santiago, Center for Mathematical Modelling , 2017-12-20

Gravitational waves - a new window on the Universe[a]
A. Królak
Torun, Uniwersytet im. M. Kopernika, 2017-02-23

New discoveries in gravitational wave astronomy[a]
A. Królak
Szczecin, Polskie Towarzystwo Fizyczne - oddział w Szczecinie, 2017-11-22

a) in Polish
b) in English

INTERNAL SEMINARS

PSF of EUSO-TA[b]
Z. Plebaniak
Chicago, Kavli Institute for Cosmological Physics at the University of Chicago, 2017-06-22

Connecting light and dark side of the universe[b]
A. Durkalec
Warszawa, National Centre for Nuclear Research, 2017-11-22

b) in English

DIDACTIC ACTIVITY

M. Bilicki - Lectures at summer school "3rd Cosmology School 2017", Kraków. Lecture title: "Cosmological surveys".

K. Małek - co-supervisor Małgorzata Bankowicz "Analysis of the physical properties and local environment of ULIRGs"

K. Małek - co-supervisor of mgr Tomasz Krakowski "Machine learning in astrophysical data"

K. Małek - co-supervisor of PhD Thesis of Małgorzaty Siudek: "Formation and evolution of stellar populations based on the red passive galaxies observed up to the redshift z ~ 1"

Z. Plebaniak - Works with students of Technical University of Lodz regarding on Cosmic Ray Physics. The work included coding in ROOT framework, data analysis, lectures on cosmic ray physics and works with scintillation detectors.

A. Pollo - NCBJ, Artem Poliszczuk
A. Pollo - NCBJ, Tomasz Krakowski
A. Pollo - OA UJ, lecture "Stellar and extragalactic astronomy II"
A. Pollo - OA UJ, mgr Agnieszka Kurcz
A. Pollo - OA UJ, mgr Aleksander Kurek
A. Pollo - OA UJ, mgr Magdalena Krupa
A. Pollo - OA UJ, mgr Małgorzata Bankowic
A. Pollo - OA UJ, mgr Oskar Kopczyński
A. Pollo - OA UJ, mgr Tobiasz Górecki
A. Pollo - OA UJ, monographic lecture "Observational cosmology"

A. Solarz - Fuzzy logic application
to data mining in sky surveys

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

K. Jędrzejczak
Member

J. Karczmarczyk
member of JEM-EUSO Collaboration

A. Królak
member

P. Łuczak
Member of the LOPES Collaboration
Member of the KASCADE-Grande Collaboration

A. Majcher
member
Member of Polish Society of Amateur Astronomers

A. Majczyna
member Polskie Towarzystwo Astronomiczne
member of Polish Fireball Network

K. Małek
member of the Seminar Organizing Committee
Delta - matematyka, fizyka, astronomia i informatyka, Delta - mathematics, physics, astronomy and computer science, University of Warsaw

Z. Plebaniak
JEM-EUSO Collaboration

A. Pollo
Session chairman on Astrofizyka Cząstek w Polsce in Kraków, Poland
Member of Organizing Committee on 3rd Cosmology School \ in Cracow, Poland
member, National Council for Astroparticle Physics

B. Szabelska
member of Collaboration JEM-EUSO

J. Szabelski
Polish PI (Principal Investigator) of JEM-EUSO Collaboration
Polish representative in the International Particle Physics Outreach Group (IPPOG)
Member of the International Advisory Committee (IAC) of the European Cosmic Ray Symposia
Polish group PI in the EUSO-Balloon Collaboration
Polish PI
Polish representative at IPPOG
member of International Advisory Committee (IAC) of the European Cosmic Ray Symposia
participant in the POLAR Collaboration
EMMA Experiment, member of the International Advisory Committee

T. Tymieniecka
JEM-EUSO Collaboration member

T. Wibig
Polish Physical Society
JEM-EUSO Collaboration member

J. Zabierowski
Member of the Polish Physical Society
Member of The LOPES Collaboration
Chairman of the Steering Committee and the Collaboration Board of The KASCADE-Grande Collaboration
Member of the WAS@COSY Collaboration Board
Chairman of the KASCADE-Grande Collaboration Board and Chairman of the KASCADE-Grande Steeering Committee

Research scientists
Maciej Bilicki, PhD *
Anna Durkalec, PhD
Andrzej Królak*, Professor
Agnieszka Majczyna, PhD
Katarzyna Małek, PhD on live
Agnieszka Pollo, Associate Professor
Marcin Sokołowski, PhD on live
Aleksandra Solarz, PhD
Barbara Szabelska, PhD
Jacek Szabelski, PhD
Teresa Tymieniecka, Professor*
Tadeusz Wibig, Associate Professor *
Janusz Zabierowski, Professor*
Adam Zadrożny, PhD

Technical and administrative staff
Arkadiusz Ćwiek, MSc
Zdzisław Dębicki
Jadwiga Feder, Eng*
Karol Jędrzejczak, MSc
Marcin Kasztelan, MSc
Adam Kutynia, MS. Eng
Ryszard Lewandowski*
Ariel Majcher, MSc
Włodzimierz Marszał
Krzysztof Nikliborc, MSc Eng
Jerzy Orzechowski, MSc Eng
Zbigniew Plebaniak, MSc Eng
Wojciech Skowronek*
Maciej Suchiński, MSc Eng
Przemysław Tokarski, MSc Eng
Anna Zwolińska, MSc Eng

**part-time employee*

DEPARTMENT OF NUCLEAR TECHNIQUES AND EQUIPMENT

Director of Department: Jacek Rzadkiewicz, PhD
Phone: +48 (22) 273 14 13
e-mail: jacek.rzadkiewicz@ncbj.gov.pl

The Department of Nuclear Techniques and Equipment has ~100 employees, including 2 professors, 6 associate professors and over 30 employees with a PhD degree. The Department includes four divisions:

- (TJ1) Particle Acceleration Physics & Technology Division,
- (TJ3) Radiation Detectors Division,
- (TJ4) Electronics and Detection Systems Division,
- (TJ5) Plasma Studies Division.

The Department supports the scientific research programme of NCBJ managed by the Head of Department, the Heads of Divisions and the Department Scientific Council. Most of the scientific achievements of the Department were summarized in top level peer reviewed publications, namely in Nuclear Instruments and Methods A, Journal of Instrumentation, Fusion Engineering and Design Physical Review A and many others. Among others, in 2017 we published important results on:

- Characteristics of silicon photomultipliers used for gamma spectroscopy ,
- Determination of two-electron one-photon transition characteristics for low-Z K-shell hollow atoms,
- Development of a Cherenkov-type and gamma-ray diagnostic systems for tokamaks.

In 2017 the Department's activitiss were focused on development of accelerators for science and industry. In particular, we delivered and commissioned a 9-MV accelerator for the GBAR experiment (proposing a gravity measurement of antihydrogen) at CERN. We also developed advanced detection systems including those for gamma spectroscopy based on silicon photomultipliers. In 2017 we obtained new theoretical results concerning exotic decays in atomic physics and new experimental results from our micro-dosimetry and air pollution labs. In 2017 the Department's activities were also related to the design and construction of neutron activation analyser and X-ray radiography prototype systems for monitoring the quality of mined copper ore in the mine and conveyor.

Our research groups participated in the followingNational and European projects (selected):

- KGHM – development of Neutron Activation Analysis and X-Ray Fluorescence (XRF) for monitoring the quality and composition of copper ore at various stages of mining,
- PGNiG - development a of Neutron Activation Analysis for borehole applications,
- EUROFUSION–engineering validation and engineering design activities for the Early Neutron Source (ENS) dedicated to fusion technology, development of gamma-ray and x-ray diagnostics based on scintillation detectors and high-resolution x-ray spectroscopy, respectively for the JET tokamak and Cherenkov-type detectors, designed for the FTU and Compass tokamaks,
- GBAR - construction and start-up of a 9-MV accelerator for the GBAR experiment at CERN,
- C-BORD - participation in the development of technologies for inspections of large volume freight, in particular design and integration of equipment for inspection of containers in seaports: passive gates, X-ray radiography and neutron activation systems,
- X-FEL - development of PLC modules for X-FEL.

Jacek Rzadkiewicz

ACCELERATOR PHYSICS AND TECHNOLOGY DIVISION

Head of Division: Sławomir Wronka, PhD DSc
Phone: +48 (22) 273 15 39
Mail: slawomir.wronka@ncbj.gov.pl

The activity of TJ1 department is focused on development of new acceleration techniques and technologies, as well as on applications of particle accelerators. The main know-how is concentrated in cavities optimisation, calculations of magnets, transfer lines, sources and targets, collimators and applicators. In particular, beam dynamics, beam optics calculations and Monte Carlo simulations of accelerator heads and detectors are continuously performed for different projects.

The main activities of the TJ1 department in 2017 year were related to installation of electron linac for GBAR experiment and preparatory phase for ESS and ENS projects.

Medical Physics group's main activity was concentrated on upgrading of Jet Counter nanodosimetry facility.

TJ1 department is quite well equipped with experimental accelerators stands. Due to availability of radiographic detectors, number of radiographic tests has been performed with good results.

The aim of ENS project is to build an accelerator-based D-Li neutron source that produces high energy neutrons at sufficient intensity to simulate the first wall neutron spectrum of future nuclear fusion reactors. Our work has been focused on using Beam Dynamics calculation to optimize the SRF-L accelerator and to provide an analysis of the ancillary systems necessary for the DONES accelerator.

Some of discussed shortly above topics are described in details in separated articles.

TJ1 department offers friendly surrounding for young people, for many years the engineering- and mater- degree theses are being realized in cooperation and under supervision of our experts.

Also summer practices are offered to students, typically from Universities or Universities of Technology.

In 2017 the research personnel consisted of 3 associate professors, 5 PhDs and 13 engineers.

Sławomi Wronka

REPORTS

Overview of the ionization chambers. Part I medical dosimetry (radiotherapy)
S. Pszona E. Jaworska, A. Dudziński
Raport NCBJ No. B-11?2017 2017)

Determination of the copper ore composition by means of Neutron Activation Analysis, i n siyu and during various processing stage
Stage II. Final repost (in polish)
M. Gierlik, ... , **S. Burakowski**, **Ł. Kaźmierczak**, **Ł. Komorowski**, **T. Krakowski**, **T. Lotz**, **J. Rzadkiewicz**, **P. Sobkowicz**, **A. Urban**, **A. Wasilewski**, ... et al.

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Mathematical modeling of experiments at the Nuclotron.
A. Polański, . Vladimir Uzhinsky
II Nica Days 2017 (Poland, Warsaw, 2017-11-02 - 2017-11-10)

Preliminary results of the dark current modelling for the polfel superconducting lead photocathode
K. Szymczyk
XL-th IEEE-SPIE Joint Symposium Wilga 2017 (Poland, Wilga, 2017-05-29 - 2017-06-04)

Oral Presentation

Measurements of spatial correlations of ionisation events in the track of carbon ions - the first results
M. Pietrzak, **A. Bancer**, **S. Pszona**
Neutron and Ion Dosimetry Symposium (NEUDOS-13) (Poland, Kraków, 2017-05-14 - 2017-05-19)
Radiat. Prot. Dosim. (2017)

Beam dynamics calculations for accelerator system analysis in the Early Neutron Source project
W. Grabowski, **K. Kosiński**, **M. Staszczak**, **A. Wysocka-Rabin**
NUTECH-2017 Conference on Development and Application of Nuclear Technologies (Poland, Kraków , 2017-09-10 - 2017-09-13)

Gallium nitride-a material for future betavoltaic
S. Grzanka, P. Laskowski, **B. Zaręba**, **M. Klimasz**
Photonics West (USA, San Francisco, 2017-01-28 - 2017-02-02)

Zastosowania i rola fizyki subatomowej oraz jej narzędzi badawczych w projektowaniu nowoczesnych akceleratorów elektronów
P. Adrich
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)
Polskie Towarzystwo Fizyczne, Wrocław No. (2017)

On the two modes of nanodosimetric experiments - exercise with Jet Counter
M. Pietrzak
17th International Symposium on microdosimetry (Venice, Italy, 2017-11-05 - 2017-11-10)

Poster

Polish In-Kind Contribution to European XFEL: Status in Summer 2017
J. Lorkiewicz, **K. Chmielewski**, Z. Gołębiewski, **W. Grabowski**, **K. Kosiński**, **K. Kostrzewa**, **P. Krawczyk**, **I.M. Kudła**, **P. Markowski**, K. Meissner, **E. Pławski**, **M. Sitek**, **J. Szewiński**, **M. Wojciechowski**, **Z. Wojciechowski**, **G. Wrochna**, **J. Sekutowicz**, J. Fydrych, M. Duda, M. Jeżabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Stodulski, M. Wiencek, J. Świerblewski, P. Grzegory, G. Michalski, P. Borowiec, M. Chorowski,

P. Duda, A. Iluk, K. Malcher, J. Poliński, E. Rusiński, J. Głowinkowski, M. Winkowski, P. Wilk
38th International Free-Electron Laser Conference (FEL2017) (USA, Santa Fe, 2017-08-20 - 2017-08-25)
Kip Bishopsberger (LNL), Volker RW Schaa (GSI) (Santa Fe, NM, USA) No. (2017)

Preliminary Results of the Dark Current Modelling for the Polfel Superconducting Lead Photocathode
K. Szymczyk, **J. Lorkiewicz**, **R. Nietubyć**, **J. Sekutowicz**
38th Interational Free Electron Laser Conference (FEL2017) (USA, Santa Fe, 2017-08-20 - 2017-08-25)
Kip Bishopsberger, Volker RW Schaa (Santa Fe, NM, USA) No. (2017)

State of The Art of Instrumentation in The Experimental Nanodosimetry
A. Bancer, P. Colautti, V. Conte, G. Hilgers, **M. Pietrzak**, **S. Pszona**, H. Rabus, A. Selva
Neutron and Ion Dosimetry Symposium (NEUDOS-13) (Poland, Kraków, 2017-05-14 - 2017-05-19)
doi:10.1093/rpd/ncx263

Experimental setup using low energy X-rays for radiobiological studies
J. Czub, J. Braziewicz, M. Brodecki, W. Gieszczyk, M. Kłosowski, **A. Wasilewski**, P. Wołowiec, **A. Wysocka-Rabin**, A. Wójcik
Fifth International Conference on Radiation and Applications in Various Fields of Research (Montenegro, Budva, 2017-06-12 - 2017-06-16)

Comparison of preliminary beam dynamic calculations between different codes for SRF-L accelerator in the Early Neutron Source project
W. Grabowski, **K. Kosiński**, **M. Staszczak**, **A. Wysocka-Rabin**
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)
Polskie Towarzystwo Fizyczne, Oficyna Wydawnicza Politechniki Warszawskiej, Wrocław 2017 No. (2017)

Monte Carlo simulation and analysis of photon beam characteristics for a new medical accelerator constructed in NCBJ
S. Allen, **A. Wasilewski**, **A. Wysocka-Rabin**
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)
Polskie Towarzystwo Fizyczne, Oficyna Wydawnicza Politechniki Wrocławskiej No. (2017)

Application of track detectors to measure neutrons emitted from 14 MeV neutron generators
A. Malinowska, **A. Szydłowski**, B. Bieńkowska, **M. Gierlik**, S. Jednorog, E. Łaszyńska, **K. Malinowski**, **J. Rzadkiewicz**, **A. Wasilewski**
27^{th} ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

Ogień z wodą - czyli o optymalizacji głowicy terapeutycznej mobilnego akceleratora do radioterapii śródoperacyjnej
P. Adrich
Konferencja Polskiego Towarzystwa Fizyki Medycznej (Poland, Poznań, 2017-06-01 - 2017-06-03)
Zeszyty Naukowe WCO, Letters in Oncology Science Vol. 14 No S1 (2017) 29-30

LECTURES, COURSES AND EXTERNAL SEMINARS

A new method for designing passive beam forming systems[a]
P. Adrich
Cracow, Institute of Nuclear Physics PAN, 2017-02-24

Accelerator Systems in ENS project[b]
A. Wysocka-Rabin
Warsaw, IFPiLM, 2017-03-02

Therapeutic beam forming system of the IntraLine accelerator[a]
P. Adrich
Otwock-Świerk, NCBJ, 2017-03-29

Physics fundamentals and optimization of beam forming systems.[a]
P. Adrich
Otwock-Świerk, NCBJ, 2017-03-30

Modelling photon and electron beams from medical accelerators using EGSnrc Monte Carlo code[b]
A. Wysocka-Rabin
Bydgoszcz, Oncological Centre, 2017-09-07

X-ray imaging in industrial and security applications.[a]
S. Wronka
Otwock, National Centre for Nuclear Research, 2017-10-12

X-ray radiography in heavy and energy production industry[a]
S. Wronka
Otwock, National Centre for Nuclear Research, 2017-11-30

Accelerator Systems in ENS project.[b]
A. Wysocka-Rabin
Warsaw, IFPiLM, 2017-12-21

Polish contribution to Accelerator Systems area in the Early Neutron Source project[b]
A. Wysocka-Rabin
Warsaw, National Centre for Nuclear Research , 2017-01-17

Approach proposed by NCBJ for shut-down dose rate calculations[b]
A. Wysocka-Rabin
Cracow, IFJ PAN, 2017-06-21

Approach proposed by NCBJ for shut-down dose rate calculations[b]
B. Zaręba
Cracov, WPENS Meeting on \, 2017-06-21

Brachytherapy, dosimetry and QA procedures - an introduction to Selective Internal Radiotherapy (SIRT)[a]
A. Wysocka-Rabin
Bydgoszcz, Oncological Centre in Bydgoszcz, 2017-04-25

Dosimetry for radioembolization of liver lesions[a]
A. Wysocka-Rabin
Bydgoszcz, Oncological Centre in Bydgoszcz, 2017-04-25

a) in Polish
b) in English

INTERNAL SEMINARS

Test of the TC activation[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-01-05

Dependence of dose deposited in germanium depending on natural lithium concentration[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-01-18

Study of causes of overload of Ge detector irradiated with 14MeV neutron emitted from neutron generator[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-01-31

Analysis of the dose recorded in the investigated cells layer associated with the presence of the cover slip[a]
A. Wasilewski

Świerk, National Centre for Nuclear Research, 2017-02-16

Experimental setup using low energy X-rays for radiobiological studies[a]
A. Wysocka-Rabin
Świerk, National Centre for Nuclear Research, 2017-02-16

MC calculations of radiation emitted from a RTG lamp and dissipating in a system containing a test sample. Study of the impact of aluminum shutter on recorded volumes.[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-03-10

MC calculations of radiation emitted from a RTG lamp and dissipating in a system containing a test sample. Study of the impact of the cover slip material on recorded volumes.[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-03-10

Study of the impact of boundaries of defined regions on the dose recorded in MC calculations[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-03-10

Doses of radiation absorbed in various materials. Comparing the results of calculations from EGS, FLUKA and MCNP codes.[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-04-24

Comparison of 30, 40 and 50kV photon spectra reflected from layers of different materials.[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-05-05

MC calculation of radiation from the RTG tube and dissipating in a system containing a test sample. The geometry was modified by: adding a Pb flange around the Be window, reducing the cover slit thickness, changing the table material from wood to Al.[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-05-08

Radiological protection analysis of a low energy X-rays experimental setup for radiobiological studies[a]
A. Wysocka-Rabin
Świerk, National Centre for Nuclear Research, 2017-05-08

Study of the effect of LaBr3 detector shield on the fluence of registered particles and the dose in the detector for 14MeV neutron and 662keV photon sources[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-05-18

Scattering of 250MeV protons on a graphite shield[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-08-21

Analysis of the possibility of constructing of detector of photon emited from an accelerator using the Compton radiation detection method[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-08-21

Analysis of the possibility of proton production by 30MeV electron accelerator[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-09-11

Nuclear Transmutations of Actinides in Gas Nuclear Reactors with spallation neutron source.[a]
A. Polański
Otwock-Swierk, National Centre for Nuclear Research, 2017-10-03

Electron transport in matter[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-10-16

Reconstruction of the energy of the primary photon beam in the Compton scattered radiation detector[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-11-29

Accelerator for Intra Operative Radiation Therapy - current state and proposals of further works[a]
P. Adrich
Otwock, National Centre for Nuclear Research, 2017-12-11

Multilayer conversion target - concept and study of the model towards determining the potential of this solution[a]
P. Adrich
Otwock, National Centre for Nuclear Research, 2017-12-11

Automatic frequency control circuit and shot detector[a]
M. Chabera
Otwock, Narodowe Centrum Badań Jądrowych, 2017-12-11

Source macroscopic parameter scaling.[a]
M. Maćkowski
Warsaw, NCBJ, 2017-12-11

Electron beam dynamics for POLFEL[a]
M. Staszczak
Otwock, National Centre for Nuclear Research, 2017-12-11

6MeV Linear Accelerator - electrical brakedowns[a]
M. Staszczak
Otwock, National Centre for Nuclear Research, 2017-12-11

Calculation of the radiation dose from the X-ray tube to the irradiated cell layer[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2017-12-11

MC modeling of experimental setup using low energy X-rays for radiobiological studies.[a]
A. Wysocka-Rabin
Świerk, NCBJ, 2017-12-11

[a)] in Polish
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DIDACTIC ACTIVITY

S. Pszona - Supervision over the master's thesis entitled "Dosimetry in therapeutic neutron beams" by Edyta Michaś.

A. Wasilewski - Assistance with installing EGS package and launch Monte-Carlo simulation in BEAM code for Sarah Rebecca Allen, NCBJ PhD student.

A. Wasilewski - Assistance with the preparation of master thesis of Cyprian Pypeć, a student of the Warsaw University of Technology, in the part concerning Monte-Carlo calculations with FLUKA code.

A. Wasilewski - Assistance with the preparation of master thesis of Weronika Modrzewska, a student of the Warsaw University of Technology, in the part concerning Monte-Carlo calculations with FLUKA code.

S. Wronka - Design of the small water phantom for measurements of the medical linac beams

S. Wronka - Lecture for Oświęcim Kids University: "Energy from a teaspoon of water"

S. Wronka - Lecturer at Warsaw University of Technology, "Biomedical accelerators"

S. Wronka - Lectures for Silesian Kids University: "Energy from a teaspoon of water", 4.03.2017
S. Wronka - Supervising of PhD candidate, thesis about fast intra-pulse energy switching in linear accelerators.

S. Wronka - Supervisor of P.Laskowski

S. Wronka - Wojciech Dziewiecki - PhD granted 27.06.2017

A. Wysocka-Rabin - A.Cichoński;"Numerical dose distribution for applicators with irradiation source in brachytherapy and its dosimetric verification".

A. Wysocka-Rabin - Lectures:" Basics or Selective Internal Radiotherapy (SIRT)" , " Dosimetry in radioembolization of lever lissions", for oncologists in Oncological Centre in Bydgoszcz

A. Wysocka-Rabin - Thessis of Sarah Allen:"Dose distribution analyses and optimization for stereotactic irradiation with linear accelerator"

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

J. Borkowski
European Spallation Source Scandinavia; member of Accelerator group

S. Wronka
Polish Society of Medical Physics

A. Wysocka-Rabin
Polish Society of Medical Physics
PTCOG
Polish Society of Radiation Oncology
WiN Poland, Women in Nuclear
Polish Nuclear Society
vice president Society of Environmentals for Nuclear
member Society of Environmentals for Nuclear
member of Programme Commission

Research Scientists
Przemysław Adrich, PhD
Aleksandr Bancer, PhD
Stanisław Pszona, PhD
Adam Wasilewski, PhD
Sławomir Wronka, Associate Professor
Jacek Sekutowicz, Associate Professor
Jolanata Wojtkowska, PhD
Anna Wysocka-Rabin, Associate Professor

Technical And Administrative Staff
Józef Bogowicz
Chabera Mariusz
Adam Dudziński
Wojciech Dziewiecki, MSc
Wojciech Grabowski, MSc
Michał Jarosz, MSc
Elżbieta Jaworska
Marian Klimasz, MSc
Jan Klimaszewski, MSc
Tymoteusz Kosiński, MSc
Andrzej Łubian
Mieszko Maćkowski, MSc
Michał Matusiak, MSc
Aleksander Polański, MSc
Marcin Pietrzak, MSc
Marcin Staszczak, MSc
Karol Szymczyk, MSc
Krzysztof Wincel, MSc
Marcin Wojciechowski, MSc
Barbara Zaręba, MSc
Anita Zugaj

RADIATION DETECTORS PHYSICS DIVISION

Head of Division: Łukasz Świderski, PhD DSc
Phone +48 (22) 273 12 62
e-mail l.swiderski@ncbj.gov.pl

^The Radiation Detectors Division was established at the beginning of 2012 as part of the former Division of Detectors and Nuclear Electronics. Most of our division's activity is focused on the characterization of scintillation detectors for neutron and gamma-ray radiation. Performance of scintillation detectors coupled to various photodetectors is also extensively studied. In the last year our efforts were concentrated on:

- study of the temperature dependence of scintillation intensity and decay time in CsI:Tl crystals and its influence on their non-proportionality and energy resolution,
- study of CsI:Tl response to gamma-rays over a wide temperature range between -185ºC and +150ºC,
- characterization of large size (48 × 48 mm^2) Silicon Photomultiplier (SiPM) performance for gamma-ray spectroscopy with large scintillators,
- characterization of the temperature dependence of La-GPS:Ce scintillator gamma-ray response up to +150ºC,
- neutron induced damage of MPPCs as photodetectors for scintillation light readout in gamma-ray spectroscopy with GAGG:Ce crystals,
- characterization of the scintillation properties of LuYAG:Pr and LuAG:Pr co-doped with molybdenum,
- study of positron lifetime in scintillators,
- GAGG response to alpha particles in comparison to gamma-ray response,
- nano-^{10}B lined proportional counters for neutron detection in security applications,
- development of orthogonal-strip Si(Li) semiconductor detectors,
- development of a transmission silicon detector for identification of ^{252}Cf fission fragments,
- optimizing the timing performance of $LaBr_3$ detectors for lifetime measurements of nuclear states carried out at the Heavy Ion Laboratory of Warsaw University.

The results of our studies were used in the realization ofa number of R&D projects, including:

C-BORD: we have been involved in the development of the Rapidly Relocatable Tagged Neutron Inspection System (RRTNIS) and Photofission System for the detection of illicit goods and dangerous materials inside containers transported through sea-ports. This project is funded by the EU.

RaM-ScaN: in cooperation with SysKon and OTJ Polon, we continued and finalized industrial tests of the demonstration version of the Prompt Gamma Neutron Activation Analysis system for controlling the chemical composition of raw materials used in cement production. This DEMO phase was realized in the "Folwark" mine in Poland, which supplies raw-materials to the largest cement plant in Europe – Górażdże.

Contract with PGNiG: we were involved in the characterization of scintillation properties at elevated temperatures and gamma-ray response simulations for detectors intended for use in well logging. This work was carried out in cooperation with the Division of Electronics and Detection Systems (TJ4).

Most of the scientific achievements of the Division were summarized in 17 refered publications, published mainly in Nuclear Instruments and Methods A, Nuclear Fusion, Physical Review and Acta Physica Polonica B. In addition, our scientists presented 13 contributions at international conferences – including 6 presentations at the IEEE Nuclear Science Symposium and Medical Imaging Conference 2017 in Atlanta, USA and 2 invited talks during various Workshops.

The Division was also involved in scientific collaborations with a number of international centre, such as the Royal Institute of Technology, Stockholm, KMUTT Bangkok, Thailand, CEA-Saclay and ILL Grenoble, France, ISC Kharkov, Ukraine, LNL INFN, Italy, ZIBJ Dubna, Russia, Tohoku University, Japan, Wake Forest University, USA, the Heavy Ion Laboratory, Poland and companies such as Saint-Gobain, France, Scionix B.V., Holland, Siemens Healthcare, USA, CAEN, Italy, Syskon, OTJ Polon Wroclaw and Lubrina, Poland, Hamamatsu Photonics K.K., Tokuyama and C-and-A, Japan.

Details regarding the Division's achievements in selected areas may be found in the dedicated records of this Annual Report.

Łukasz Świderski

REPORTS

Determination of the copper ore composition by means of Neutron Activation Analysis, i n siyu and during various processing stage
Stage II. Final repost (in polish)
M. Gierlik, ... , **S. Burakowski**, **Ł. Kaźmierczak**, **Ł. Komorowski**, **T. Krakowski**, **T. Lotz**, **J. Rzadkiewicz**, **P. Sobkowicz**, **A. Urban**, **A. Wasilewski**, ... et al.

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Two-electron one-photon transition characteristics for low-Z K-shell hollow atoms
J. Rzadkiewicz, **K. Kozioł**
ADAS Workshop (United Kingdom, Abingdon, 2017-12-04 - 2017-12-05)

Energy Resolution of Scintillation Detectors
M. Moszyński
Emerging Technologies (Poland, Warsaw, 2017-05-28 - 2017-05-30)

Archaeological face of the surface non-invasive analysis
A. Gójska, **E. Miśta**, **P. Sibczyński**
International conference silver in early medieval central Europe (Poland, Warsaw, 2017-11-30 - 2017-12-01)

SiPMs in Gamma Spectrometry with Scintillation Detectors
M. Grodzicka-Kobyłka, **M. Moszyński**, **T. Szczęśniak**
Emerging Technologies (Poland, Warsaw, 2017-05-28 - 2017-05-30)

Oral Presentation

Application of track detectors to measure neutrons emitted from 14 MeV neutron generator
R. Kwiatkowski, **A. Malinowska**, **A. Szydłowski**, 2, B. Bieńkowska, **M. Gierlik**, S. Jednoróg, E. Łaszyńska, **K. Malinowski**, **J. Rzadkiewicz**
PhDiaFusion 2017 Summer School of Plasma Diagnostics (Poland, Podlesice n. Cracow, 2017-09-11 - 2017-09-15)

NCBJ\'s contribution to the construction of large research infrastructures in EU
A. Syntfeld-Każuch
II NICA Days in Warsaw (Poland, Warsaw, 2017-11-06 - 2017-11-10)

Study of applicability of non-destructive analyses methods in archaeology
A. Gójska, **E. Miśta**, **P. Sibczyński**
TECHNART 2017Non-destructive and microanalytical techniques in art and cultural heritage (Spain, Bilbao, 2017-05-02 - 2017-05-06)

Scintillation Properties of Promising Rare Earth Activated Oxides - Pt. 2: GAGG:Ce and β-Ga2O3:Ce
W. Drozdowski, M.E. Witkowski, M. Makowski, **K. Brylew**, P. Solarz, P. Głuchowski, M. Głowacki, Z. Gałązka
FAST WG2 Meeting (Poland, Toruń, 2017-10-13 - 2017-10-13)

Poster

Non-proportionality of GAGG:Ce scintillators down to 50 eV electron equivalent with application of an alpha particle probing technique
P. Sibczyński, **W. Czarnacki**, **S. Mianowski**, **Z. Mianowska**, **M. Moszyński**, **T. Sworobowicz**, **Ł. Świderski**, A.A. Bezbakh, A.S. Fomichev, S.A. Krupko, A.V. Sabelnikov, K. Kamada, Y. Shoji, A. Yoshikawa
International Conference on Scintillating Materials and their Applications - SCINT (France, Chamonix, 2017-09-18 - 2017-09-22)

Application of track detectors to measure neutrons emitted from 14 MeV neutron generators
A. Malinowska, **A. Szydłowski**, B. Bieńkowska, **M. Gierlik**, S. Jednorog, E. Łaszyńska, **K. Malinowski**, **J. Rzadkiewicz**, **A. Wasilewski**
27th ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

Temperature Dependence of CsI:Tl Scintillation Pulse Shapes from -183°C to +90°C Measured with a SiPM Readout
Ł. Świderski, **M. Moszyński**, **W. Czarnacki**, **M. Grodzicka-Kobyłka**, **Z. Mianowska**, **T. Sworobowicz**, **T. Szczęśniak**, **A. Syntfeld-Każuch**
IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, Atlanta, 2017-10-21 - 2017-10-28)

Shaping of neutron spectra emitted from 14-MEV neutron generator
E. Łaszyńska, K. Mikszuta, S. Jednoróg, B. Bieńkowska, **M. Gierlik**, **A. Malinowska**, **J. Rzadkiewicz**, **A. Szydłowski**
NEUDOS 13 Neutron and Ion Dosimetry Symposium (Poland, Kraków, 2017-05-14 - 2017-05-19)

Temperature dependence of scintillation properties of La-GPS(Ce)
J. Iwanowska-Hanke, **M. Moszyński**, **K. Brylew**, **P. Sibczyński**, **A. Dziedzic**
IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, Atlanta, 2017-10-21 - 2017-10-28)
IEEE NSS Conf. Rec. (2017)

C-BORD - an overview of efficient toolbox for high-volume freight inspection
P. Sibczyński, **A. Dziedzic**, **K. Grodzicki**, **J. Iwanowska-Hanke**, **Z. Mianowska**, M. Moszyński, **Ł. Świderski**, **A. Syntfeld-Każuch**, **M. Szawłowski**, **D. Wolski**, A. Dołębska, W. Gęsikowski, J. Godlewski, F. Carrel, A. Grabowski, F. Laine, G. Sannie, A. Sari, S. Moretto, C. Fontana, F. Pino, B. Perot, A. Sardet, C. Carasco
IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, Atlanta, 2017-10-21 - 2017-10-28)
IEEE Xplore Digital Library, Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (in press)

New perspectives for undoped CaF_2 scintillator as a threshold activation neutron detector
P. Sibczyński, **A. Dziedzic**, **K. Grodzicki**, **J. Iwanowska-Hanke**, **M. Moszyński**, **Ł. Świderski**, **A. Syntfeld-Każuch**, **D. Wolski**, F, Carrel, A. Grabowski, M. Hamel, F. Laine, A. Sari, A. Iovene, C. Tintori, C. Fontana, F. Pino
Advancements in nuclear instrumentation measurement methods and their applications (Belgium, Liege, 2017-06-19 - 2017-06-23)
EPJ Web Conf. Vol. 170 (2018) 07012

Polish In-Kind Contribution to European XFEL: Status in Summer 2017
J. Lorkiewicz, **K. Chmielewski**, Z. Gołębiewski, **W. Grabowski**, **K. Kosiński**, **K. Kostrzewa**, **P. Krawczyk**, **I.M. Kudła**, **P. Markowski**, K. Meissner, **E. Pławski**, **M. Sitek**, **J. Szewiński**, **M. Wojciechowski**, **Z. Wojciechowski**, **G. Wrochna**, **J. Sekutowicz**, J. Fydrych, M. Duda, M. Jeżabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Stodulski, M. Wiencek, J. Świerblewski, P. Grzegory, G. Michalski, P. Borowiec, M. Chorowski, P. Duda, A. Iluk, K. Malcher, J. Poliński, E. Rusiński, J. Głowinkowski, M. Winkowski, P. Wilk
38th International Free-Electron Laser Conference (FEL2017) (USA, Santa Fe, 2017-08-20 - 2017-08-25)
Kip Bishopsberger (LNL), Volker RW Schaa (GSI) (Santa Fe, NM, USA) No. (2017)

Light pulse decays and non-proportionality characteristics of CsI:Tl at temperatures down to -70°C
Z. Mianowska, **M. Moszyński**, A. Gektin, S. Gridin, X. Lu, M.R. Mayhugh, **S. Mianowski**, **Ł. Świderski**, **A. Syntfeld-Każuch**, **T. Szczęśniak**, R.T. Williams, S. Vasyukov
International Conference on Scintillating Materials and their Applications - SCINT (France, Chamonix, 2017-09-18 - 2017-09-22)

Non-proportionality and energy resolution of $Lu_xY_{1-x}AG$:Pr and LuAG:Pr,Mo crystals
K. Brylew, **P. Sibczyński**, **M. Moszyński**, W. Drozdowski, J. Kisielewski
IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, Atlanta, 2017-10-21 - 2017-10-28)
IEEE NSS Conf. Rec. (in press)

Cerium-doped gadolinium fine aluminum gallate GFAG(Ce) in gamma-ray spectrometry
J. Iwanowska-Hanke, **M. Moszyński**, **K. Brylew**, **P. Sibczyński**, **T. Szczęśniak**
International Conference on Scintillating Materials and their Applications - SCINT (France, Chamonix, 2017-09-18 - 2017-09-22)

Evolution of MPPC properties as a function of neutron fluence
S. Mianowski, J. Baszak, Yu.M. Gledenov, Yu.N. Kopatch, **Z. Mianowska**, **M. Moszyński**, **P. Sibczyński**, **T. Szczęśniak**
IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, Atlanta, 2017-10-21 - 2017-10-28)
IEEE NSS Conf. Rec. (in press)

Performance of 2 inch and 3 inch Scintillation Detectors with SiPM Light Readout
T. Szczęśniak, **M. Grodzicka-Kobyłka**, **M. Moszyński**, **M. Szawłowski**, **S. Mianowski**, **D. Wolski**
IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, Atlanta, 2017-10-21 - 2017-10-28)

LECTURES, COURSES AND EXTERNAL SEMINARS

Experimental methods for characterization of scintillators response to gamma-rays[b]
Ł. Świderski
Warsaw, Heavy Ion Laboratory, 2017-09-29

[b)] in English

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

M. Moszyński
Fellow of IEEE
Member of TransNational Committee of IEEE Nuclear and Plasma Science Society
Member of the Management Committee of COST Action TD1007, "Bimodal PET-MRI molecular imaging technologies and applications for in vivo monitoring of disease and biological processes" (www.pet-mri.eu)
Neutron Detectors Array (NEDA)
Warsaw Scientific Society
Nuclear Instruments & Methods in Physics Research A, Elsevier, Member of Advisory Editorial Board
Journal of Instrumentation, Institute of Physics Publishing, Member of Editorial Board
Recent Patents on Engineering, Bentham Science Publishers, Member of Editorial Board
National Centre for Nuclear Research, Member of Scientific Council
Deputy President of Scientific Council National Centre for Nuclear Research
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Agnieszka Syntfeld-Każuch, PhD
Marek Szawłowski, MSc Eng
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ELECTRONICS AND DETECTION SYSTEMS DIVISION

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2017 was another intense year of new challenges. Some of the older projects gained momentum, and brand new ones were started. Below are short descriptions of our main activities, categorized by the subdivisions and projects they belong to.

Laboratory of Spectrometry and Nuclear Electronics (Dr Michał Gierlik)

MSc Eng Piotr Mazerewicz, MSc Łukasz Kaźmierczak, *R&D tasks for KGHM "Polska Miedź" S. A.*

In 2017 MSc Eng Piotr Mazarewicz and his group advanced in their project under the contract with KGHM "Polska Miedź" S. A. The challenging goal is defined as an X-Ray Fluorescence prototype for appraising the quality and composition of copper ore in the excavation wall. The appliance is expected to begin trials in the middle of 2018. In the meantime MSc Łukasz Kaźmierczak focused on development of neutron analysis techniques with the aim of applying them to a running belt conveyor. As the year 2017 comes to an end, NCBJ and KGHM lawyers are finalizing the contract for the approaching year.

MSc Łukasz Kaźmierczak, Dr Michał Gierlik, MSc Tomasz Krakowski, *R&D contract for PGNiG*

In Septemer 2017 a 13-month long R&D project for PGNiG began. While the details of the project are classified, the general idea is the development of nuclear detection techniques for well logging.

Prof. Izabella Zychor, *EUROfusion_NCBJ_JET4*

We are involved in the JET4 Enhancements Projects dealing with the modernization of the Gamma-ray Camera and Gamma-ray Spectrometer at the Joint European Tokamak (JET). Upgrade of the gamma-ray diagnostics is necessary because in planned deuterium-tritium (D-T) campaigns measurements at high count rates are expected.

We tested $CeBr_3$ and $LaBr_3$:Ce scintillators for both upgraded devices. These crystals are characterized by good energy resolution, short decay time and relatively high detection efficiency for a few MeV gamma rays. Tests with dedicated new detector setups were performed at both NCBJ and JET, under laboratory conditions. In 2017 we delivered to JET 19 detectors for the Gamma-ray Camera based on a $\phi 25.4 \times 16.9$ mm $LaBr_3$:Ce scintillator coupled to a silicon photomultiplier (MPPC). A dedicated MPPC Temperature Compensation Device (MTCD@NCBJ) and a filter box (FilterBox@NCBJ) were designed and produced at NCBJ –they are now installed at JET. All tests performed at both JET and NCBJ have shown that the new detectors are well suited for measurements at rates up to ~1 Mcps. Preliminary results on runaway electron production at JET, obtained with the new detectors installed at the Gamma-ray Camera, indicate that this diagnostics will be useful to investigate disruption processes caused by such electrons. The understanding of runaway electron generation and proposing operational methods for control of the runaway are necessary to ensure safe operation of both operating and future tokamaks. The EUROfusion_NCBJ_JET4 project will continue in 2018.

Dr Jarosław Szewiński, *PLC Modules for X-FEL Experiments*

On 1.09.2017, the X-FEL Accelerator was officially started, switching the project from the construction to the operational phase. By this time, Poland has finished all in-kind contributions, including the PL08 final task – "*Delivery of 200 PLC modules for the first six experiments*." During the X-FEL opening ceremony it was emphasized that Poland has finished all contributions to the construction phase on time and in budget. To cover all needs of the X-FEL experiments more than 200 units are required. Because of the high quality of the PLC modules delivered under in the PL08 task, X-FEL GmbH has invited NCBJ to participate in the call for tender for delivering another 60 modules. NCBJ has won that tender, and is now delivering PLC units to X-FEL on the basis of a commercial contract.

Dr Eng. Jarosław Szewiński, *LLRF for the European Spallation Source (ESS)*

In the first Quarter of 2017 the ESS announced that the general project delay is of the order of 16 months. Due to this reason it was necessary to perform *Value Engineering* at ESS, which led to the decision, that the final 40 RF sections will be installed in the future (not within the actual budget). This caused NCBJ and the whole PEG (Polish Electronic Group) Consortium change of the work scope for. The in-kind contract, schedule and tasks, were renegotiated with ESS and later approved by the Polish Ministry of Science and Higher Education. During contract negotiation, in addition modifying existing tasks, new tasks were identified. As a result, the overall value of the PEG in-kind contract has been increased, by transferring of the polish ESS in-cash contribution to in-kind.

During the 2017, PEG completed *Task-01 "Preparation of the LLRF system components specifications"*, which covered the specification of the RTM Carrier AMC board, the design is of which assigned to NCBJ. By the end of 2017, the RTM Carrier design was finished, and in December the first prototypes of the RTM Carrier were manufactured, assembled and delivered to NCBJ

Dr Michał Gierlik, *Gamma-ray spectrometer for the MARIA nuclear reactor hot cell (ENS)*

A team from the Electronics and Detection Systems Division has introduced a gamma-ray spectrometer for the MARIA nuclear reactor hot cell. The instrument is a contribution to the larger diagnostic system, which is being developed for the reactor under the Early Neutron Source project.

Laboratory of Environment Preservation Physics (Dr Janusz Licki)

The Mobile Air Monitoring Laboratory offer has been extended with measurements of the concentration of nitric oxides in ambient air. The mobile container has been equipped with: an NO/NO2/NOx model T 200 Teledyne API analyzer, CMK 5 calibrator and zero air supply type NGA 19S from MCZ Umwelttechnik, and a calibration gas mixture in a gas cylinder. This modified laboratory was used for the determination of air quality at the NCBJ site.

Continuous measurements were performed in August 2017. In these studies the following index of air quality was obtained: "excellent" regarding recorded concentrations of NO2 and "good" regarding measured concentrations of PM10 and PM2,5 fractions of suspended particulate.

Michał Gierlik

REPORTS

GCU D20 Report on M25: Detector assembly and laboratory tests with radioactive source and C&M
G. Bołtruczyk, **A. Brosławski**, **M. Gosk**, **S. Korolczuk**, **A. Urban**, **I. Zychor**
Świerk

Determination of the copper ore composition by means of Neutron Activation Analysis, i n siyu and during various processing stage
Stage II. Final repost (in polish)
M. Gierlik, ... , **S. Burakowski**, **Ł. Kaźmierczak**, **Ł. Komorowski**, **T. Krakowski**, **T. Lotz**, **J. Rzadkiewicz**, **P. Sobkowicz**, **A. Urban**, **A. Wasilewski**, ... et al.

M. Snopek, **M. Laskus**, **P. Mazerewicz**, **K. Grodzicki**, **J. Szymanowski**, Iinni

ENS-1.1.2.4-T7-02: IFMIF-DONES Project Integration Document (PID)
I. Petrenko
Eurofusion, WPENS (in press)

ENS-2.1.5.0-T25-08: Tritiated waste generation and management
K. Szewczak, **M. Maciak**, **S. Domański**, **A. Burakowska**, **I. Petrenko**
Eurofusion, WPENS (in press)

ENS-4.1.3.0-T16-02: “Hot Cell needs for Modules and other components dismantling 2017”
I. Petrenko
Eurofusion, WPENS (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

The Prototype Dosimetry System to Protect NICA Slow Control Electronic Equipment
A. Chłopik, **A. Bancer**, **M. Bielewicz**, A. Dąbrowski, **A. Dudziński**, **E. Jaworska**,
M. Peryt, K. Rosłoń, J. Rzadkiewicz

II Nica Days 2017 (Poland, Warsaw, 2017-11-02 - 2017-11-10)

Napromieniowanie spalin wiązką elektronów z z akceleratora dla jednoczesnej redukcji emisji SO_2, NO_x i WWA z kotłów opalanych pyłem węglowym
J. Licki, A.G. Chmielewski, Z. Zimek
X Konferencja Naukowa Ochrona Powietrza w Teorii i Praktyce (Poland, Zakopane, 2017-10-18 - 2017-10-21)
Instytut Podstaw Inżynierii Środowiska Polskiej Akademii Nauk w Zabrzu No. (2017) p. 51

Analiza stężeń PM_{10}, $PM_{2,5}$ i PM_1 pyłu zawieszonego w powietrzu w wybranej lokalizacji przy użyciu mobilnego laboratorium NCBJ
J. Licki, **J. Sernicki**, **M. Kowalski**, **M. Lasiewicz**, **A. Bigos**, **M. Laskus**
X Konferencja Naukowa Ochrona Powietrza w Teorii i Praktyce (Poland, Zakopane, 2017-10-18 - 2017-10-21)
Instytut Podstaw Inżynierii Środowiska Polskiej Akademii Nauk w Zabrzu No. (2017) p. 22

Oral Presentation

Machine learning in astrophysics
T. Krakowski, **K. Małek**, **M. Bilicki**, M. Siudek, **A. Pollo**
XXXVIII Zjazd Polskiego Towarzystwa Astronomicznego (Poland, Zielona Góra, 2017-09-11 - 2017-09-14)
Proceedings of the Polish Astronomical Society (2017)

Application of track detectors to measure neutrons emitted from 14 MeV neutron generator
R. Kwiatkowski, **A. Malinowska**, **A. Szydłowski**, 2, B. Bieńkowska, **M. Gierlik**, S. Jednoróg, E. Łaszyńska, **K. Malinowski**, **J. Rzadkiewicz**
PhDiaFusion 2017 Summer School of Plasma Diagnostics (Poland, Podlesice n. Cracow, 2017-09-11 - 2017-09-15)

MTCA.4 Components Designed by Polish Electronic Group for ESS LLRF Control System
J. Szewiński, A. Abramowicz, W. Cichalewski, K. Czuba, **Z. Gołębiewski**, **M. Gosk**, M. Grzegrzółka, G. Jabłoński, **P. Krawczyk**, **I.M. Kudła**, D. Makowski, A. Mielczarek, A. Napieralski, P. Perek, P. Plewiński, I. Rutkowski, **D. Rybka**, A. Szubert
6th MicroTCA Workshop for Industry and Research (Germany, Hamburg, 2017-12-06 - 2017-12-07)

Poster

Application of track detectors to measure neutrons emitted from 14 MeV neutron generators
A. Malinowska, **A. Szydłowski**, B. Bieńkowska, **M. Gierlik**, S. Jednorog, E. Łaszyńska, **K. Malinowski**, **J. Rzadkiewicz**, **A. Wasilewski**
27th ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

C-BORD - an overview of efficient toolbox for high-volume freight inspection
P. Sibczyński, **A. Dziedzic**, **K. Grodzicki**, **J. Iwanowska-Hanke**, **Z. Mianowska**, M. Moszyński, **Ł. Świderski**, **A. Syntfeld-Każuch**, **M. Szawłowski**, **D. Wolski**, A. Dołębska, W. Gęsikowski, J. Godlewski, F. Carrel, A. Grabowski, F. Laine, G. Sannie, A. Sari, S. Moretto, C. Fontana, F. Pino, B. Perot, A. Sardet, C. Carasco
IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, Atlanta, 2017-10-21 - 2017-10-28)
IEEE Xplore Digital Library, Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (in press)

Shaping of neutron spectra emitted from 14-MEV neutron generator
E. Łaszyńska, K. Mikszuta, S. Jednoróg, B. Bieńkowska, **M. Gierlik**, **A. Malinowska**, **J. Rzadkiewicz**, **A. Szydłowski**
NEUDOS 13 Neutron and Ion Dosimetry Symposium (Poland, Kraków, 2017-05-14 - 2017-05-19)

New perspectives for undoped CaF_2 scintillator as a threshold activation neutron detector
P. Sibczyński, **A. Dziedzic**, **K. Grodzicki**, **J. Iwanowska-Hanke**, **M. Moszyński**, **Ł. Świderski**, **A. Syntfeld-Każuch**, **D. Wolski**, F, Carrel, A. Grabowski, M. Hamel, F. Laine, A. Sari, A. Iovene, C. Tintori, C. Fontana, F. Pino
Advancements in nuclear instrumentation measurement methods and their applications (Belgium, Liege, 2017-06-19 - 2017-06-23)
EPJ Web Conf. Vol. 170 (2018) 07012

Characterization of a compact $LaBr_3$ detector with Silicon photomultipliers at high 14 MeV neutron fluxes
D. Rigamonti, **A. Brosławski**, **S. Korolczuk**, **I. Zychor**
2nd European Conference on Plasma Diagnostics (France, Bordeaux, 2017-04-18 - 2017-04-21)

New FPGA processing code for JET gamma-ray camera upgrade
A. Fernandes, **G. Bołtruczyk**, **A. Brosławski**, **M. Gosk**, **S. Korolczuk**, **R. Kwiatkowski**, **A. Urban**, **I. Zychor**
11th IAEA Technical Meeting on Control, Data Acquisition, and Remote Participation for Fusion Research (Germany, Greifswald, 2017-05-08 - 2017-05-12)

Control and Data Acquisition Software Upgrade for JET Gamma-Ray Diagnostics
B. Santos, **G. Bołtruczyk**, **A. Brosławski**, **M. Gosk**, **S. Korolczuk**, **R. Kwiatkowski**, **A. Urban**, **I. Zychor**
11th IAEA Technical Meeting on Control, Data Acquisition, and Remote Participation for Fusion Research (Germany, Greifswald, 2017-05-08 - 2017-05-12)

Detectors for high count rate measurements with a compensation for MPPC gain dependence on temperature
A. Urban, **A. Brosławski**, **G. Bołtruczyk**, **M. Gosk**, **S. Korolczuk**, **D. Rybka**, V. Kiptily, M. Nocente, D. Rigamonti, M. Tardocchi, **I. Zychor**
Advancements in nuclear instrumentation measurement methods and their applications (Belgium, Liege, 2017-06-19 - 2017-06-23)

Contribution to the ESS LLRF system by Polish electronic group
J. Szewiński, A. Abramowicz, W. Cichalewski, K. Czuba, **Z. Gołębiewski**, **M. Gosk**, M. Grzegrzółka, G. Jabłoński, **P. Krawczyk**, **I.M. Kudła**, D. Makowski, A. Mielczarek, A. Napieralski, P. Perek, I. Rutkowski, **D. Rybka**
LLRF 2017 Low Level Radio Frequency Workshop (Spain, Barcelona, 2017-10-16 - 2017-10-19)

Contribution to the ESS LLRF system by Polish electronic group
J. Szewiński, **Z. Gołębiewski**, **M. Gosk**, **P. Krawczyk**, **I.M. Kudła**, W. Cichalewski, D. Makowski, A. Napieralski, A. Abramowicz, K. Czuba, M. Grzegrzółka, I. Rutkowski
8^{th} International Particle Accelerator Conference (IPAC 2017) (Denmark, Kopenhaga, 2017-05-14 - 2017-05-19)

Polish In-Kind Contribution to European XFEL: Status in Summer 2017
J. Lorkiewicz, **K. Chmielewski**, Z. Gołębiewski, **W. Grabowski**, **K. Kosiński**, **K. Kostrzewa**, **P. Krawczyk**, **I.M. Kudła**, **P. Markowski**, K. Meissner, **E. Pławski**, **M. Sitek**, **J. Szewiński**, **M. Wojciechowski**, **Z. Wojciechowski**, **G. Wrochna**, **J. Sekutowicz**, J. Fydrych, M. Duda, M. Jeżabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Stodulski, M. Wiencek, J. Świerblewski, P. Grzegory, G. Michalski, P. Borowiec, M. Chorowski, P. Duda, A. Iluk, K. Malcher, J. Poliński, E. Rusiński, J. Głowinkowski, M. Winkowski, P. Wilk
38th International Free-Electron Laser Conference (FEL2017) (USA, Santa Fe, 2017-08-20 - 2017-08-25)
Kip Bishopsberger (LNL), Volker RW Schaa (GSI) (Santa Fe, NM, USA) No. (2017)

LECTURES, COURSES AND EXTERNAL SEMINARS

Analysis of RE data from JET Gamma-ray Camera[b]
A. Brosławski
Culham, United Kingdom, Culham Centre for Fusion Energy, 2017-04-05

Analysis of RE data from JET Gamma-ray Camera[b]
A. Urban
Culham, Culham Centre for Fusion Energy (CCFE), 2017-04-05

Analysis of run-away electron data from JET Gamma-ray Camera[b]
I. Zychor
Culham, UK, Culham Centre for Fusion Energy, 2017-04-05

Analysis of RE data from JET Gamma-ray Camera – progress[b]
A. Brosławski
Culham, United Kingdom, Culham Centre for Fusion Energy, 2017-04-12

Analysis of run-away electron data from JET Gamma-ray Camera – progress[b]
I. Zychor
Culham, UK, Culham Centre for Fusion Energy, 2017-04-12

Analysis of RE data from JET Gamma-ray Camera – progress[b]
A. Urban
Culham, Culham Centre for Fusion Energy (CCFE), 2017-07-12

Study of runaway electrons with a new detector in Gamma-ray Camera[b]
A. Brosławski
Culham, United Kingdom, Culham Centre for Fusion Energy, 2017-11-16

Study of runaway electrons with a new detector in Gamma-ray Camera[b]
A. Urban
Culham, Culham Centre for Fusion Energy (CCFE), 2017-11-16

Study of runaway electrons with a new detector in Gamma-ray Camera[b]
I. Zychor
Culham, UK, Culham Centre for Fusion Energy, 2017-11-16

[b)] in English

INTERNAL SEMINARS

Chernobyl Nuclear Power Plant: Nuclear Monitoring in Shelter Object and Chernobyl Exclusion Zone, short description of projects in the field of nuclear safety[a]
I. Petrenko
Otwock, National Centre for Nuclear Research, 2017-06-27

[a)] in Polish

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

Z. Guzik
Polski Komitet Normalizacyjny, Polish Normalization Commetee

J. Licki
Polish Standards Committe, member of Technical Committe No 280 on Air Quality
Polish Academy of Sciences, member of the Plasma Physics Section of Physics Committe

I. Zychor
PhD Proceedings Admission Committee Chairperson (since 2016), National Centre for Nuclear Research (NCBJ) Scientific Council

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Arkadiusz Chlopik, MSc
Marcin Gosk, MSc
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Stefan Korolczuk, MSc
Tomasz Krakowski, MSc
Dominik Rybka, MSc

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Tadeusz Batsch, PhD Eng
Andrzej Brosławski, MSc
Szymon Burakowski
Łukasz Komorowski, MSc
Ignacy Kudła, MSc Eng
Maciej Lińczuk
Ievgen Petrenko, MSc Eng
Maciej Sitek
Arkadiusz Urban, MSc Eng
Krystian Trela, MSc

Administration
Agata Mikulska, MSc

PLASMA STUDIES DIVISION

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The main tasks of the Plasma Studies Division staff in 2017 were as follows:

1) Studies of fast electrons, ions, neutrons, and X-ray emissions within different research facilities of the PF, RPI-, ICF- and Tokamak-type;

2) Investigation of high-temperature plasma streams and their interactions with solid targets.

As regards the first task, the activities of the Plasma Studies Division (TJ5) were focused on studies of physical phenomena in high-current discharges of the Plasma-Focus type and of runaway electrons in the COMPASS tokamak, as well as on applications of solid-state nuclear detectors (SSNTDs) for studies of laser-driven nuclear fusion reactions.

Due to the effective scientific collaboration of the NCBJ (Otwock-Świerk), IFPiLM (Warsaw) and CVUT (Prague), valuable new results were obtained at the modified PF-1000U facility, in particular: the life-time of plasma-filaments moving together with a plasma stream was estimated, subsequent neutron pulses were combined with the formation of plasmoids and plasma instabilities, the influence of an additional conical tip (located in the centre of the anode) on neutron yield was investigated, and local electron temperatures inside a pinch column were determined. It was also proved experimentally that PF-type facilities can generate intense plasma streams which can be used for simulations of astrophysical phenomena.

Investigation of runaway electrons (REs) was continued in the framework of the EUROfusion Work Package MST2. A three-channel detection system of the Cherenkov-type was installed in the COMPASS tokamak at the IPP ASCR in Prague. The application of Cherenkov-type detectors within the COMPASS facility enabled the monitoring of REs, studies on correlations of Cherenkov signals with MHD activity of plasmas, and estimation of REs losses due to observed MHD perturbations.

Studies of laser-driven nuclear fusion reactions were performed by means of solid-state nuclear detectors at the PALS laser system in Prague. The use of such detectors made it possible to estimate the alpha - particle yield per unit area. The values obtained appeared to be in good agreement with the theoretical estimations. A proton energy distribution was also measured at the PALS facility by means of a Thomson Parabola Spectrometer.

The second task, concerning investigation of high-temperature plasma streams and their interactions with solid targets, was realised in the framework of the scientific collaboration with the IPP KIPT in Kharkov, Ukraine. The main efforts concerned research on modifications of Cr18Ni10Ti-steel and Eurofer-alloy samples which were irradiated by intense plasma streams. Studies of the optical emission spectra of plasmas produced from different stainless-steel samples exposed to pulsed plasma streams were also performed. The main experiments, concerning the erosion of such samples, were performed within the RPI-IBIS facility at NCBJ. The joint Polish-Ukrainian team also performed a surface analysis of different steel samples irradiated by intense laser beams and pulsed plasma streams.

Jarosław Żebrowski

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Two-electron one-photon transition characteristics for low-Z K-shell hollow atoms
J. Rzadkiewicz, **K. Kozioł**
ADAS Workshop (United Kingdom, Abingdon, 2017-12-04 - 2017-12-05)

Experimental research of neutron and HXR emission from the dense plasma focus
P. Kubes, M. Paduch, J. Cikhardt, B. Cikhardtova, D. Klir, J. Karvarik, V. Munzar, K. Rezac, S. Jednorog, **E. Składnik-Sadowska**, **M.J. Sadowski**, **D. Załoga**, E. Zielinska
PhDiaFusion 2017 Summer School of Plasma Diagnostics (Poland, Podlesice n. Cracow, 2017-09-11 - 2017-09-15)

Research on PF-1000U during last year
P. Kubes, J. Cikhardt, B. Cikhardtova, D. Klir, J. Kravarik, K. Rezac, V. Munzar, M. Paduch, E. Zielinska, S. Jednorog, **M.J. Sadowski**, **E. Składnik-Sadowska**, **D. Załoga**, K. Tomaszewski
International Workshop and Expert Meeting ICDMP 2017 (Poland, Warsaw, 2017-09-22 - 2017-09-24)

Last results in laboratory simulation of astrophysical jets with Plasma Focus
V.I. Krauz, M. Paduch, R. Miklaszewski, A. Szymaszek, E. Zielinska, **E. Składnik-Sadowska**, **M.J. Sadowski**, **R. Kwiatkowski**, K. Tomaszewski, S.A. Dan'ko, A.M. Kharrasov, K.N. Mitrofanov
International Workshop and Expert Meeting ICDMP 2017 (Poland, Warsaw, 2017-09-22 - 2017-09-24)

Oral Presentation

Preliminary Results of Fast Electrons Measurements by Means of a Cherenkov-type Three-channel Detector
M. Rabiński, **L. Jakubowski**, **M.J. Jakubowski**, **K. Malinowski**, **M.J. Sadowski**, **J. Żebrowski**, **R. Mirowski**, V. Weinzettl, O. Ficker, J. Mlynar, R. Panek, R. Paprok, M. Vlainic, COMPASSteam
Mini-conference on Run-Away Electrons (Czech Republic, Prague, 2017-02-14 - 2017-02-14)

Laboratory Simulations of Astrophysical Jets: Results from Experiments within the PF-3, PF-1000U, and KPF-4 Facilities
V.I. Krauz, V.V. Myalton, V.P. Vinogradov, E.P. Velikhov, S.S. Anan'ev, S.A. Dan'ko, Yu.G. Kalinin, A.M. Kharrasov, Yu.V. Vinogradova, K.N. Mitrofanov, M. Paduch, R. Miklaszewski, E. Zielinska, **E. Składnik-Sadowska**, **M.J. Sadowski**, **R. Kwiatkowski**, K. Tomaszewski, D.A. Vojtenko
44th Zvenigorod International Conference on Plasma Physics and Controlled Fusion (Russian Federation, Zvenigorod, 2017-02-13 - 2017-02-17)
J Phys Conf Ser Vol. 907 (2017) 012026

Acceleration of deuterons and electrons in the dense plasma focus
P. Kubes, M. Paduch, J. Cikhardt, B. Cikhardtova, D. Klir, J. Kravarik, K. Rezac, **M.J. Sadowski**, **E. Składnik-Sadowska**, A. Szymaszek, K. Tomaszewski, **D. Załoga**
International Conference on Dense Z-Pinches DZP2017 (USA, Stateline, Nevada, 2017-08-13 - 2017-08-17)

Studies of runaway electrons via Cherenkov effect in tokamaks
J. Żebrowski, **M. Rabiński**, **L. Jakubowski**, **M.J. Sadowski**, **M.J. Jakubowski**, **R. Kwiatkowski**, **K. Malinowski**, **R. Mirowski**, J. Mlynar, V. Weinzettl, F. Causa, COMPASSandFTUTeams
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Materials surface damage and modification under high power plasma exposures
I. Garkusha, V. Maklaj, O. Byrka, V. Taran, S. Herashchenko, S. Malykhin, **K. Nowakowska-Langier**, **M.J. Sadowski**, **E. Składnik-Sadowska**
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Studies of plasma flows in the PF-1000U facility at different gas fillings
V. Krauz, M. Paduch, R. Miklaszewski, A. Szymaszek, E. Zielinska, **E. Składnik-Sadowska**, **M.J. Sadowski**,

R. Kwiatkowski, K. Tomaszewski, S.A. Danko, A.M. Kharrasov, K.N. Mitrofanov
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Recent experiments on RE beam generation and mitigation in COMPASS
O. Ficker, J. Mlynar, E. Macusova, V. Weinzettl, M. Vlainic, J. Cerovsky, M. Imrisek, M. Farnik, J. Urban, A. Casolari, R. Paprok, J. Havlicek, M. Tomes, P. Vondracek, T. Markovic, J. Varju, E. Mateeva, P. Hacek, P. Junek, M. Gospodarczyk, **M.J. Jakubowski**, **M. Rabiński**, **J. Żebrowski**, V. Plyusnin, R. Panek, M. Hron, COMPASSteam, EUROfusionMST1team
30th MHD, Disruptions and Control Topical Group Meeting (Spain, Barcelona, 2017-10-09 - 2017-10-11)

Consideration about deuteron acceleration in dense plasma focus experiments
P. Kubes, M. Paduch, J. Cikhardt, B. Cikhardtova, D. Klir, J. Kravarik, V. Munzar, K. Rezac, S. Jednorog, **E. Składnik-Sadowska**, **M.J. Sadowski**, **D. Załoga**, E. Zielinska
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Influence of gas conditions on electron temperature inside a pinch column of plasma-focus discharge
D. Załoga, **M.J. Sadowski**, **E. Składnik-Sadowska**, M. Paduch, E. Zielinska, K. Tomaszewski
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Application of track detectors to measure neutrons emitted from 14 MeV neutron generator
R. Kwiatkowski, **A. Malinowska**, **A. Szydłowski**, 2, B. Bieńkowska, **M. Gierlik**, S. Jednoróg, E. Łaszyńska, **K. Malinowski**, **J. Rzadkiewicz**
PhDiaFusion 2017 Summer School of Plasma Diagnostics (Poland, Podlesice n. Cracow, 2017-09-11 - 2017-09-15)

Poster

Development of a Cherenkov-type diagnostic system to study runaway electrons within the COMPASS tokamak
M. Rabiński, **L. Jakubowski**, **K. Malinowski**, **M.J. Sadowski**, **J. Żebrowski**, **M.J. Jakubowski**, **R. Mirowski**, V. Weinzettl, O. Ficker, J. Mlynar, R. Panek, R. Paprok, M. Vlainic
2nd European Conference on Plasma Diagnostics (France, Bordeaux, 2017-04-18 - 2017-04-21)

Dawka lokalna i jej rola w biologicznej odpowiedzi linii komórkowych ssaków in vitro
U. Kaźmierczak, D. Banaś, J. Braziewicz, J. Czub, **M. Jaskóła**, **A. Korman**, M. Kruszewski, A. Lankoff, H. Lisowska, **A. Malinowska**, T. Stępkowski, Z. Szefliński, M. Wojewódzka
44. Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-09-15)

Control and Data Acquisition Software Upgrade for JET Gamma-Ray Diagnostics
B. Santos, **G. Bołtruczyk**, **A. Brosławski**, **M. Gosk**, **S. Korolczuk**, **R. Kwiatkowski**, **A. Urban**, **I. Zychor**
11th IAEA Technical Meeting on Control, Data Acquisition, and Remote Participation for Fusion Research (Germany, Greifswald, 2017-05-08 - 2017-05-12)

Runaway Electron diagnostic development and performance at the COMPASS tokamak
J. Mlynar, V. Weinzettl, J. Cerovsky, O. Ficker, M. Farnik, E. Macusova, R. Paprok, P. Svihra, J. Urban, M. Vlainic, P. Vondracek, D. Carnevale, **M.J. Jakubowski**, G. Papp, V. Plyusnin, **M. Rabiński**, **J. Żebrowski**, J. Havlicek, T. Markovic, R. Panek
2nd European Conference on Plasma Diagnostics (France, Bordeaux, 2017-04-18 - 2017-04-21)

Progress in diagnostics of the COMPASS tokamak
V. Weinzettl, J. Adamek, M. Berta, P. Bilkova, O. Bogar, P. Bohm, J. Cavalier, R. Dejarnac, M. Dimitrova, O. Ficker, D. Fridrich, O. Grover, P. Hacek, J. Havlicek, A. Havranek, J. Horacek, M. Hron, M. Imrisek, M. Komm, K. Kovarik, J. Krbec, T. Markovic, E. Matveeva, K. Mitosinkova, J. Mlynar, D. Naydenkova, R. Panek, R. Paprok, M. Peterka, A. Podolnik, J. Seidl, M. Sos, J. Stockel, M. Tomes, M. Varavin, J. Varju, M. Vlainic, P. Vondracek, J. Zajac, F. Zacek, M. Stano, G. Andra, D. Dunai, T. Krizsanoczi, D. Refy, S. Zoletnik, A. Silva, R. Gomes, T. Pereira, T. Popov, D. Sarychev, G. Ermak, **J. Żebrowski**, **M.J. Jakubowski**, **M. Rabiński**, **K. Malinowski**, S. Nanobashvili, M. Spolaore, N. Vianello, E. Gauthier, J. Gunn, A. Devitre

2nd European Conference on Plasma Diagnostics (France, Bordeaux, 2017-04-18 - 2017-04-21)

RE beam generation in MGI disruptions on COMPASS
O. Ficker, J. Mlynar, E. Macusova, M. Vlainic, V. Weinzettl, J. Urban, J. Cerovsky, M. Farnik, R. Paprok, P. Vondracek, M. Imrisek, J. Havlicek, J. Varju, O. Bogar, A. Havranek, M. Gospodarczyk, **M. Rabiński**, **M.J. Jakubowski**, **K. Malinowski**, **J. Żebrowski**, V. Plyusnin, G. Papp, R. Panek, M. Hron, TheCOMPASSteamandtheEUROfusionMST1Team
44th European Physical Society Conference on Plasma Physics (EPS), Belfast, Northern Ireland (United Kingdom, Belfast, 2017-06-26 - 2017-06-30)
European Physical Society No.Vol. 41F (2017) p. P5.126

Measurements of primary protons emitted from PF-1000 facility by means of SSNTD
A. Szydłowski, **R. Kwiatkowski**, **A. Malinowska**, M. Paduch, R. Miklaszewski, E. Zielińska
PLASMA 2017. International Conference on Research and Applications of Plasmas (Poland, Warszawa, 2017-09-18 - 2017-09-22)

Measuring the protons participating in the ^{11}B(p, α)2α nuclear-fusion reaction using CR-39 TASTRAK
A. Malinowska, A. Szydłowski, **R. Kwiatkowski**, M. Paduch, R. Miklaszewski, **K. Malinowski**, E. Zielińska, **M. Jaskóła**, **A. Korman**, **M. Kuk**
27th ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

Surface analysis of steel samples irradiated by laser beams and pulsed plasma streams
K. Nowakowska-Langier, **E. Składnik-Sadowska**, M. Kubkowska, P. Gasior, **R. Kwiatkowski**, **M.J. Sadowski**, A.K. Marchenko
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Alpha-particle spectroscopy by the use of polyallyl-diglycol-carbonate (PADC) detectors
A. Malinowska, **A. Szydłowski**, **R. Kwiatkowski**, K. Malinowski, **M. Jaskóła**, **A. Korman**, **M. Kuk**
27th ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

Analysis of optical spectra from steel samples exposed to pulsed plasma streams
A.K. Marchenko, **E. Składnik-Sadowska**, **R. Kwiatkowski**, **K. Nowakowska-Langier**, **M.J. Sadowski**, M. Kubkowska, I.E. Garkusha, V.A. Makhlai
PLASMA-2017 International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2017-09-18 - 2017-09-22)

Application of track detectors to measure neutrons emitted from 14 MeV neutron generators
A. Malinowska, **A. Szydłowski**, B. Bieńkowska, **M. Gierlik**, S. Jednorog, E. Łaszyńska, **K. Malinowski**, **J. Rzadkiewicz**, **A. Wasilewski**
27th ICNTRM International Conference on Nuclear Tracks and Radiation Measurement (France, Strasbourg, 2017-08-28 - 2017-09-01)

Shaping of neutron spectra emitted from 14-MEV neutron generator
E. Łaszyńska, K. Mikszuta, S. Jednoróg, B. Bieńkowska, **M. Gierlik**, **A. Malinowska**, **J. Rzadkiewicz**, **A. Szydłowski**
NEUDOS 13 Neutron and Ion Dosimetry Symposium (Poland, Kraków, 2017-05-14 - 2017-05-19)

New FPGA processing code for JET gamma-ray camera upgrade
A. Fernandes, **G. Bołtruczyk**, **A. Brosławski**, **M. Gosk**, **S. Korolczuk**, **R. Kwiatkowski**, **A. Urban**, **I. Zychor**
11th IAEA Technical Meeting on Control, Data Acquisition, and Remote Participation for Fusion Research (Germany, Greifswald, 2017-05-08 - 2017-05-12)

INTERNAL SEMINARS

Studies of physical phenomena in discharges of the PF type, and interactions of plasma with chosen materials[a]
M.J. Sadowski
Otwock-Swierk, National Centre for Nuclear Research(NCBJ), 2017-12-12

[a)] in Polish

DIDACTIC ACTIVITY

M.J. Sadowski - Superviser of a Ph.D thesis of Dobromil Zaloga, entitled "Studies of visible and x-ray radiation, and estimations of electron temperature in discharges of Plasma-Focus type", defended at NCBJ on 20 July, 2017.

M.J. Sadowski - Tutalage of the preparation of a Ph.D. thesis by M.Sc. Ewa Laszynska (from IFPiLM in Warsaw).

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

R. Kwiatkowski
Member of Polish Physics Society

A. Malinowska
International Nuclear Track Society, member
Plasma Physics Section of the Committee of Physics at the Polish Academy of Sciences
Polish Physical Society (PPS) Member of the Board of Plasma Physics Section

M. Rabiński
Member of the Board of the Polish Nuclear Society, Head of the Information Committee
Member of the European Nuclear Society
Member of the Board of the Environmentalists for Nuclear Energy - Poland (treasurer)
Polish Physical Society
Postępy Techniki Jądrowej, Member of the Editorial Board of the Advances of Nuclear Technique, National Atomic Energy Agency
Ekoatom, "Ecoatom" - Environmentalists for Nuclear Energy - Poland

M.J. Sadowski
Session chairman on PhDiaFusion 2017 Summer School of Plasma Diagnostics \ in Podlesice n. Cracow, Poland
Session chairman on PLASMA-2017 International Conference on Research and Applications of Plasmas in Warsaw, Poland
Member of Advisory Board on PLASMA-2017 International Conference on Research and Applications of Plasmas in Warsaw, Poland
Member of Advisory Board on PhDiaFusion 2017 Summer School of Plasma Diagnostics \ in Podlesice n. Cracow, Poland
Member of Advisory Board on International Workshop and Expert Meeting ICDMP 2017 in Warsaw, Poland
Member of the European Physical Society (Plasma Physics Division)
Fellow of the Institute of Physics, London, UK
Member of the Polish Physical Society (PPS), since 2012 - Chairman of Plasma Physics Section at PPS
Member of the Polish Society of Applied Electromagnetics
Member of the Warsaw Scientific Society.
Nukleonika, Institute of Nuclear Chemistry and Technology, and Polish Nuclear Society.
Member of the Scientific Council, National Centre for Nuclear Research
Honorary Chairman of the Scientific Council, Institute of Plasma Physics and Laser Microfusion

A. Szydłowski
International Nuclear Track Society, member

Scientific staff
Karol Kozioł. PhD
Roch Kwiatkowski, PhD
Aneta Malinowska, PhD
Karol Malinowski, PhD
Marek Rabiński, PhD
Marek Sadowski, Professor
Elżbieta Składnik-Sadowska, PhD
Adam Szydłowski, Associate Professor
Dobromił Załoga, PhD
Jarosław Żebrowski, PhD

Technical and administrative staff
Krzysztof Bigolas
Krzysztof Gątarczyk
Alicja Gawrońska
Marcin Jakubowski
Marek Jędrzejczyk
Paweł Karpiński

DIVISION OF NUCLEAR EQUIPMENT - HITEC

Director of Centre Edyta Dymowska-Grajda, Eng
Phone: (22) 273 21 00
e-mail: edyta.dymowska-grajda@ncbj.gov.pl

The Division of Nuclear Equipment - HITEC carries out research and development, design, manufacture, installation and commissioning, sales and after sales support of high technology devices, including equipment producing ionizing radiation for industry and medicine.

The scope of research and development, implementation, manufacturing and services covers in particular:

- Electron linear accelerators for radiography, medicine and other applications,
- Devices supporting the operation of radiographic accelerators,
- Construction of research equipment at the request of other scientific departments of NCBJ as well as external recipients,
- Carrying out maintenance services,
- Cooperation with other scientific departments of NCBJ and other research institutions in Poland and abroad.

In 2017 HITEC completed many R&D and commercial projects, in particular:

The intraoperative radiotherapy system built within the INTRA-DOSE project, i.e. the accelerator named IntraLine-IOERT, was awarded first place in the Polish Product of the Future at the 20th anniversary competition organized by PARP and NCBiR. The competition promotes innovative products and technologies with possibilities for commercialization in the domestic and global markets.

IntraLine-IOERT is an electron accelerator used for irradiation of tissues affected with a tumour directly after surgery in the operating room.

It was built by the HITEC Department of the National Centre for Nuclear Research in cooperation with the Greater Poland Cancer Centre (WCO). Efforts have been made to commercialize the device, obtaining the proper certification according to the most recent EU medical standards, setting up the first device in Poznań and introducing the product to the American market.

On May 9, 2017 the Division of Nuclear Equipment - HITEC celebrated together with CERN the inauguration of the Linac 4 accelerator. Linac 4 is composed of as many as four accelerating stages that accelerate particles to higher and higher energies. The final stage, composed of 12 accelerating Pi-Mode Accelerating Structures (PIMS), was successfully manufactured by HITEC.

Linac 4 is the continuation of the Collaboration Agreement with CERN aimed at upgrading the performance of the CERN Large Hadron Collider (LHC). Linac 4 will make possible improved performance of the LHC, the largest research facility on Earth.

In 2017 HITEC, together with other NCBJ scientific departments and in cooperation with its commercial partner continued the construction of the pilot installation of the CANIS Large Cargo Inspection System at the NCBJ entry gate where, in addition to demonstrating the operation of the system under industrial conditions, the system will be used to control trucks entering the NCBJ site.

Finally, it should be mentioned that in 2017 HITEC developed and supplied to the market a new line of radiographic accelerators - Lillyput - built using a solid state modulator, triode electron gun and touch screen control panel.

HITEC's offer was also extended by a range of precise manipulators for linear accelerators, object and digital imaging systems, which was the subject of inquiries from customers abroad.

The Division of Nuclear Equipment HITEC has implemented and certified an integrated quality management system complying with PN-EN ISO 9001:2015-10 and PN-EN ISO 13485:2012 standards.

Edyta Dymowska-Grajda

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Oral Presentation

Beam dynamics calculations for accelerator system analysis in the Early Neutron Source project
W. Grabowski, **K. Kosiński**, **M. Staszczak**, **A. Wysocka-Rabin**
NUTECH-2017 Conference on Development and Application of Nuclear Technologies (Poland, Kraków , 2017-09-10 - 2017-09-13)

MTCA.4 Components Designed by Polish Electronic Group for ESS LLRF Control System
J. Szewiński, A. Abramowicz, W. Cichalewski, K. Czuba, **Z. Gołębiewski**, **M. Gosk**, M. Grzegrzółka, G. Jabłoński, **P. Krawczyk**, **I.M. Kudła**, D. Makowski, A. Mielczarek, A. Napieralski, P. Perek, P. Plewiński, I. Rutkowski, **D. Rybka**, A. Szubert
6th MicroTCA Workshop for Industry and Research (Germany, Hamburg, 2017-12-06 - 2017-12-07)

Poster

Comparison of preliminary beam dynamic calculations between different codes for SRF-L accelerator in the Early Neutron Source project
W. Grabowski, **K. Kosiński**, **M. Staszczak**, **A. Wysocka-Rabin**
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)
Polskie Towarzystwo Fizyczne, Oficyna Wydawnicza Politechniki Warszawskiej, Wrocław 2017 No. (2017)

Polish In-Kind Contribution to European XFEL: Status in Summer 2017
J. Lorkiewicz, **K. Chmielewski**, Z. Gołębiewski, **W. Grabowski**, **K. Kosiński**, **K. Kostrzewa**, **P. Krawczyk**, **I.M. Kudła**, **P. Markowski**, K. Meissner, **E. Pławski**, **M. Sitek**, **J. Szewiński**, **M. Wojciechowski**, **Z. Wojciechowski**, **G. Wrochna**, **J. Sekutowicz**, J. Fydrych, M. Duda, M. Jeżabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Stodulski, M. Wiencek, J. Świerblewski, P. Grzegory, G. Michalski, P. Borowiec, M. Chorowski, P. Duda, A. Iluk, K. Malcher, J. Poliński, E. Rusiński, J. Głowinkowski, M. Winkowski, P. Wilk
38th International Free-Electron Laser Conference (FEL2017) (USA, Santa Fe, 2017-08-20 - 2017-08-25)
Kip Bishopsberger (LNL), Volker RW Schaa (GSI) (Santa Fe, NM, USA) No. (2017)

CONTRIBUTION TO THE ESS LLRF SYSTEM BY POLISH ELECTRONICGROUP
J. Szewiński, **Z. Gołębiewski**, **M. Gosk**, **P. Krawczyk**, **I.M. Kudła**, W. Cichalewski, D. Makowski, A. Napieralski, A. Abramowicz, K. Czuba, M. Grzegrzółka, I. Rutkowski
8th International Particle Accelerator Conference (IPAC 2017) (Denmark, Kopenhaga, 2017-05-14 - 2017-05-19)

CONTRIBUTION TO THE ESS LLRF SYSTEM BY POLISH ELECTRONIC GROUP
J. Szewiński, A. Abramowicz, W. Cichalewski, K. Czuba, **Z. Gołębiewski**, **M. Gosk**, M. Grzegrzółka, G. Jabłoński, **P. Krawczyk**, **I.M. Kudła**, D. Makowski, A. Mielczarek, A. Napieralski, P. Perek, I. Rutkowski, **D. Rybka**
LLRF 2017 Low Level Radio Frequency Workshop (Spain, Barcelona, 2017-10-16 - 2017-10-19)

Akcelerator do Radioterapii Śródoperacyjnej – wyniki prac projektu Inta-Dose
A. Misiarz, **J. Pracz**, M. Kruszyna
Konferencja Polskiego Towarzystwa Fizyki Medycznej (Poland, Poznań, 2017-06-01 - 2017-06-03)

DEPARTMENT OF COMPLEX SYSTEM

Director of Department Professor Wojciech Wiślicki
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DIVISION OF NUCLEAR ENERGY AND ENVIRONMENTAL STUDIES

Head of the Division: Professor Mariusz Dąbrowski
phone: +48 (22) 273 14 30
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Main scientific and technical achievements.

The Neutronics and New Technologies Section main activities were:

1. Neutron-physics analysis of the research and power nuclear reactors:

   Burnup calculations of the MARIA research reactor fuel elements and poisoning in beryllium blocks using the APOLLO, SERPENT, TRIPOLI and MCNP codes. Calculations were performed in the framework of BENICE Project and NCBJ&CEA cooperation.

   Analysis of the possibilities of using the ANNA zero power reactor infrastructure for research on high-temperature reactors.

   Criticality study and burnup calculations of the pin and assembly of the ALLEGRO reactor core.

   Criticality study and burnup of metallic DFR reactor design.

   Neutron-physics safety analysis of the PWR core with new cladding material using the MCNP code.

   Modelling of EPR, AP-1000, ABWR, APR1400 fuel assemblies using the SCALE/NEWT code. Analysis of the isotopic composition and radiotoxicity of the spent nuclear fuel.

   Participation in the OECD NEA benchmark: Code Comparison for Depletion of Gadolinium-Bearing Fuel Rods in Boiling Water Reactor Assemblies.

   National and international projects: BENICE, BRILLIANT, VINCO, GEMINI+

2. Education:

Scientific supervision of bachelor and master papers.

The Reactor Analyses Section together with the Fuel Cycle Section has been engaged in a number of activities – the most important were the following:

1. Activities in the field of safety assessment, code development and validation:

   Development of a model of the core supporting plate in the PWR reactor, including phenomena occurring during severe accidents – molten core propagation and its impact on the plate;

   Continuation of work on the molten core retention and propagation in the framework of the UE Horizon 2020 Euratom Project “In-Vessel Melt Retention – IVMR”; (i) Studying the effects of turbulence on mixing and heat exchange between the layers (ii) Analytical evaluation and analysis of external boiling and convection, (iii) Strength calculations of the internal structure elements of the reactor pressure vessel;

Continuation of work on the “dryout” phenomena (drying fuel elements in a BWR reactor) and on the possibilities of the system code CATHARE-3 in predicting dryout; a semi-phenomenological model for the "Initial entrained fraction" phenomenon was developed, implemented and validated in the CATHARE-3 code for wide two-phase flow conditions; a statistical analysis was also carried out for various models of entrainment and deposition of water droplets phenomena in the context of the results obtained compared to experiment;

Development of the thermal-hydraulic model of the cooling system of Allegro – gas-cooled fast reactor using the CATHARE2 code – analyses of steady state and selected accident scenarios;

Continuation of development of the new code “DARIA” for modelling of selected thermal-hydraulic phenomena: (i) a simulation engine balancing mass and energy in two-phase flow with heat exchange taking into account three fields flow, (ii) prediction of dryout phenomena.

2. In the field of the fuel cycle the following tasks were conducted:

Actinide burning and determination of the energy spectrum of neutrons in the “KWINTA” assembly: (i) Analysis and processing of experimental results from 2016 and previous years was continued; (ii) New samples of Np-237 were irradiated with 660 MeV protons; (iii) Analysis of the use of minority actinides as detectors of neutron fluence

Behaviour of fuel during operation: Prediction of the release of helium atoms from the sample (U, Am) O2 during irradiation with neutrons as a function of temperature (capabilities of immobilization of helium in the fuel);

Dynamic modelling of the fuel cycle of the molten salts power reactor (MSR);

Transmutation of spent nuclear fuel with electron beams, protons and heavy nuclei

The structure of electron-photon cascades in dense amorphous matter

Kinematic correlations in nuclear reactions in the GeV energy range

3. The study:

Technology and costs estimation of a technological steam source with a high-tempera ture gas-cooled reactor (HTGR). Various construction versions and technology providers were considered. The results were used in the economic analyses and report of the team “Committee for deployment of high-temperature reactors” for Polish industry appointed by the Minister of Energy;

The work of the **Centre of Hazard Analyses MANHAZ** (previously the Probabilistic Safety Analysis Team) was concentrated mainly on the analysis of environmental issues and risk analyses.

The most important activities are as follows:

1. Development of methods and practical approach for performing probabilistic safety assessment analysis:

Classification of systems/equipment for the MARIA reactor requested to fulfil safety functions and estimation of probabilities of postulated initiating events

Framework for non-electric applications of nuclear reactors: safety issues and licensing problems for HTR and DFR

Expertize for the National Atomic Energy Agency on the methodology of performing PSA for lower power and shutdown states.

2. High fidelity models for energetic reactors suited the high performance computing:

Within the collaboration with the Nuclear Research and Consultancy Group (NRG Netherlands) initial simulations were performed aimed at the generation of a high quality thermo-hydraulic DNS database for a rod bundle configuration; the generated database will serve as a reference for the validation purposes.

A series of work was carried out in order to generate 3D geometries of different components of the Maria research reactor - this database will be used in safety analyses.

Simulations of fire propagation were performed for the planned DONES (Demo Oriented Early Neutron Source) installation within the Eurofussion framework programme.

3. Development of tools for the analysis of the impact of nuclear installations on the environment:

Participation in the UDINEE (Urban Dispersion International Evaluation Exercise) project aimed at the evaluation of atmospheric dispersion models in order to improve Decision Support Systems following radiological dispersion events in an urban environment.

Development of a prototype version of a computerized system for risk assessment of major accidents in industrial installations with potential off-site hazards – within the national project EVARIS.

Contribution to safety and reliability analyses for the planned DONES installation within the Eurofussion framework programme.

Conference organization:

1. Organization of the international conference: ERMSAR 2017, the 8th European Review Meeting on Severe Accident Research, Warsaw, Poland, 15-18.05.2017.

2 Organization of the conference: 9th International School on Nuclear Energy, Warsaw, Poland, 14-17.11.2017.

Mariusz Dąbrowski

REPORTS

Analysis of the possibilities of using the existing infrastructure of the ANNA zero power reactor to prepare a critical assembly of the high temperature reactor
Ł. Koszuk, **M. Klisińska**, **K. Andrzejewski**
National Centre for Nuclear Power

Comparative analysis of the isotopic composition and radiotoxicity of spent fuel assemblies of EPR, AP-1000, ABWR and APR1400 reactors using high accuracy models
Ł. Koszuk, **M. Klisińska**, **K. Andrzejewski**
National Centre for Nuclear Research

Comparison of the Solutions of the First VINCO Neutronic Methodological Benchmark
A. Keresztúri, ... , **Ł. Koszuk**, **M. Klisińska**, ... et al.
VUJE

Engineered Zircaloy Cladding Modifications for Improved Accident Tolerance of LWR FuelFinal Report
BrentHeuser, ... , **T. Kozłowski**, ... et al.
UIUC

Estimation of HTR reactor construction costs for the production of process heat.; in the frame of project Comparative study of steam feeding from HTGR high-temperature gas-cooled reactor in relation to conventional boiler installations, for Grupy Azoty S.A.; The order of Energoprojet-Warszawa S.A.
J. Malesa, **D. Muszyński**, **J. Sierchuła**
NCBJ

Report of on-job training and learning exercise "Generation IV Neutronic Benchmark" final report - Part B
T. Chrebet, ... , **Ł. Koszuk**, **M. Klisińska**, ... et al.
VUJE

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Damage accumulation studies in ion-irradiated oxides: Current status and new perspectives
J. Jagielski, L. Thomé, A. Chartier, **O. Dorosh**, **C. Mieszczyński**, I. Jozwik
19th International Conference on Radiation Effects in Insulators (REI-19) (France, Versailles, 2017-07-02 - 2017-07-07)
Nucl. Instr. and Meth. B (in press)

Varying speed of light cosmologies. Theory and observations.
M.P. Dąbrowski
12 Iberian Cosmology Meeting (Spain, Valencia, 2017-04-10 - 2017-04-12)

Reversed engineered 3D fuel bundle for CFD uncertainty study
P. Prusiński, **T. Kwiatkowski**, **P. Warzybok**
NUTECH 2017 – International Conference on Development and Applications of Nuclear Technologies (Poland, Kraków, 2017-09-10 - 2017-09-13)

Modelling and calculations of critical core configurations of the ANNA zero-power reactor using KENO-VI/SCALE
Ł. Koszuk, **M. Klisińska**
European Research Reactor Conference (Netherlands, Rotterdam, 2017-05-14 - 2017-05-18)

Cyclic universes and the multiverse
M.P. Dąbrowski
SpringCosmo17 - Spring Cosmology Meeting (Poland, Międzyzdroje, 2017-05-19 - 2017-05-21)

ALLEGRO Core Neutron Physics Studies

P. Dařílek, A. Keresztúri, M. Gren, **Ł. Koszuk**, A. Vasile, R. Zajac, T. Chrebet
International Conference on Fast Reactors and Related Fuel Cycles: Next Generation Nuclear Systems for Sustainable Development (FR17) (Russia, Yekaterinburg, 2017-06-26 - 2017-06-29)

Stałe fundamentalne i multiwszechświat
M.P. Dąbrowski
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)

Inter-universal entanglement in the multiverse
M.P. Dąbrowski
The 4th Conference of the Polish Society on Relativity (Poland, Kazimierz Dolny, 2017-09-24 - 2017-09-28)

Modele i programy obliczeniowe na potrzeby systemu wyznaczania ryzyka obszarowego
M. Korycki
Innowacje w modelowaniu ryzyka wystąpienia awarii w obiektach przemysłowych (Poland, Józefów, 2017-03-20 - 2017-03-20)

The Prototype Dosimetry System to Protect NICA Slow Control Electronic Equipment
A. Chłopik, **A. Bancer**, **M. Bielewicz**, A. Dąbrowski, **A. Dudziński**, **E. Jaworska**,
M. Peryt, K. Rosłoń, J. Rzadkiewicz

II Nica Days 2017 (Poland, Warsaw, 2017-11-02 - 2017-11-10)

Prediction of annular flows in vertical pipes with new correlations for the CATHARE-3 three-field model.
M. Spirzewski, P. Fillion, M. Valette
NURETH - 17th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (China, Xi'an, Shaanxi, 2017-09-03 - 2017-09-08)

Beryllium Poisoning Model For Research Reactors
M. Wróblewska, **A. Boettcher**, **Z. Marcinkowska**, **K. Pytel**, **J. Jagielski**, P. BLAISE, P. SIRÉTA
European Research Reactor Conference (Netherlands, Rotterdam, 2017-05-14 - 2017-05-18)

The In-Vessel melt Retention Strategy for existing and future nuclear power plants – computational fluid dynamics simulations within and besides the Horizon2020 project
M. Skrzypek, **E. Skrzypek**
NUTECH 2017 – International Conference on Development and Applications of Nuclear Technologies (Poland, Kraków, 2017-09-10 - 2017-09-13)

The Computational Fluid Dynamics software use for the Severe Accident issues investigation for high power Pressurized Water Reactors –capabilities and challenges.
E. Skrzypek, **M. Skrzypek**
XIII Research & Development in Power Engineering Conference, 2017 (Poland, Warsaw, 2017-11-28 - 2017-12-01)

Analysis of In-Vessel Corium Behaviour Using CFD Tools
C. LeGuennic, **E. Skrzypek**, L. Vyskocil, **M. Skrzypek**, A. Shams, L. Saas
NURETH - 17th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (China, Xi'an, Shaanxi, 2017-09-03 - 2017-09-08)

Rayleigh-Bénard and Bénard-Marangoni convection in a thin metallic layer on top of corium pool
L. Saas, **E. Skrzypek**
8th Conference on Servere Accident Research - European Review Meeting on Severe Accident Research (ERMSAR) (Poland, Warsaw, 2017-05-16 - 2017-05-18)

Hypothetical mathematical construct of helium release from uranium dioxide fuel during neutron irradiation in terms of defect trap model
M. Szuta, **L. Dąbrowski**
13th Meeting and Workshop of the Working Party on Multiscale Modelling of Fuels and Structural Materials (France, Boulogne-Billancourt, France, 2017-05-09 - 2017-05-11)

Experimental determination of delayed nuclear heating in MARIA reactor by using Karolina calorimeter and Gamma Thermometer
M. Tarchalski, **K. Pytel**, **R. Prokopowicz**, C. Reynard-Carette, J. Brun, A. Lyoussi, P. Sireta, **J. Jagielski**, D. Fourmentel, L. Barbot, **Z. Marcinkowska**, **M. Wróblewska**, A. Luks
Advancements in Nuclear Instrumentation Measurement Methods and their Applications (Belgium, Liege, 2017-06-19 - 2017-06-23)

Oral Presentation

IPPLM/NCBJ contribution to FMECA/PIE study, Accident Analysis and Non-radiological Safety
M. Borysiewicz, **O. Dorosh**, **K. Kowal**, **T. Kwiatkowski**, **S. Potempski**, **P. Prusiński**
3rd WPENS Technical Meeting (Italy, Brasimone, 2017-04-04 - 2017-04-06)

Analiza Niezawodności Systemu Grawitacyjnego Chłodzenia Reaktora Typu ESBWR
A. Kaszko, M. Stępień, G. Niewiński
II Międzynarodowa Konferencja Naukowo - Techniczna p.t.:Problemy inżynierii bezpieczeństwa obiektów antropogenicznych (Poland, Warszawa, 2017-11-16 - 2017-11-17)

Reversed engineered 3D fuel bundle for CFD uncertainty study
P. Prusiński, **T. Kwiatkowski**, **P. Warzybok**
NUTECH 2017 – International Conference on Development and Applications of Nuclear Technologies (Poland, Kraków, 2017-09-10 - 2017-09-13)

Cogeneration: technologies, possibilities, challenges
T. Jackowski, **K. Kowal**, **S. Potempski**
53rd ESReDA Seminar, Safety: the Challenge of Foresight (Italy, Ispra, 2017-11-14 - 2017-11-15)
JRC Ispra No.JRC 108605 (2017) p. 150-161

IPPLM/NCBJ contribution to FMECA/PIE study, Accident Analysis and Non-radiological Safety 2017
M. Borysiewicz, **O. Dorosh**, **K. Kowal**, **S. Potempski**
WPENS 4th Technical Meeting (Germany, Karlsruhe, 2017-10-25 - 2017-10-27)

Application of WRF wind fields and QUIC model in UDINEE exercise
P. Kopka, **M. Korycki**, **S. Potempski**
Second Urban Dispersion International Evaluation Exercise (UDINEE) workshop (Italy, Ispra, 2017-03-27 - 2017-03-28)

Neutron flux measurement in the energy range near spallation maximum energy (20-40 MeV) inside the QUINTA assembly
M. Bielewicz, **E. Strugalska-Gola**, **S. Kilim**, **M. Szuta**, S. Tiutiunnikov
NEUDOS 13 Neutron and Ion Dosimetry Symposium (Poland, Kraków, 2017-05-14 - 2017-05-19)
Radiat. Prot. Dosim. (2017)

Man-made hazards modelling and implementation in extended PSA
S. Potempski, H. Brinkman
European Safety and Reliability Conference ESREL 2017 (Slovenia, Portoroz, 2017-06-18 - 2017-06-22)
CRC Press, Taylor & Francis Group No. (2017) p. 489

The measurements of the high energy evaporated neutrons by means of ^{89}Y threshold reaction activation method
M. Bielewicz, **E. Strugalska-Gola**, **S. Kilim**, **M. Szuta**, S. Tiutiunnikov
NUTECH-2017 Conference on Development and Application of Nuclear Technologies (Poland, Kraków , 2017-09-10 - 2017-09-13)

Identification of main source of uncertainties in the EVEDA phase RAMI studies
M. Borysiewicz, **A. Kaszko**, **P. Stano**, **S. Potempski**
3rd WPENS Technical Meeting (Italy, Brasimone, 2017-04-04 - 2017-04-06)

Plant Systems 1 & 2 RAMI analysis WPENS 4th Technical Meeting

P. Stano, **A. Kaszko**, **S. Potempski**, **M. Borysiewicz**
WPENS 4th Technical Meeting (Germany, Karlsruhe, 2017-10-25 - 2017-10-27)

Mathematics of helium behavior in uranium dioxide fuel during neutron irradiation in terms of defect trap model.
M. Szuta, **L. Dąbrowski**
12th International conference on WWER Fuel Performance, Modelling and Experimental Support. (Bulgaria, Burgas, 2017-09-16 - 2017-09-23)

Poster

Search for periodic interferences in LIGO O1 data
O. Dorosh, **A. Królak**
LSC-Virgo August 2017 Meeting (Switzerland, Genewa, 2017-08-28 - 2017-09-01)

LECTURES, COURSES AND EXTERNAL SEMINARS

Neutronic calculations for safety analysis of nuclear reactors[a]
Ł. Koszuk
Warsaw, Faculty of Physics, University of Warsaw, 2017-05-05

Polish critical assemblies as the topics of benchmarks for physical calculations[a]
M. Klisińska
Warsaw, Faculty of Physics, University of Warsaw, 2017-05-12

Global Sensitivity Analysis with Sobol method and its application to RAMI analysis[a]
P. Stano
Kraków (Cracow), Uniwersytet Jagielloński, Wydział Matematyki i Informatyki, Zakład Matematyki Stosowanej (Jagiellonian University, Institute of Applied Mathematics), 2017-05-30

Renaissance of nuclear energy[a]
Ł. Koszuk
Warsaw, Faculty of Physics, University of Warsaw, 2017-06-09

Cyclic multiverse and inter-universal entanglement[b]
M.P. Dąbrowski
Tufts, Boston, Institute for Cosmology, Tufts University, USA, 2017-02-16

Hierarchy of varying-c theories - theory and observations.[b]
M.P. Dąbrowski
Waterloo, Perimeter Institute, Waterloo, Kanada, 2017-02-23

Varying speed of light cosmologies. Theory and observations.[b]
M.P. Dąbrowski
Valencia, University of Valencia, Hiszpania, 2017-04-11

Nuclear Cogeneration – the Current Situation in Poland[b]
J. Malesa
Vienna, International Atomic Energy Agency, 2017-05-29

Is Baltic Region good for Nuclear Power?[b]
M.P. Dąbrowski
Szczecin, Szczecin Geoscience Institute , 2017-06-01

Polish nuclear roadmap[b]
A. Boettcher
Paris, OECD NEA, 2017-07-05

Baltic Region, Poland, and Nuclear Power[b]
M.P. Dąbrowski
Stockholm, KTH (Kings Technological Institute) Stockholm, Sweden, 2017-09-26

Status of Advanced Fast Reactors and Gas Cooled Reactors Technology Development and Research in Poland[b]
A. Boettcher
Vienna, IAEA, 2017-10-30

[a)] in Polish
[b)] in English

INTERNAL SEMINARS

Modeling of beryllium block poisoning [a]
M. Wróblewska
Otwock, Świerk, Otwock, Świerk, 2017-01-17

Testing Accuracy of Rectangular Diffusion Model of MARIA Reactor[a]
D. Muszyński
Otwock-Swierk, National Centre for Nuclear Research, 2017-01-24

High performance computing and computational fluid dynamics[b]
S. Potempski
Otwock, National Centre for Nuclear Research, 2017-01-24

Project WPENS as part of EUROfusion[a]
O. Dorosh
Świerk, NCBJ, 2017-02-14

FLACS - software for dispersion, fire and explosion safety analysis.[a]
T. Kwiatkowski
Otwock-Świerk, National Centre for Nuclear Research, 2017-02-28

Methods for estimation the effects of failure in industrial facilities[a]
A. Wawrzyńczak-Szaban
Swierk, NCBJ, 2017-03-28

Thermal mechanical modelling of the core support plate during severe accident in Pressurised Water Reactor[a]
M. Skrzypek
Otwock, National Centre for Nuclear Research, 2017-04-25

Fukushima & doubts of Polish people regarding Nuclear Energy[a]
P. Stano
Świerk (Swierk), Narodowe Centrum Badań Jądrowych (National Centre for Nuclear Research), 2017-05-09

Numerical simulations of airflow in central Warsaw - preliminary results [a]
M. Korycki
Jablonna, Polish Academy of Science, 2017-05-19

Global Sensitivity Analysis with Sobol approach: Application to RAMI type of analysis[a]
P. Stano
Świerk (Swierk), Narodowe Centrum Badań Jądrowych (National Centre for Nuclear Research), 2017-05-23

Gas Fast Reactor, GFR, Demonstrator ALLEGRO, Neutronics Benchmarks[a]
M. Klisińska
Swierk, National Centre for Nuclear Research, 2017-06-06

Gas fast reactor, GFR, Demonstrator ALLEGRO, Neutronic benchmarks[a]
Ł. Koszuk
Otwock, National Centre for Nuclear Research, 2017-06-06

Forward and Inverse Uncertainty Quantification of Thermal-Hydraulics Physical Model Parameters[a]
T. Kozłowski
Warsaw, NCBJ, 2017-06-20

Methods of estimating overpressure during vapor cloud explosion[a]
M. Korycki
Otwock-Świerk, National Centre for Nuclear Research, 2017-10-17

National Energy Security and its dependnce of high-end engineering software[a]
P. Prusiński
Otwock-Świerk, National Center for Nuclear Research, 2017-11-07

High energy neutron flux density measurement[b]
E. Strugalska-Gola
Świerk, National Centre for Nuclear Research, 2017-11-14

Reverse Engineering as a source of CFD uncertainty[b]
T. Kwiatkowski
Otwock-Świerk, National Centre for Nuclear Research, 2017-11-21

Reverse Engineering as a source of CFD uncertainty[b]
P. Prusiński
Otwock-Świerk, National Center for Nuclear Research, 2017-11-21

The results of the CFD analysis of the uranium converter.[a]
T. Kwiatkowski
Otwock-Świerk, National Centre for Nuclear Research, 2017-11-27

The results of the CFD analysis of the uranium converter[a]
P. Prusiński
Otwock-Świerk, National Center for Nuclear Research, 2017-11-27

An improved phenomenological model of annular two-phase flow with high-accuracy dryout prediction capability[a]
M. Spirzewski
Otwock, Narodowe Centrum Badań Jądrowych, 2017-11-28

Searching gravitational waves emitted by rotating neutron stars[a]
O. Dorosh
Swierk, NCBJ, 2017-12-05

a) in Polish
b) in English

DIDACTIC ACTIVITY

K. Andrzejewski - K. Andrzejewski, Ł. Koszuk: MSc Thesis, student: Arkadiusz Siwiec, Faculty of Physics, Warsaw University, Topic: Neutron-physics calculations for power reactors (Dry storage containers, which can be used both for storage and transport of spent fuel elements).

K. Andrzejewski, Ł. Koszuk: MSc Thesis, student: Marcel Bajdel, Faculty of Physics, Warsaw University , Topic: Neutron - physics for power reactors (comparison of PWR fuel assemblies with thorium and uranium fuel).

K. Andrzejewski - Testing Accuracy of Rectangular Diffusion Model of MARIA Reactor, Promotor: dr N. Uzunow (PW), dr K. Andrzejewski (NCBJ)- student: D. Muszyński, March 27, 2017.

M. Borysiewicz - Lectures on a environmental risk mangement for students of Lodz Technical Univeristy

M.P. Dąbrowski - University of Szczecin: classical and relativistic mechanics, mathematical methods of physics II, gravitation and cosmology

M. Klisińska - "Workshops on reactor Physics: Thermalhydraulics"
Facoulty of Physics, Univerity of Warsaw
Course ID: 1100-4WFRJ

M. Klisińska - Students mentoring (with Ł. Koszuk), work topic: >Burnup calculations of EPR and AP1000 reactors fuel assemblies using POLARIS/SCALE code- analysis of code capabilities< in the frame of classes >Team student project< - Faculty of Physics, University of Warsaw, Students: P. Potrykus, M. Bajdel

Ł. Koszuk - "Workshops on reactor physics: Neutronics",
Faculty of Physics, University of Warsaw,
Course ID: 1100-4WFRJ

Ł. Koszuk - Students mentoring (with Ł. Koszuk), work topic: >Burnup calculations of EPR and AP1000 reactors fuel assemblies using POLARIS/SCALE code - analysis of code capabilities< in the frame of classes >Team student project< - Faculty of Physics, University of Warsaw, students: P. Potrykus, M. Bajdel

K. Kowal - Basic physics laboratory courses with carrying out of selected experiments in different branches of physics (mechanics, heat, optics) for students of Bachelor's degree program (1st cycle mode) in Computer Science at Siedlce University of Natural Sciences and Humanities

K. Kowal - Basic physics laboratory courses with carrying out of selected experiments in different branches of physics (mechanics, magnetism, optics, radiation) for students of Bachelor's degree program (1st cycle mode) in Computer Science at Lublin University of Technology.

K. Kowal - Lecture on Transportation Risk Assessment and Management for students of postgraduate studies "Safety of Industrial Processes" at Lodz University of Technology

K. Kowal - Lectures on risk analysis methods for managers participating in the POLRISK Risk Management Association Academy program. The objective of this program is to provide the course participants appropriate knowledge and practical skills required to obtain the certification in risk management.

K. Kowal - Supervision of trainees - students of the Warsaw University of Technology (Nuclear Power Engineering) during their Master Internship at NCBJ

T. Kozłowski - Research tools and methods in nuclear engineering

T. Kwiatkowski - Education & Training of new CFD specialist (Anna Talarowska, Eng.) for Nuclear Facilities Operations Department (NCBJ)

J. Malesa - Carying internship student: Basics of the thermal-hydraulic modelling of nuclear reactor systems and development of supporting tools.

S. Potempski - High Performance Computing, NCBJ PhD Studies, Warsaw University Faculty of Physics

S. Potempski - Industrial installations for safety and mitigation of the consequences of industrial accidents, Main School of Fire Services, postgraduate studies

P. Prusiński - Education & Training of new CFD specialist (Anna Talarowska, Eng.) for Nuclear Facilities Operations Department (NCBJ)

G. Siess - Certified Manager of Risk Management - Module 3 "Methods and techniques of risk analysis"

G. Siess - Lecture on environmetal risk assessment and management for students of postgraduate studies in Lodz University of Technology

B. Słowiński - One semester lectures (30h) for undergraduate students of the Faculty of Physics, Warsaw University of Technology "Physics background of nuclear power".

B. Słowiński - One semester lectures (30h) for undergraduate students of the Faculty of Production Technology, Warsaw University of Life Sciences "Global developments of energetics".

B. Słowiński - PhD student Rafał Korzeniowski prepared under my scientific leadership his PhD thesis entitled Correlations in nuclear reactions initiated by pions of several GeV energy as a space intranuclear probe.
The defence of the thesis is foreseen during the first quater of 2018

B. Słowiński - PhD thesis defended by Artur Pacan at the Physics Faculty, Warsaw University of Technology, Warsaw, Poland. His thesis is entitled as: Physics effects in spalation targets of reactor systems driven by electrons and protons beams.

M. Spirzewski - Introduction to Python programming and introduction to Linux MINT operating system

P. Stano - Supervision of student trainees following MSc track in Nuclear Power Engineering

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

K. Andrzejewski
Nukleonika, Institute of Nuclear Chemistry and Technology

M. Bielewicz
Polish Astronomical Society

M. Borysiewicz
Member of the European Safety, Reliability and Data Association (ESReDA)

M.P. Dąbrowski
Session chairman on 44 Zjazd Fizyków Polskich in Wrocław, Poland
Session chairman on IX Międzynarodowa Szkoła Energetyki Jądrowej w Warszawie, Świerku i Różanie. in Warszawa, Poland
Member of Organizing Committee on ERMSAR2017 in Warszawa, Poland
Member of Organizing Committee on SpringCosmo17 - Spring Cosmology Meeting in Międzyzdroje, Poland
Member of Organizing Committee on 44 Zjazd Fizyków Polskich in Wrocław, Poland
Polish Physical Society
Universe, Universe, MDPI Switzerland
Co-proposer, Management Committee Member

Ł. Koszuk
Session chairman on 9th International School on Nuclear Power in Warszawa - Świerk - Różan, Poland
Member of Organizing Committee on 9th International School on Nuclear Power in Warszawa - Świerk - Różan, Poland
ATOMIC FORUM Foundation, President
Polish Nuclear Society, member

T. Kozłowski
Session chairman on ERMSAR in warsaw, Poland
American Nuclear Society
Science and Technology of Nuclear Installations, Science and Technology of Nuclear Installations, Hidawi
Chairmen of the OECD/NEA Nuclear Science Committee Uncertainty Analysis Methodology Expert Group

J. Malesa
Chairman of the Technical Committee no 266 for Nuclear Equipment, Polish Committee for Standardization

S. Potempski
European Geophysical Union, regular membership
Member of the Advisory Group for high temperature nuclear reactors, Ministry of Energy

M. Skrzypek
Polish Nuclear Society, member

B. Słowiński
Journal of Nuclear and Radiation Physics. A Periodical of the Egyptian Nuclear Physics Association, Journal of Nuclear and Radiation Physics
a member of the Faculty Council, Faculty of Physics, Warsaw University of Technology

E. Strugalska-Gola
member, Association of Polish Electricians, Committee of Nuclear Power

M. Szuta
OECD/NEA

A. Wawrzyńczak-Szaban
członek
member

Research staff
Krzysztof Andrzejewski, PhD
Marcin Bielewicz, PhD
Agnieszka Boettcher, MSc
Mieczysław Borysiewicz, PhD
Ludwik Dąbrowski, Professor
Mariusz Dąbrowski, Professor
Orest Dorosh, PhD
Aleksej Kaszko, MSc Eng
Stanisław Kilim, MSc Eng
Małgorzata Klisińska, MSc
Piotr Kopka, MSc
Michał Korycki, MSc
Łukasz Koszuk, MSc
Karol Kowal, PhD Eng
Tomasz Kozłowski, Associate Professor
Tomasz Kwiatkowski, MSc Eng
Anna Padee, MSc Eng.
Janusz Malesa, MSc Eng.
Dominik Muszyński, Eng
Sławomir Potempski, PhD
Piotr Prusiński, MSc Eng
Jagoda Sendal, MSc
Grzegorz Siess, MSc Eng
Maciej Skrzypek, MSc Eng
Eleonora Skrzypek, MSc Eng
Bronisław Słowiński, Prof. PhD DSc
Michał Spirzewski, MSc Eng.
Paweł Stano, PhD
Elżbieta Strugalska-Gola, PhD
Marcin Szuta, PhD Eng Assoc. Prof.
Anna Wawrzyńczak-Szaban, PhD
Henryk Wojciechowicz, MSc
Andrzej Wojciechowski, PhD
Ewa Kowalik-Pilarska, MSc Eng
Małgorzata Wróblewska, MSc Eng

Ph.D. Students
Artur Miroszewski, MSc
Albin Nilsson, MSc
Jakub Sierchuła, MSc Eng

Administrative staff
Jolanta Przyłuska

EDUCATION AND TRAINING DIVISION

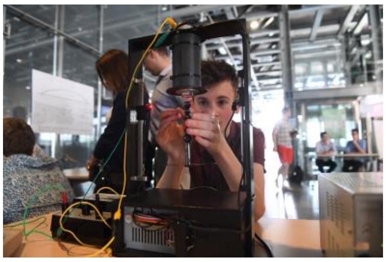
Head of Division: Professor Ludwik Dobrzyński
Phone: +48 22 273 15 70
e-mail: Ludwik.Dobrzynski@ncbj.gov.pl

Education and Training Division employes 7 teachers/scientists, and 4 technical staff. One observes that the Division is steadily, year to year, gaining the popularity. In 2017 it hosted over 8,800 visitors. On the average, we are working with groups consisteing of about 30 persons, and typical time dedicated to such a group is 3 hours. For most of the groups, the most attractive place at NCBJ is experimental reactor MARIA, so it is not strange that we do our best to satisfy such needs. However, our Division guides visitors also to other attractive research laboratories at NCBJ, not speaking about our own, very unique Laboratory of Atomic and Nuclear Physics for Schools. We also strenthened the collaboartion with Visiatom, France, by visiting this center and starting talks about future common projects.

As usual, our main activity has been focused on education of high-schoolstudents from all over Poland. However many university students and persons (including foreigners) from the broadly understood society has bee visiting the Division. Several courses on radiological protection were also organised. Our employees was very active during the Science Picnic and the Science Festival, inWarsaw and other towns. Also, some new educational tools to be used next year were proposed and technical preparation started.

A monograph “Outline of Nucleonics”, prepared by our employees, has been published by PWN – the most prominent editor of scientific books in Poland.

.The Division organised (in collaboration with the Institute of Physics and the Polish Academy of Sciences) the annual 13th high-school student competition “The Paths of Physics”. It is always amazing to see how young pupils see physics, its beauty and importance in everyday life. The contest was organized under auspices of the Minister of National education, and the Minister of Higher Education and Science, and supported by Marshal of Mazovian District.



Director of the Division, prof. L. Dobrzyński, was a member of the Polish Delegation to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Ludwik Dobrzyński

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Konsekwencje zdrowotne awarii w Czarnobylu i Fukushimie
L. Dobrzyński
Ochrona Radiologiczna w Weterynarii (Poland, Łomża, 2016-04-24 - 2016-04-25)

Myths and Reality of the Impact of Ionizing Radoation on Living Organisms
L. Dobrzyński,
3rd Central & European Nuclear Power Congress 2016 (Poland, Warszawa, 2016-11-28 - 2016-11-29)

Katastrofy w przemyśle jądrowym
L. Dobrzyński,
II Międzynarodowa Konferencja nuklearna (Poland, Poznań, 2016-12-03 - 2016-12-03)

Ionizing radiation: myths and reality
L. Dobrzyński
LowRad2016 (Poland, Warsaw, 2016-12-12 - 2016-12-13)

Oral Presentation

Czy radon powoduje wzrost zachorowań na raka płuc?
L. Dobrzyński, **J. Reszczyńska**, K.W. Fornalski
XVII Zjazd Polskiego Towarzystwa Badań Radiacyjnych (Poland, Siedlce, 2016-09-27 - 2016-09-30)

Modelowanie transformacji komórek nowotworowych poddanych działaniu niskich dawek promieniowania
L. Dobrzyński, K.W. Fornalski, Y. Socol, **J. Reszczyńska**
XVII Zjazd Polskiego Towarzystwa Badań Radiacyjnych (Poland, Siedlce, 2016-09-27 - 2016-09-30)

Lung Cancers and Residential Radon
L. Dobrzyński, **J. Reszczyńska**, K.W. Fornalski
LowRad2016 (Poland, Warszawa, 2016-12-12 - 2016-12-13)

Low Dose Radiation Response: Modeling of Irradiated Cell Transformation
J. Reszczyńska, **L. Dobrzyński**, K.W. Fornalski, Y. Socol:
LowRad2016 (Poland, Warszawa, 2016-12-12 - 2016-12-13)

Are Kaons Poissonian?
M. Kirejczyk
The Third Strangeness Workshop Spring 2016 (Poland, Warszawa, 2016-04-22 - 2016-04-23)

DIDACTIC ACTIVITY

Ł. Adamowski - Lectures for visitors in NCBJ Department of Education and Training.

Ł. Adamowski - Preparing and conducting practical laboratory exercises for Jednostka Wojskowa Komandosów.

Ł. Adamowski - Preparing and conducting practical laboratory exercises for Military University of Technology.

K. Deja - Laboratory classes for the Military Technical Academy

K. Deja - Laboratory classes for the Volunteer Fire Brigade from Krokowa

K. Deja - Teaching classes and laboratory for groups of junior high, high school and student.

E. Droste - Participation in educational programs for pupils, students and other persons , visiting our Department.

M. Kirejczyk - Delivering lectures on "Physical basics of radioprotection", "Basics of accelerator physics" and "Biological effects of ionising radiation" to the workers of NCBJ (A, B and AA category)

M. Kirejczyk - Lectures for pupils, students and other visitors of NCBJ

M. Kirejczyk - Overseeing of lab practice of pupils and students visiting teaching laboratory at NCBJ

M. Kirejczyk - Support in the scientific overseeing of Joanna Reszczyńska, MSc

A. Skwarek - Conducting practical laboratory exercises for Krokowa Volunteer Fire Department

A. Skwarek - Conducting practical laboratory exercises for Military Technical Academy

A. Skwarek - Lectures for visitors to NCBJ

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

L. Dobrzyński
Session chairman on LowRad2016 in Warsaw, Poland
Adviser of the Polish Delegation to UNSCEAR, alternate of the delegate of Polish delegation since 2011

M. Kirejczyk
Member of Organizing Committee on The Third Strangeness Workshop Spring 2016 in Warszawa, Poland

Ludwik Dobrzyński, Professor
Ewa Droste, MSc (2/5)
Łukasz Adamowski, MSc Eng
Marek Matych
Grażyna Swiboda, MSc
Anna Rędaszek, MSc
Gabryela Kosicka
Marek Kirejczyk, PhD
Maja Marcinkowska-Sanner, MSc
Martyna Gąsowska, MSc
Katarzyna Deja, PhD
Artur Skwarek, MSc
Joanna Reszczyńska MSc, PhD student

RADIOISOTOPE CENTRE POLATOM

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The Radioisotope Centre POLATOM is a self-contained unit of the National Centre for Nuclear Research engaged in scientific research and development in the field of the use of radioisotopes in nuclear medicine, industry and science and the production of radiopharmaceuticals and radioactive sources.

The history of POLATOM's operations dates back to the 1950s. Then, in 1957, at the then Institute of Nuclear Research in Świerk, near Warsaw, Ewa, the first research reactor in Poland was commissioned. This was the beginning of the country's activities related to the development of methods for obtaining isotopes and radioactive preparations. Further opportunities for development came in 1974, with the commissioning of Maria, another research reactor with which POLATOM's activities have been inextricably connected until today.

Currently, POLATOM combines basic scientific statutory objectives and successful commercialisation of its own potential and research achievements. In the scientific arena, it is a leading centre in Poland conducting interdisciplinary research in the production of radioactive preparations. The main areas of POLATOM's research activities include nuclear chemistry, radiochemistry, the physical chemistry of radioactive elements, analytical chemistry, biochemistry and the metrology of ionising radiation. POLATOM carries out intensive scientific cooperation in Poland and abroad, taking part in international projects and research programmes. The research and development conducted are primarily oriented towards applications and often lead to the implementation of innovative products and technologies. The vast majority of commercial products on offer, including approximately 150 items, are the results of our own work.

In recent years POLATOM has launched the manufacture of several innovative products, among them ^{99m}Tc-Tektrotyd - a radiopharmaceutical kit for diagnostic imaging of tumours expressing somatostatin receptors useful in oncology, Tchimmuna - a radiopharmaceutical kit for detection and localization of inflammatory lesions or ItraPol (^{90}Y) and LutaPol (^{177}Lu) as radiopharmaceutical precursors for radiolabelling of peptides and other biomolecules for cancer therapy.

POLATOM is a world famous supplier of high quality radiopharmaceuticals and diagnostic kits for nuclear medicine and an important manufacturer of radiochemical products for customers all over the world. Its products are exported to more than 80 countries.

POLATOM is Poland's only producer of radioactive preparations and radiopharmaceuticals. The current POLATOM commercial package includes

- A wide range of scintigraphic kits for ^{99m}Tc labelling for the examination of organs and cancer diagnoses,
- Preparations of radioactive iodine-131 for the diagnosis and treatment of thyroid diseases,
- Preparations for the palliative treatment of bone metastases,
- Radionuclide ^{99}Mo/^{99m}Tc generator,
- Precursors for the preparation of therapeutic radiopharmaceuticals,
- Industrial sealed sources,
- Radioactive standard solutions,
- Radiochemical reagents,
- A wide range of special customised radioactive preparations,
- Accessories for nuclear medicine units,
- The calibration and servicing of dose calibrators,
- The installation and maintenance of isotopic equipment,
- The handling and transportation of radioactive materials.

POLATOM's activities in all areas meet European and international standards; with regard to its quality-assurance system, POLATOM holds the PN-EN/ISO 9001:2015 Certificate of Compliance and with regard to trading of dual use items and technology the Internal Control System Certificate. Its standard of radiopharmaceutical production is confirmed by the GMP Certificate and qualifications in the area of the ionising radiation metrology laboratory are confirmed by the Accreditation Certificate of Calibration Laboratory on compliance with the PN-EN/ISO 17025:2005.

The Radioisotope Center POLATOM is currently implementing the CERAD project (Center of Design and Synthesis of Radiopharmaceuticals for Molecular Targeting) from the Polish Roadmap of Research Infrastructures. The goal of the project is to improve and expand the research infrastructure located at NCBJ for research programme oriented towards the design and pre-clinical evaluation of new drugs carrying a radioactive probe (radiopharmaceuticals).

Dariusz Socha

REPORTS

Validation of radionuclide purity measurements in a HPGe spectrometric system with Ortec GEM20P4 detector.
Z. Tymiński, ... , **P. Saganowski**, **T. Dziel**, **E. Kołakowska**, **A. Listkowska**, **E. Lech**, **D. Cacko**, **A. Jęczmieniowski**, **T. Ziemek**, **R. Broda**, ... et al.
NCBJ RC POLATOM (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Preparation of ^{57}Co sources for Mössbauer Spectroscopy
M. Żółtowska, **I. Cieszykowska**, **T. Janiak**, **T. Barcikowski**
International Symposium on Magnetism and Magnetic Materials 2017 The Korean Magnetics Society (Korea, Gyeongju, 2017-11-29 - 2017-12-01)

^{177}Lu labelled antibodies and other developments
R. Mikołajczak
World Rhenium Congress. World Theranostics Academy. (India, Coimbatore, 2017-08-13 - 2017-08-16)

Radiofarmaceutyki, zastosowanie izotopów promieniotwórczych w medycynie
R. Mikołajczak
44 Zjazd Fizyków Polskich (Poland, Wrocław, 2017-09-10 - 2017-06-15)

Radionuclides and Radiopharmaceuticals - Current Developments at Polatom
R. Mikołajczak
Mini-Symposium on Chemistry and Biochemistry of Medical Imaging (Hungary, Debrecen, 2017-09-08 - 2017-09-08)

From radionuclides to radiopharmaceuticals - the overview of research programs carried out at Radioisotope Centre POLATOM
R. Mikołajczak
1st Joint CNRS/PAN Workshop (France, Gif-sur-Yvette, 2017-12-11 - 2017-12-12)

Oral Presentation

Theranostic management of medullary thyroid cancer (MTC) with (^{111}In/^{177}Lu) CP04: how close are we to a clinical solution?
A. Hubalewska-Dydejczyk, P. Erba, C. Decristoforo, K. Zaletel, **R. Mikołajczak**, H. Maecke, Th. Maina-Nock, M. Konijnenberg, P. Kolenc-Peitl, M. Trofimiuk-Müldner, E. Przybylik-Mazurek, I. Virgolini, **D. Pawlak**, M. DeJong, A.C. Froberg, Ch. Rangger, G. Goebel, L. Scarpa, K. Skórkiewicz, L. Lezaic, **P. Garnuszek**, A. Sowa-Staszczak, B.A. Nock, D. Bergant, S. Rep, B. Glowa
19th European Congress of Endocrinology, ECE 2017 (Portugal, Lisbon, 2017-05-20 - 2017-05-23)

Bilateral comparison of C-14 activity measurements at the NCBJ RC POLATOM and the ENEA-INMRI
T. Ziemek, M. Capogni, **R. Broda**, P. DeFelice, **T. Dziel**, **A. Listkowska**
International Conference on Advances in Liquid Scintillation Spectrometry (Denmark, Copenhagen, 2017-05-01 - 2017-05-05)
J. Radioanal. Nucl. Chem. Vol. 314 (2017) 721-725

Comparison of I-131 activity measurements at the NCBJ RC POLATOM and the ENEA-INMRI linked to the BIPM SIR system
T. Ziemek, M. Capogni, G. Ratel, **R. Broda**, **T. Dziel**, A. Fazio, **A. Listkowska**
ICRM-2017, International Conference on Radionuclide Metrology (Argentina, Buenos Aires, 2017-05-15 - 2017-05-18)
Appl. Radiat. Isot. Vol. 134 (2018) 380-384

Nowości wspomagające diagnostykę raka prostaty
R. Mikołajczak
V Konferencja Naukowo-Szkoleniowa Diagnostyka i Terapia Izotopowa w Onkologii (Poland, Szklarska Poręba, 2017-10-13 - 2017-10-15)

An influence of the TDCR system settings on the radionuclides standardization
T. Ziemek, **A. Jęczmieniowski**, **R. Broda**, **E. Lech**, **A. Listkowska**
International Conference on Advances in Liquid Scintillation Spectrometry (Denmark, Copenhagen, 2017-05-01 - 2017-05-05)

Results of the CCRI(II)-S12.H-3 supplementary comparison: Comparison of methods for the calculation of the activity and standard uncertainty of a tritiated-water source measured using the LSC-TDCR method
P. Cassette, T. Altzitzoglou, A. Antohe, M. Rossi, A. Arinc, M. Capogni, R. Galea, A. Gudelis, K. Kossert, K.B. Lee, J. Liang, Y. Nedjadi, P.O. Verdecia, T. Shilnikova, W. Wyngaard, **T. Ziemek**, B. Zimmerman
ICRM-2017, International Conference on Radionuclide Metrology (Argentina, Buenos Aires, 2017-05-15 - 2017-05-18)
Appl. Radiat. Isot. Vol. 134 (2018) 257-262

An analysis of the ESIR exercise performed at BIPM. A tentative proposal for the ESIR system organization.
R. Broda, G. Ratel, **T. Ziemek**
CCRI(II) Key Comparison Working Group meeting (France, Sevres, 2017-11-20 - 2017-11-21)

Study of properties of copper nitride layers obtained by pulsed magnetron sputtering
K. Nowakowska-Langier, S. Okrasa, R. Chodun, **G. Strzelecki**, **K. Król**, R. Minikayev, K. Zdunek,
10-th Symposium on Vacuum based Science and Technology (Poland, Kołobrzeg, 2017-11-27 - 2017-11-30)

First biosafety, biodistribution and dosimetry study of the gastrin analogue ^{111}In-CP04 in medullary thyroid cancer. Phase I clinical trial, GRANT-T-MTC
M. Konijnenberg, P.A. Erba, **R. Mikołajczak**, C. Decristoforo, H. Maecke, T. Maina-Nock, K. Zaletel, P. Kolenc-Peitl, I. Virgolini, E. Przybylik-Mazurek, C. Rangger, M. Trofimiuk-Muldner, K. Skorkiewicz, L. Ležaić, L. Scarpa, G. DiSanto, A. Sowa-Staszczak, M. DeJong, L. Froberg, **P. Garnuszek**, **D. Pawlak**, G. Göbel, B. Nock, D. Bergant, A. Hubalewska-Dydejczyk
Annual Congress of the European Association of Nuclear Medicine (Austria, Wienna, 2017-10-21 - 2017-10-25)

Results of an international comparison of activity measurements of ^{68}Ge
J.T. Cessna, R. Fitzgerald, B.E. Zimmerman, L. Laureano-Pérez, D.E. Bergeron, F. VanWyngaardt, M. Smith, T. Jackson, B. Howe, C.J. DaSilva, A. Iwahara, P.A.L. DaCruz, M. Zhang, H. Liu, J. Liang, C. Fréchou, C. Bobin, P. Cassette, K. Kossert, O. Nähle, J. Marganiec-Gałązka, L. Joseph, A. Ravindra, D.N. Kulkarni, A. Yunoki, Y. Sato, K.B. Lee, J.M. Lee, Agung, **T. Dziel**, **A. Listkowska**, **Z. Tymiński**, M. Sahagia, A. Antohe, M.-R. Ioan, A. Luca, M. Krivosek, J. Ometakova, A. Javornik, M. Zalesakova, E. García-TorañoMartinez, M. Roteta, M. Mejuto, Y. Nedjadi, F. Juget, M.-C. Yuan, C.Y. Yeh, E. Yeltepe, A. Dirican, J. Keightley, A. Pearce
ICRM-2017, International Conference on Radionuclide Metrology (Argentina, Buenos Aires, 2017-05-15 - 2017-05-18)
Appl. Radiat. Isot. Vol. 134 (2018) 385-390

New Possibilities for Imaging of Advanced Medullary Thyroid Cancer - a Challenge for Targeted Therapy
A. Hubalewska-Dydejczyk, K. Zaletel, P. Erba, C. Decristoforo, **R. Mikołajczak**, H. Maecke, P. Kolenc-Peitl, T. Maina-Nock, E. Przybylik-Mazurek, I. Virgollini, B. Nock, **P. Garnuszek**, M. Konijnenberg, **D. Pawlak**, G. Goebel, M. DeJong, L. Froberg, Ch. Rangger, M. Trofimiuk-Muldner, A. Sowa-Staszczak, K. Skorkiewicz, B. Glowa, B. Solnica, D. Fedak, P. Gawenda, D. Bergant, L. Lezaic, L. Scarpa, A. Jabrocka-Hybel, S. Rep
40th Annual Meeting of the European Thyroid Association (Serbia, Belgrade, 2017-09-09 - 2017-09-12)

Poster

Kit for preparation of ^{68}Ga-PSMA-11. The critical parameters during labelling and storage of the kit.
M. Maurin, **M. Radzik**, **P. Garnuszek**, **D. Pawlak**, **U. Karczmarczyk**, **R. Mikołajczak**
22nd International Symposium on Radiopharmaceutical Sciences (Germany, Dresden, 2017-05-14 - 2017-05-19)

In vitro evaluation of biological activity of radiopharmaceuticals
M. Orzełowska, **W. Wojdowska**, **U. Karczmarczyk**, **M. Maurin**, **P. Garnuszek**
Young Research Fellow Meeting 2017 (France, Châtenay-Malabry, 2017-02-08 - 2017-02-10)

Influence of DOTA chelators on radioimmunotherapy of ^{177}Lu-DOTA-Rituximab
U. Karczmarczyk, **W. Wojdowska**, L. Balog, **R. Mikołajczak**, **M. Maurin**, Z. Pöstényi, V. Kovács-Haász, A. Polyák, **P. Garnuszek**
22nd International Symposium on Radiopharmaceutical Sciences (Germany, Dresden, 2017-05-14 - 2017-05-19)

In vitro evaluation of of biological activity of radiopharmaceuticals
M. Orzełowska, **W. Wojdowska**, **U. Karczmarczyk**, **M. Maurin**, **P. Garnuszek**
1st Joint CNRS/PAN Workshop (France, Gif-sur-Yvette, 2017-12-11 - 2017-12-12)

Comparative studies of stability and receptor affinity of radiolabeled DOTA-TATE and HA-DOTA-TATE peptides
M. Radzik, **M. Maurin**, **A. Sawicka**, **P. Garnuszek**
Young Research Fellow Meeting 2017 (France, Châtenay-Malabry, 2017-02-08 - 2017-02-10)

Impurities in Tc-99m radiopharmaceutical solution obtained from Mo-100 in cyclotron
Z. Tymiński, **P. Saganowski**, **E. Kołakowska**, **A. Listkowska**, **T. Ziemek**, **E. Lech**, **D. Cacko**, **A. Jęczmieniowski**, **R. Broda**, **T. Dziel**
ICRM-2017, International Conference on Radionuclide Metrology (Argentina, Buenos Aires, 2017-05-15 - 2017-05-18)

Physico-chemical and biological evaluation of radiopharmaceuticals
M. Maurin, **P. Garnuszek**
1st Joint CNRS/PAN Workshop (France, Gif-sur-Yvette, 2017-12-11 - 2017-12-12)

^{47}Sc and ^{67}Cu as novel radioisotopes for radiopharmaceuticals
I. Cieszykowska, **D. Pawlak**, **W. Wojdowska**, **M. Żółtowska**, **T. Janiak**, **J.L. Parus**, **R. Mikołajczak**
NUTECH-2017 Conference on Development and Application of Nuclear Technologies (Poland, Kraków , 2017-09-10 - 2017-09-13)

Chemical Reference Substance (CRS) in process development of active pharmaceutical ingredients (API) used in the kits for radiopharmaceuticals preparations
K. Jerzyk, **D. Kłudkiewicz**, **J. Pijarowska-Kruszyna**, **P. Garnuszek**
Young Research Fellow Meeting 2017 (France, Châtenay-Malabry, 2017-02-08 - 2017-02-10)

Exendin-4 labeled with ^{99m}Tc, ^{111}In and ^{68}Ga - a comparative pharmacokinetics evaluation
B. Janota, **U. Karczmarczyk**, **E. Laszuk**, **P. Garnuszek**, **R. Mikołajczak**
Annual Congress of the European Association of Nuclear Medicine (Austria, Wienna, 2017-10-21 - 2017-10-25)

The method of production and quality control of volume multigamma sources with different matrices
A. Listkowska, **E. Lech**, **P. Saganowski**, **Z. Tymiński**, **D. Cacko**, **T. Ziemek**, **E. Kołakowska**, **R. Broda**, **A. Jęczmieniowski**, **T. Dziel**
ICRM-2017, International Conference on Radionuclide Metrology (Argentina, Buenos Aires, 2017-05-15 - 2017-05-18)

Production of Sc radionuclides by separation of scandium from calcium target using UTEVA resin
D. Pawlak, **W. Wojdowska**, **J.L. Parus**, **M. Żółtowska**, **P. Garnuszek**, **R. Mikołajczak**
Annual Congress of the European Association of Nuclear Medicine (Austria, Wienna, 2017-10-21 - 2017-10-25)

^{26}Al Isotope in Pułtusk Meteorite Fragments
Z. Tymiński, A. Krzesińska, **A. Burakowska**, M. Stępisiewicz, **K. Tymińska**, **T. Dziel**, **P. Saganowski**, **E. Kołakowska**, **T. Ziemek**, A. Olech, M. Wiśniewski, P. Żołądek
80th Annual Meeting of The Meteoritical Society (USA, Santa Fe, 2017-07-23 - 2017-07-28)

Somatostatine receptor PET/CT imaging in patients with sarcoidosis - preliminary report
J. Kunikowska, **D. Pawlak**, L. Królicki;
Annual Congress of the European Association of Nuclear Medicine (Austria, Wienna, 2017-10-21 - 2017-10-25)

Heavy metal content in cellulosic environmental enrichment for laboratory animals.
P. Ochniewicz, N. Ławreniuk, **U. Karczmarczyk**, **Ł. Sochaczewski**, **E. Laszuk**, **W. Wojdowska**, **P. Garnuszek**
V Konferencja z cyklu „Zwierzęta w badaniach naukowych (Poland, Warszawa, 2017-09-11 - 2017-09-13)

Separation of scandium from macro amounts of calcium target. Preliminary results.
W. Wojdowska, **D. Pawlak**, **J.L. Parus**, **M. Żółtowska**, **P. Garnuszek**, **R. Mikołajczak**
22nd International Symposium on Radiopharmaceutical Sciences (Germany, Dresden, 2017-05-14 - 2017-05-19)

Influence of mandatory legal provisions on the reliability of biodistribution research results based on the radiopharmaceuticals quality control.
U. Karczmarczyk, **P. Ochniewicz**, **E. Laszuk**, **W. Wojdowska**, **P. Garnuszek**
V Konferencja z cyklu „Zwierzęta w badaniach naukowych (Poland, Warszawa, 2017-09-11 - 2017-09-13)

LECTURES, COURSES AND EXTERNAL SEMINARS

Sharing & developing protocols to further minimize radioactive gaseous releases to the environment in the manufacture of medical radioisotopes, as good manufacturing practice in Poland[b]
M. Konior
Vienna, International Atomic Energy Agency, 2017-03-07

[b)] in English

INTERNAL SEMINARS

Inventions vs patent research[a]
K. Małetka
Otwock-Świerk, RC POLATOM, 2017-01-27

Irradiation Mo and evaluation of the impurity profile Mo-99[a]
M. Konior
Otwock, NCNR RC POLATOM, 2017-02-10

[a)] in Polish

DIDACTIC ACTIVITY

P. Garnuszek - Lecture for students of Pharmacy at WUM "Radiopharmaceuticals"

P. Garnuszek - Lectures for students of specialisation in the field of Radiopharmacy - Module IX - Future developments in Radiopharmacy. Faculty of Pharmacy,Medical University in Lodz

U. Karczmarczyk - Care of the apprentice Ms. Natalia Ławreniuk, 5th year student of Medical Analyze, Medical University of Bialystok. The practice was to familiarize with the work in the Laboratory of Preclinical Research.Practice period 3 months.

U. Karczmarczyk - Mr. Michał Żukiem from the 5th year of the Faculty of Chemistry, Warsaw University of Technology was under my chargé. The scope of the 5-month practice included the labeling of hyaluronic nanoparticles with lutetium-177 and yttrium-90.

U. Karczmarczyk - Scientific supervisor of Michał Tomasz Żuka's MA thesis (confidential) defended at BioMedical Engineering Laboratory, Faculty of Chemical and Process Engineering, Warsaw University of Technology.

U. Karczmarczyk - The work of Mr Karola Osica entitled "I-131 release test of gelatine capsules depending on the characteristics of the medicinal product." defended at the Military University of Technology, Faculty of Advanced Technologies and Chemisrty.

M. Korytkowski - Training for OR POLATOM's customers: Quality control and radiolabeling scintigraphic kits.

R. Mikołajczak - Medical University in Lodz, Specialisation in Radiopharmacy, lectures for Block IX and X, Trends in Radiopharmacy

R. Mikołajczak - Supervisor of specialization in Radiopharmacy

P. Ochniewicz - Supervising of monthly internship of first year student of Faculty of Animal Science, Warsaw University of Life Science.

D. Pawlak - Supervisor of specialization in Radiopharmacy

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

K. Bańko
Member of Europen Association of Nuclear Medicine
Member of Reactor and Isotope Group of Association of Imaging Producers & Equipment Suppliers
Member of Polish Society of Nuclear Medicine.

R. Broda
Delegate. Consultative Committee for Ionizing Radiation (CCRI). Section II - Measurement of radionuclides.
Member. Polish Physical Society.
Delegate member. International Committee for Radionuclide Metrology (ICRM).
Elected member. Committee for Metrology and Scientific Instrumentations of Polish Academy of Science
Member of EURAMET Task Group "Environment"
The member of the Doctoral Studies Committee, National Centre for Nuclear Research
Central Office of Measures

I. Chwalińska
Europen Association of Nuclear Medicine, member

I. Cieszykowska
Member of Scientific Council of NCBJ

T. Dziel
Radiation Protection Inspectors Association
Polish Society of Medical Physics

P. Garnuszek
European Association of Nuclear Medicine (EANM)
Polish Society of Nuclear Medicine
Expert of Group 14 (radioactive compounds) European Pharmacopoeia,European Directorate for the Quality of Medicines & HealthCare, Council of Europe
Member of the Expert Group for elaboration of the programme of specialisation in the field of Radiopharmacy
Chairman of the Expert Group giving opinions of institutions applaying for acreditation to conduct trainings in

the field of Radiopharmacy
Member of Scientific Council of National Centre for Nuclear Research

E. Iller
European Association of Nuclear Medicine (EANM)
National Centre for Nuclear Research
Institute of Nuclear Chemistry and Technology
Institute of Nuclear Chemistry and Technology

B. Janota
member, Polish Association of Nuclear Medicine

U. Karczmarczyk
Member, Polish Society of Nuclear Medicine
member, National Centre for Nuclear Research

M. Konior
Polish Chemical Society

E. Laszuk
Polish Laboratory Animal Science Association

M. Maurin
Member, Polish Society of Nuclear Medicine

R. Mikołajczak
Session chairman on 22nd International Symposium on Radiopharmaceutical Sciences in Dresden, Germany
Session chairman on V Konferencja Naukowo-Szkoleniowa Diagnostyka i Terapia Izotopowa w Onkologii in Szklarska Poręba, Poland
European Association of Nuclear Medicine, EANM
Polish Society of Nuclear Medicine, PTMN, member of the General Board of PTMN since 2006
Society of Radiopharmaceutical Sciences
European Society for Molecular Imaging, ESMI
member of Expert Group evaluating units applying for the rights to run specialization program in Radiopharmacy, called by The Medical Centre of Postgraduate Education
Society of Nuclear Medicine and Molecular Imaging
PRP Group (Radiopharmaceutical Precursors) of European Pharmacopoeia, EDQM, European Directorate for the Quality of Medicines
member of Expert Team for preparation of specialization program in the area of radiophamacy
member of Expert Team for evaluation of institutions applying for accrediation to carry out specialized teaching and training program in the field of radiopharmacy
member of Expert Team for preparation of specialization program in the field of nuclear medicine
Nuclear Medicine Review , member of Editorial Board, Grupa Via Medica
National Centre for Nuclear Research

D. Pawlak
European Association of Nuclear Medicine
Society of Radiopharmaceutical Sciences
Polish Society of Nuclear Medicine
World Association of Radiopharmaceutical and Molecular Therapy

Z. Tymiński
Polish Fireball Network
Meteoritical Society

W. Wojdowska
Polish Society of Nuclear Medicine
European Association of Nuclear Medicine

Grażyna Birnbaum, MSc
Ryszard Broda, Assoc. Prof.
Ewa Byszewska-Szpocińska, PhD
Izabela Cieszykowska, PhD
Tomasz Dziel, MSc
Anna Filiks, MSc
Marzena Fiszer, MSc
Piotr Garnuszek, Professor
Edward Iller, Professor
Tomasz Janiak, MSc Eng
Barbara Janota, MSc
Antoni Jaroń, MSc Eng
Katarzyna Jeżyk, MSc Eng
Urszula Karczmarczyk, PhD Eng
Dominik Daniel Kłudkiewicz, MSc
Marcin, Konior, PhD
Agnieszka, Korsak, MSc
Michał Korytkowski, MSc
Ewa Laszuk, MSc
Robert Lipka, PhD
Anna Listkowska, MSc
Krzysztof Małetka, PhD Eng
Alina Markiewicz, MSc
Michał Maurin, MSc Eng
Renata Mikołajczak, Assoc. Prof. Eng
Piotr Ochniewicz, MSc
Monika Orzełowska, MSc
Leon Parus, Professor
Dariusz Pawlak, MSc Eng
Justyna Pijarowska-Kruszyna, MSc Eng
Marcinb Radzik, MSc
Małgorzata Romańczuk, MSc
Iwona Sasinowska, MSc
Agnieszka Sawicka, PhD
Arkadiusz Sikora, PhD
Dariusz Socha, PhD Eng
Joanna Staniszewska, PhD
Tomasz Szyszko vel Chorąży, PhD Eng
Zbigniew Tymiński, MSc
Wioletta Wojdowska, PhD Eng
Małgorzata Żółtowska, MSc

REPORTS ON RESEARCH

Astrophysics, Cosmic Rays & Elementary Particle Physics, Observational Astronomy

NCBJ participation in searches for gravitational waves by the LIGO and VIRGO detectors

A. Królak (Leader of the POLGRAW group)
National Centre for Nuclear Research, Warsaw, Poland
Institute of Mathematics PAS, Warsaw, Poland

The two detectors of the Laser Interferometer Gravitational wave Observatory – LIGO located in the USA began their first observational run (O1) in September 2015. The run lasted till January 2016. On 14th of September 2015 LIGO made the first direct detection of gravitational waves. The waves originated form the merger of a binary black hole system. This landmark event is referred to as GW150914 [1]. For this discovery the three founders of the LIGO project – R. Wiess, K. Thorne and B. Barish were awarded the Nobel prize in physics for 2017 [8]. One more event was recorded by LIGO during the O1 run in December 2015. In November 2016 the LIGO observatory started its second observational run (O2). After an upgrade and commissioning Virgo joined this observational run on August 1st 2017. Virgo is a laser interferometric detector located near Pisa in Italy. The LIGO-Virgo observatories made joint observations in August 2017 until 25th of August when the three detectors were shut down for further upgrades.

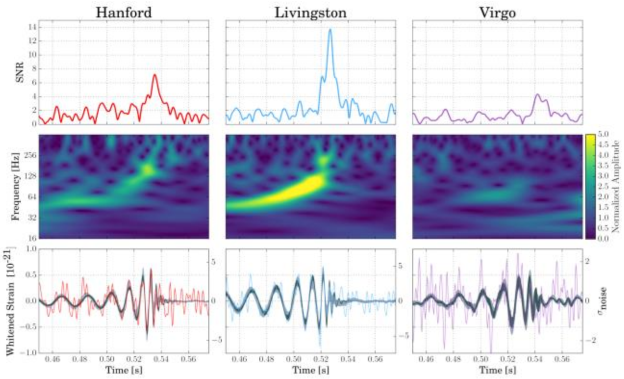

Fig. 1. The top panel shows the signal-to-noise ratio (SNR) as a function of time in the LIGO and VIRGO detectors. The peak indicates the presence of a gravitational wave signal. The middle panel shows the time-frequency plot where the brightness of a given pixel indicates the strength of the signal at the given frequency at the given time. Characteristics of an inspiral signal where the amplitude and frequency of the signal increase with time can be clearly spotted in the plots. The lower panel shows detector output superimposed with the best fit signal inferred from matched filtering and unmodelled search. Image by the LIGO Collaboration.

Two events of joint detection of gravitational waves were registered by LIGO and VIRGO during the joint run. The first event was registered on August 14th [3] and the second was recorded on August 17th [4]. The first gravitational wave signal was due to the merger of two black holes. This event is referred to as GW170814 and was quite similar to the first detection (see Fig. 1). The second gravitational wave signal was produced by the merger of two neutron stars and is referred to as GW170817. The second event was quite remarkable since it was accompanied by an optical counterpart, a gamma ray burst or GRB which was recorded by the Fermi and INTEGRAL satellites merely 1.7 second after the gravitational wave event. The source was promptly identified and is located in the galaxy NGC 4993 (see Fig. 2). This followed a worldwide campaign of electromagnetic follow-up across the entire spectrum by various ground based and space based facilities. This marks the beginning of the era of so called multi-messenger astronomy. A seminal result was a measurement of the value of the Hubble constant from an estimation of the parameters of the GW170817 signal in data from all three detectors which was consistent both with the standard candle and CMB measurements [6].

During the O2 run the LIGO detectors also observed two more gravitational wave signals from the merger of black holes ([2],[7]). In Figure 3 the masses of all the binary systems from which gravitational wave signals have been detected by the LIGO and Virgo interferometers are depicted.

The POLGRAW group is a member of the Virgo project (Virgo Collaboration). Four employees of NCBJ – prof. Andrzej Królak (group leader), dr Orest Dorosh, eng. Adam Kutynia, dr Adam Zadrożny are mebers of POLGRAW.

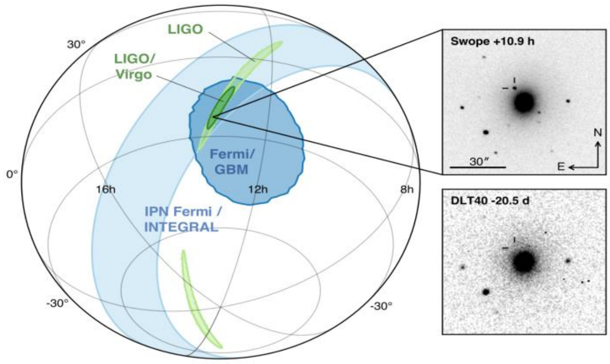

Fig. 2. The localization of the gravitational wave source based on LIGO and LIGO-VIRGO is shown in light green and green coloured regions respectively. The location of the short-duration GRB by Fermi-INTEGRAL is shown in pale blue and blue respectively. Based on the overlap of these and the distance of the source estimated from LIGO, 49 galaxies were identified in the catalogue of the local galaxies. An optical transient was found by the Swope telescope in Chile in the galaxy NGC 4993 which is absent in the image taken 20 days before the merger. Images are taken from Ref. [5].

Three of them are co-authors of all the discovery papers of the LIGO-Virgo collaboration as they contribute most of their professional time to these projects. Prof. A. Królak is currently a member of the Board of the Virgo project which together with the Board of the LIGO project supervises the projects and publications of all observational results. Prof. A. Królak made a number of contributionsw to the development of the algorithms to search for gravitational wave signals from merging binaries. Dr A. Zadrożny led the joint observation of the Polish Pi of the Sky telescope with the LIGO and Virgo detectors [5]. Dr O. Dorosh is participating in searches for gravitational waves from rotating neutron stars in LIGO and Virgo data [9] and Eng. A. Kutynia is contributing to the development of electronic systems for the Virgo detector.

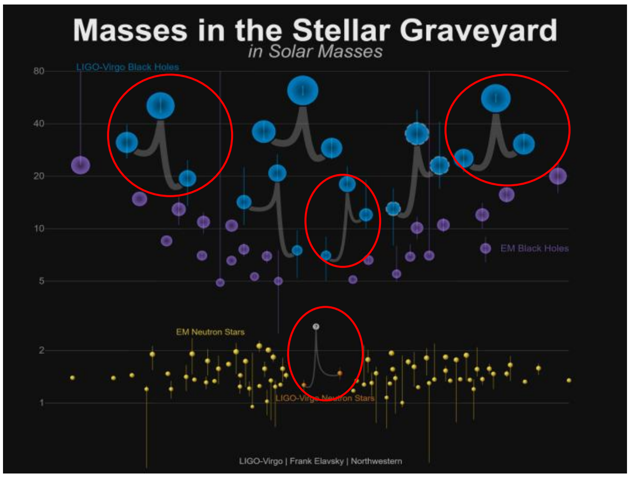

Fig. 3. Masses of Neutron Stars and Black Holes. The masses of stellar remnants are measured in many different ways. This graphic shows the masses for black holes detected through electromagnetic observations (purple); the black holes measured by gravitational-wave observations (blue); neutron stars measured with electromagnetic observations (yellow); and the masses of the neutron stars that merged in the event called GW170817, which were detected in gravitational waves (orange). The remnant of GW170817 is unclassified, and labelled as a question mark. Image by LIGO-Virgo/Frank Elavsky/NorthwesternUniversity.

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Search for unusual sources in the WISE all-sky survey

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In recent years astronomy has experienced an enormous increase in the amount and complexity of information collected by ground-based and space-borne missions. Observational data are now reaching volumes measured in petabytes, and contain billions of objects of astrophysical interest with hundreds of associated parameters obtained for each source. For these reasons we must ask ourselves the question how to use efficiently the gathered information to extract scientific knowledge hiding in the heap of data. We are not only interested in gathering statistically larger samples of already known sources, but we also should be ready to find unusual or even new kinds of astronomical phenomena. However, identifying such unexpected sources is a challenging task: we can either assume that the unusual objects will display traits not encountered before, which will make them stand out from among the known sources, or their presence will be hidden from us within the bulk of ordinary objects as they could mimic their behavior.

Observations performed by the **Wide-field Infrared Sky Explorer** satellite (WISE, [1]) currently provide the deepest publicly available all-sky survey, containing over 740,000,000 sources detected in four infrared pass-bands covering a wavelength range of 3.6-22 µm. All this makes the WISE dataset the perfect playground to search for abnormally behaving sources. In our work [2], to tackle the task of novel source detection, we used Machine Learning (ML) techniques which belong to the family of artificial intelligence methods. They are designed to learn how to recognize given patterns within the data and classify them into several desired categories (like stars, galaxies and quasars). The learning examples must be provided by the supervisor and must be described by discriminating properties of such objects. The algorithm used in our work is called **One-Class Support Vector Machines** (OCSVM), and is a modification of the classical SVM algorithm [3] used for source classification. Instead of separating the data into several specific categories, as in the standard SVM, here we create one class of *known* objects: spectroscopically confirmed stars, galaxies and quasars, detected by the Sloan Digital Sky Survey (an optical sky survey covering ~20% of the sky but providing class information about each contained object). Then, the OCSVM algorithm learns how those *known* sources behave in the WISE parameter space (e.g. a high-dimensional colour space) and through this process it can pinpoint all those sources which do not display already recognized patterns, and mark them as *novel.*

The application of the OCSVM algorithm to the WISE data resulted in identifying a population of ~40,000 highly obscured extragalactic sources, out of which 90% remain un? detected at any other wavelength. This means that either these sources are very distant or that they contain larger than expected amounts of hot dust (characteristic for obscured active galactic nuclei or other sources of policyclic aromatic hydrocarbon lines).

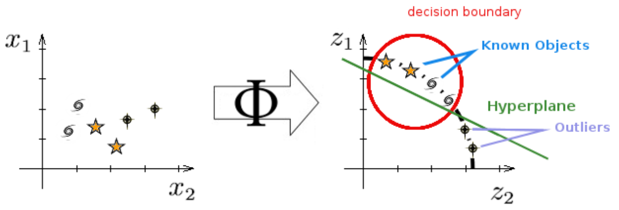

Fig. 1. Schematic representation of the OCSVM algorithm.

A pilot survey to obtain spectroscopic observations of the objects in question has been recently approved by the European Southern Observatory. With precise measurements of infra-red spectra we will further investigate the potential reasons for their peculiar behaviour.

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Hard photoproduction of a diphoton with a large invariant mass

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Understanding the structure of nucleons in terms of the elementary building blocks of quantum chromodynamics, i.e. quarks and gluons, is among the most important questions of high energy physics. During the last twenty years we have witnessed very active progress in this field due to the discovery of Generalized Parton Distributions (GPDs) and their role in the description of exclusive processes. Two features of GPDs attracted most attention: their relation to the total angular momentum of partons allowing a splution of the proton spin puzzle, and information about the position of quarks and gluons in the plane transverse to the direction of the proton's motion, allowing for the so-called "hadron tomography".

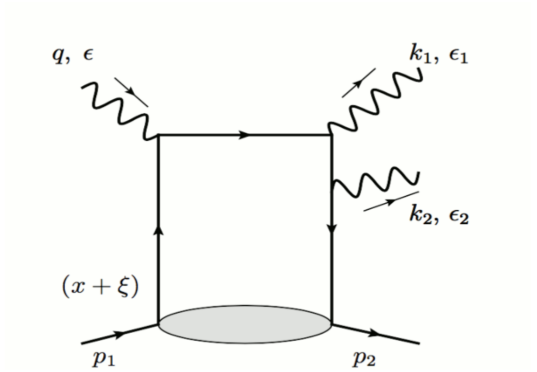

Fig. 1. Feynman diagram contributing to the amplitude of the process $\gamma + N \rightarrow \gamma + \gamma + N$

Recently, we have proposed an interesting new process allowing for GPD extraction, i.e. exclusive photoproduction of a photon pair with large invariant mass:

$$\gamma + \mathrm{N} \rightarrow \gamma + \gamma + \mathrm{N}$$

We have shown that this reaction can be studied at intense photon beam facilities such as JLab (Fig.2), with cross sections of a similar order to already planned experiments. Also, the use of linearly polarized real photons opens the way to large asymmetries (Fig. 3), which could be a useful tool for future GPD extraction programmes.

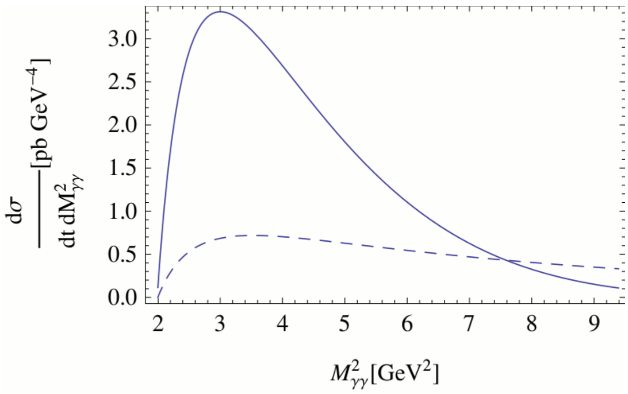

Fig. 2. The dependence of the unpolarized differential cross section on the invariant mass of the photon pair, for a typical JLab (solid) and COMPASS (dashed) kinematics.

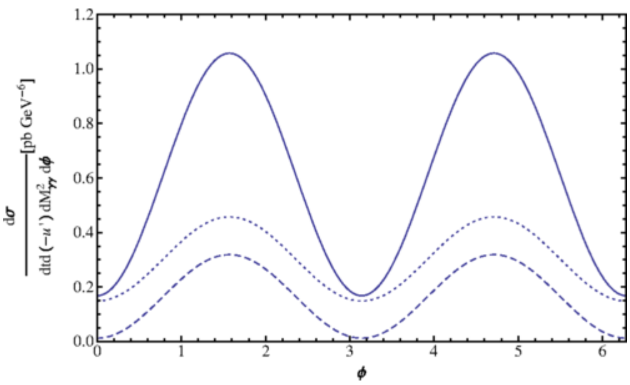

Fig. 3. The azimuthal dependence of the differential cross section for 3 different kinematical points relevant for JLab. ϕ is the angle between the initial photon polarization and the momentum of one of the final photons in the transverse plane.

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First measurement of the Sivers asymmetry for gluons using SIDIS data

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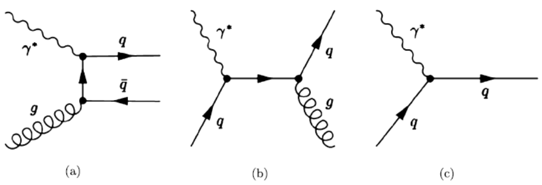
An interesting and recently examined property of the quark distribution in the nucleon polarized transversely to its momentum, is that it is not left-right symmetric with respect to the plane defined by the direction of the nucleon spin and momentum. This asymmetry of the distribution is called the Sivers asymmetry. Such an asymmetry was first observed by the HERMES collaboration and then by the COMPASS collaboration and the Hall A experiment at JLB. From combined analyses of these data non-zero Sivers functions of opposite sign were found for *u* and *d* quarks (for reviews see Refs.[1-3]). These results imply transverse motion of quarks in the nucleon, although presently the connection between the Sivers function and the parton orbital momentum in the nucleon can only be described in a model-dependent way.

At this point, the question arises whether or not the gluon distribution in a transversely polarized nucleon is also left-right asymmetric, which may indicate non-zero orbital angular momentum of gluons in the nucleon. An estimate of the gluon orbital momentum in the nucleon is still a missing piece in "the nucleon spin puzzle", i.e. in understanding how the nucleon spin equal to ½ is composed of spins and the orbital angular momenta of quarks and gluons.

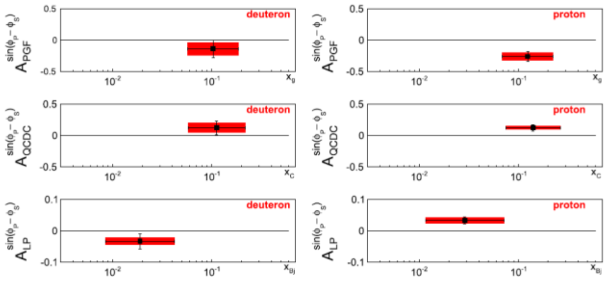
Here, we report on the first measurement of the Sivers asymmetry for gluons from semi-inclusive deep inelastic scattering (SIDIS). The result was obtained using COMPASS data collected by scattering a 160 GeV/c muon beam off transversely polarized deuterons and protons. The Feynman diagrams of the main processes that contribute to SIDIS are depicted in the sketch below.



In the sketch the two subleading processes, photon-gluon fusion (PGF) and QCD Compton are represented by (a) and (b), respectively, while (c) denotes the leading order process (LP) in the total cross section. In order to extract the gluon Sivers asymmetry, two-hadron events produced in muon-nucleon scattering, $\mu + N \rightarrow \mu' + 2h + X$, were selected. The requirement that the two hadrons, resulting from the fragmentation of final-state partons, should have large transverse momenta with respect to the virtual photon, ensures that the contribution of the two subleading processes is enhanced.

The measured azimuthal distribution as a function of the so called Sivers angle was then fitted as a superposition of the three individual azimuthal distributions, each corresponding to one of the three aforementioned processes. The values of the three asymmetries were the parameters of the fit, while the probabilities R_{PGF}, R_{QCDC}, R_{LP} for each of the three processes to contribute to a given event were obtained on an event-by-event basis using a Neural Network, previously trained on a Monte Carlo (MC). The MC events were generated using LEPTO with special tuning of parameters describing fragmentation into hadrons with high transverse momenta. The response of the experimental set-up to the generated events was simulated and the simulated detector responses were further processed in the same way as for the experimental data. The agreement between the data and MC was good for all distributions of kinematic variables that were used in the NN training procedure. A special method of weighting events entering the asymmetry fit was applied in order to minimize statistical uncertainties. The details of the analysis can be found in Refs. [4, 5].

The results for the gluon Sivers asymmetry for the deuteron and the proton are shown in the top panels of the figure below, together with asymmetries of two other subprocesses, i.e. QCD Compton (middle) and leading process (bottom).



Here the error bars indicate the statistical errors and the red bands the systematic uncertainties. The results for the deuteron is consistent within its large uncertainties with both zero and the more precise result for the proton. The two results are expected to be consistent, as presumably the transverse motion of gluons is the same in the neutron and the proton. Combining the proton and deuteron results, the measured effect is negative, $A_{\mathrm{PGF}}^{\mathrm{Siv}} = -0.23 \pm 0.08(\mathrm{stat}) \pm 0.05(\mathrm{syst})$, which is away from zero by more than two standard deviations of the quadratically combined uncertainties. This result appears particularly interesting in view of the gluon contribution to the proton spin, as a non-zero gluon Sivers asymmetry is a signature of gluon orbital momentum [6].

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The CMS experiment in 2017. Observation of Higgs boson decays into a pair of τ leptons and the results of the search for long-lived charged particles

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During 2017 the LHC accelerator run at 13 TeV centre of mass energy with bunch crossing frequency reaching 40 MHz. The maximum instantaneous luminosity obtained was equal to $1.8*10^{34}$ cm^{-2} s^{-1} and its integrated value was 42 events/femtobarn.

The Warsaw CMS group consisting of about 20 members from NCBJ, Warsaw University and Warsaw Technical University, continued work on improving one of muon triggering subsystems – the so-called OMTF (Overlap Muon Track Finder) operating in the barrel-endcap region.

The data analysis was devoted to two subjects: Higgs boson decays into a pair of τ leptons and the search for long-lived charged particles.

Within the first subject work concentrated on the optimization of τ lepton identification and reconstruction and Higgs boson observation. The τ lepton reconstruction is not an easy task, as part of the lepton energy is carried away by neutrinos, always present in its decay.

Such an analysis is crucial since in this decay channel the Higgs couples directly to fermions and therefore serves as an important test of theoretical predictions, see Fig. 1. The current significance of the measurement is about 5 σ and the ratio of observed signal strength to the theoretical prediction is 1.09±0.27.

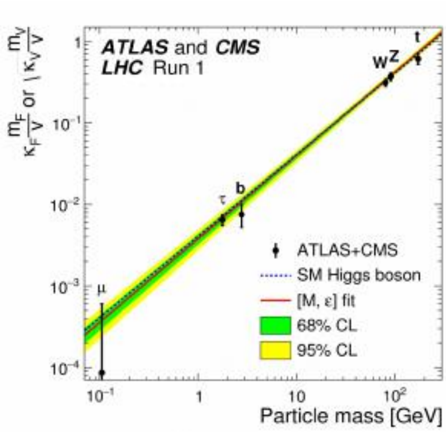

Fig. 1. The observed Higgs coupling as a function of decay product mass. Excellent agreement between data and predictions is seen.

For a long time the Warsaw group has participated in the search for heavy charged particles with long decay time. Such objects are proposed in various extensions of the Standard Model. The detectors used for the muon reconstruction have the ability to register particles traveling with velocity lower than that of light and are used in this analysis. The information on the energy loss in the central silicon detector and track velocity (based on the Time Of Flight from the muon system) are used here. Presently no signal has been found and we are able to obtain only limits on the production cross section for such objects as a function of their mass. The results are shown in Fig. 2.

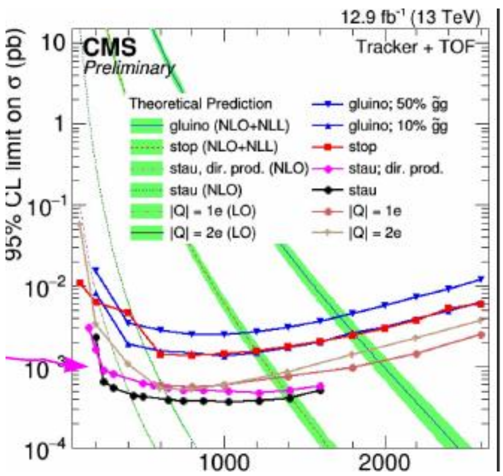

Fig. 2. Predictions from various theoretical models of cross section for the production of heavy stable charged particles and the experimental limits as a function of their mass .

Study of CP and CPT symmetry breaking and exotic baryons in the LHCb experiment

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The phenomenon of charge-parity symmetry breaking is one of the least-known parts of the Standard Model, which is one of the most important theories of modern physics, describing the effects of elementary particles. Processes breaking CP symmetry are responsible for the difference between matter and antimatter. It is estimated that the known size of CP symmetry breaking in the Standard Model is a facto9r of a billion too small to explain the amount of matter remaining in the Universe. Therefore, the search for new sources of CP symmetry is being carried out by the Warsaw LHCb Group. One such test is the measurement of the phase ϕ_s, which is very small in the Standard Model, on the order of two degrees and is predicted with very high accuracy. If a difference is found between the predicted and the measured value it will be an indirect indication of the existence of signals from New Physics, i.e. phenomena outside the Standard Model. The phase ϕ_s is tested in decays, $B^0_s \rightarrow J/\psi\ \phi$, when the meson J/ψ decays into two electrons, and the ϕ meson decays into two kaons.

CP symmetry breaking is also being searched for in the decays of charged baryons $\Xi^+_c \rightarrow pK^-\pi^{\square}$. Multi-body decays are realized via resonant states, which are visible in a Dalitz plot. Studies of these decays give hope for observation of local CP asymmetries around the resonance states, because the strong phase, which is a necessary condition to observe CP violation, changes the sign at transitions through the maximum mass of the resonant state. This approach can help in observing a small CP asymmetry that is below 10^{-3} in the charm particles.

The Warsaw LHCb group is also looking for sources of CPT symmetry breaking. These tests are carried out in the decays of neutral mesons $D^0 \rightarrow K^-\pi^+$. The estimated sensitivity of the measurement is of the order of 10^{-14}, and this is an order of magnitude better than previous studies carried out in other experiments. The exotic states $Z^+(4050)$ and $Z^+(4250)$ are also studiedd in $B^+ \rightarrow \chi_{c1}\pi^+\pi^-K^+$ decays. It is estimated that the branching ratio for these decays will be measured with an accuracy of 10% better than is currently known. Ω_c resonance states are also searched for. In the LHCb experiment, five narrow states of Ω_c decaying into $\Xi^+_cK^-$ were observed. Three of these states are well understood, while the interpretation of the other two is not unambiguous. One of the theoretical models predicts that they may be pentaquarks. The analysis should help to solve this puzzle.

The RASNIK optical system was also developed, which is used to measure the exact position of the LHCb Outer Tracker detector. The position measurement is carried out with an accuracy of 1 µm. In 2017, two papers concerning the RASNIK system were published. One appeared in the form of a public note with the number LHCb-PUB-2017-020, and the second appeared in JINST 12 (2017) P11016.

In addition to physical issues, the Warsaw LHCb Group is also involved in the development of the DIRAC system and in providing computing resources under the so-called Tier2 for the LHCb experiment. In 2017, a workshop devoted to the DIRAC system was organized, attended by over 30 experts from various experiments.

Studies of neutrino physics in the T2K experiment

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The Warsaw Neutrino Group (official website http://neutrino.ncbj.gov.pl/) has participated in the T2K experiment from its beginning. T2K is a long baseline neutrino oscillation experiment dedicated to the precise measurement of neutrino oscillation parameters [1]. It is the second accelerator based experiment located in Japan after the successful operation of the K2K experiment. Gaining on the experience of its predecessor, which produced the first confirmed neutrino oscillation under controlled beam conditions, the T2K experiment was able to obtain valuable physics results such as a study of muon neutrino disappearance and a precise measurement of the θ_{23} mixing angle [2], the first observation of the appearance oscillation of $\nu_\mu \rightarrow \nu_e$ and a measurement of the θ_{13} mixing angle consistent with reactor measurements [3]. Nowadays the main effort is focused on the search for CP violation in the neutrino sector. T2K probes the already mentioned $\nu_\mu \rightarrow \nu_e$ oscillation mode and compares it to similar oscillations in an antineutrino beam, looking for $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$ transitions. Recently, a sample of $1.49 \cdot 10^{21}$ POT of neutrino data were analyzed together with antineutrino data with accumulated statistics of $0.76 \cdot 10^{21}$ POT [4]. The predicted numbers of ν_e events are 61.5 and 62.0 for CP conserving values of δ_{CP} of 0π and 1π, respectively, while the prediction for the number of ν_e induced events for $\delta_{CP} = -0.5\pi$ is 73.5. This may be compared with the measured value of 74 charged current quasi-elastic events induced by ν_e oscillated from ν_μ. On the other hand, when the antineutrino beam results are taken into account, the predicted numbers of events are 9.04 and 8.93 for δ_{CP} of 0π and 1π, respectively. In the case of the CP violating value of $\delta_{CP} = -0.5\pi$ the number of expected events is 7.93 which may be compared to 7 observed $\overline{\nu}_e$ events for the antineutrino beam. To conclude, more ν_e appearance and less $\overline{\nu}_e$ appearance events are observed than expected for δ_{CP} values of 0π and 1π. These results can be expressed as anallowed region of oscillation parameters δ_{CP} and $\sin^2\theta_{13}$ as shown in Fig.1.

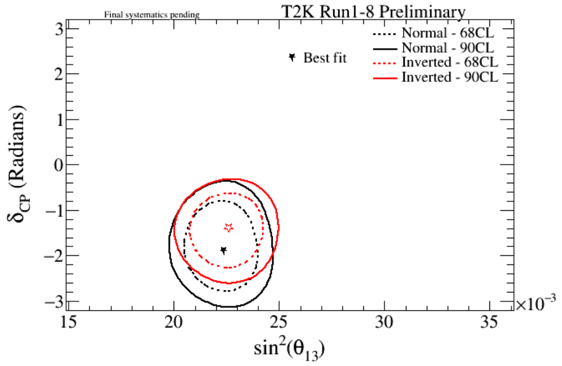

Fig. 1. Allowed region of oscillation parameters derived using T2K and reactor data.

Summarizing, the 95% confidence intervals allow for δ_{CP} between [-2.98, -0.60] rad for Normal Hierarchy and [-1.54, -1.19] rad for Inverted Hierarchy. They exclude the CP conserving values of δ_{CP} at the 2σ level so far.

The effort of our group is focused on activities targeted towards improvement of the measurement of CP violation in T2K.

Although charged current quasi-elastic interactions are dominant for the peak energy of the T2K neutrino beam (about 700 MeV), interactions with pion production start to be important for neutrino interactions above 700 MeV. Understanding their modelling is crucial for precise neutrino oscillation measurements. A model has been developed which consists of resonant pion production and non-resonant background contributions including the interference effect [5]. It agrees well with bubble chamber data, concerning the distributions of pion momenta and the cross sections. It also shows improvement when the T2K neutrino interactions on water with pion production are taken into account. The model has been implemented in the NEUT Monte Carlo generator officially used by T2K.

Analyses targeted towards cross-section measurements are also performed in our group. One of them is a measurement of single pion production in antineutrino data. We are at the level of establishing and improving selection criteria and working on the methodology of the cross-section measurement.

The other analysis is concentrated on a search for the neutrino interactions in correlated pairs of nucleons. The analysis uses two neutrino event generators to be compared with neutrino data, the official NEUT and the NuWro, developed by theorists from Wrocław University. Both generators have implemented interactions on a correlated pair of nucleons but they treat differently the other aspects e.g. modelling of low momentum protons which are important for the measured processes since events with at least two protons leaving the nucleus after the interaction are the signature of processes searched for. Here two methods of analysis are used. One is concentrated on kinematic variables while the other looks at the energy deposited near the neutrino interaction vertex to find out what's happening with low momentum protons, too short to be reconstructed as tracks in the detector.

Our group is additionallyinvolved in work dedicated to the upgrade of the T2K near detector. The main goal of this work is to ensure better angular acceptance for events with muons at high angles which are not probed by the current setup. The new scintillator targets are also supposed to provide better reconstruction for low momentum protons.

The upcoming years will bring not only an upgrade of the near detector, but also improvement of the far detector, Super-Kamiokande, which will be doped with Gadolinium allowing for detection of neutrons. An upgrade of the power of the primary proton beam is also expected that will provide more intense neutrino beam, so I encourage all readers to stay tuned for upcoming results of the T2K experiment.

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Dark matter searches and neutrino astrophysics at Super-Kamiokande and KM3NeT

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Astrophysical activities within the neutrino group revolve around the experimental programme at the Super-Kamiokande (Kamioka Mine, Japan) and KM3NeT (the Mediterranean Sea) neutrino telescopes. The first detector has been in operation since 1996, the latter is currently under construction in two locations, near the coast of Capo Passero (Sicily) and Toulon in France.

This part of the NCBJ neutrino group is led by dr Piotr Mijakowski and in 2017 consisted of 2 PhD students: Katarzyna Frankiewicz, Piotr Kalaczyński and one M.Sc. student, Jerzy Mańczak, from the Department of Physics (UW). Employment of a new post-doc is foreseen in 2018.

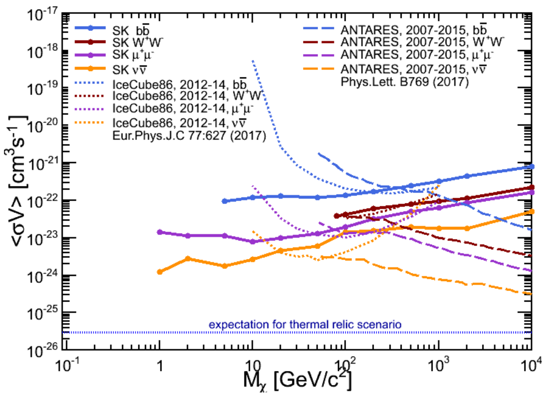

Fig. 1. 90% confidence level upper limits on the DM self-annihilation cross section <σV> (region above the lines is excluded). The NFW halo profile for the dark matter distribution in the Galaxy is assumed.

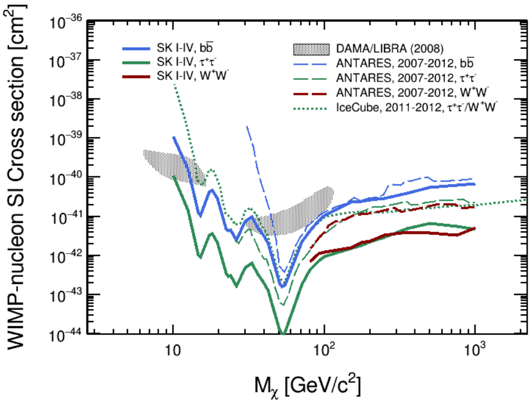

Fig. 2. 90% confidence level upper limit on the spin independent WIMP-nucleon cross section assuming WIMP annihilation in the Earth's core and equilibrium state between the capture and annihilation rate of the relic particles.

In Super-Kamiokande (SK) our group is fully responsible for the indirect searches for dark matter (DM) particles. We are looking for a potential excess of DM-induced neutrinos related to the Centre of the Galaxy or coming from the Earth's core with respect to the background level of atmospheric neutrinos. Our results yield the most stringent limits to date for the DM particle masses below ~100 GeV among all neutrino experiments (see Fig. 1 and 2). In 2017 these results were presented by us at major international conferences [1].

The KM3NeT detector is currently in its construction phase. We are responsible for simulations of cosmic ray muon and neutrino production by cosmic ray showers. This work aims at background estimation in the search for neutrinos of cosmic origin. Moreover, in 2018 we plan to start a sensitivity analysis for DM-induced neutrinos at KM3NeT.

We are involved in educational outreach and science popularization. Katarzyna Frankiewicz is one the leaders of the international programme oriented at the development of portable and cheap cosmic ray muon detectors for schools and education (http://cosmicwatch.lns.mit.edu/). These activities are led in collaboration with MIT and in 2017 were highlighted in several science magazines and news media [2].

Our activities are supported by the National Science Centre, Poland: (1) SONATA-BIS grant 2015/18/E/ST2/00758 (P.Mijakowski, 2016-2020) and (2) PRELUDIUM grant 2015/17/N/ST2/04064 (K.Frankiewicz, 2016-2018); (3) the European Union H2020 RISE-GA641540-SKPLUS grant (P.Mijakowski, 2014-2018) and the corresponding supplement: (4) Premia na Horyzont provided by the Ministry of Science and Higher Education (328780/PnH/2016).

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The VIMOS Public Extragalactic Redshift Survey (VIPERS): the universe at z~1

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The VIMOS Public Extragalactic Redshift Survey (VIPERS) released its final set of nearly 90,000 galaxy redshifts in November 2016. In 2017, the release was followed by a series of scientific papers that covered the subject range from the evolution of galaxies to the growth rate of cosmological structures over the past 8 Gyr. These results were derived from a 3D a map of galaxies with precisely measured properties, which is unprecedented in its combination of a large volume and detailed sampling of the Universe as it was between 5 and 8 Gyrs ago.

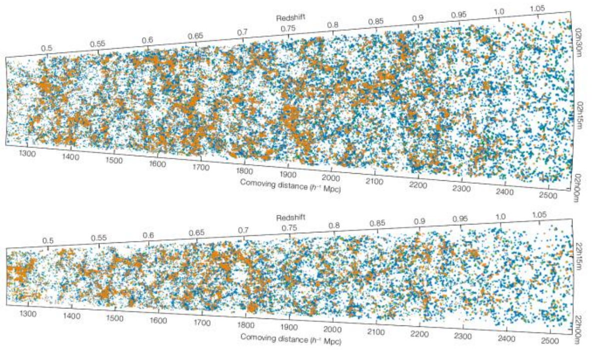

Fig. 1: The detailed picture of the large-scale structure of the Universe at 0.45 < z < 1.1, delivered by the VIPERS survey over the W1 and W4 CFHTLS fields (upper and lower panesl, respectively). The colours of the dots reflect the intrinsic U-B colour of each galaxy (red passive galaxies marked as red dots, blue, star-forming galaxies represented by blue dots). From [1].

VIPERS has opened the way to accurate statistical studies of galaxy population when the Universe was about half its currentage. Data obtained by VIPERS were used to refine the scaling relationships that were only approximately known until now.

The description of the physical properties of the VIPERS galaxies was significantly enhanced by the availability of a series of ancillary data. These data were combined to perform reliable spectral energy distribution fits and, in turn, estimate luminosities, colours, stellar masses and other physical properties.

All these quantities, together with spectral information (like the amplitude of the 4000 Å break) and structural parameters from the morphological analysis [2], allowed to study the evolution of classic relationships observed in our Local Universe to be studied. We have found that 6 Gyr ago red passive galaxies were already at place. Our analysis confirmed the downsizing scenario, as the redshift of formation increases with stellar mass, and massive galaxies have older stellar populations than less massive galaxies, with metallicity variations with stellar mass providing only a relatively minor perturbation to this overall evolutionary picture [3]. Haines et al. [4] combined VIPERS and Local Universe surveys to trace the evolution of the bimodality of galaxy properties, producing a clear and coherent picture and pointing to a sudden change of properties of a fraction of massive blue galaxies ~6 Gyrs ago. This was confirmed by measurements of the ratio of star forming vs red passive galaxies as a function of local density [5], and the evolution of the number density of massive passive galaxies and their stellar population ages. Thanks to VIPERS data we were able to provide a novel scenario of how the current population of massive passive galaxies could have been formed [6].

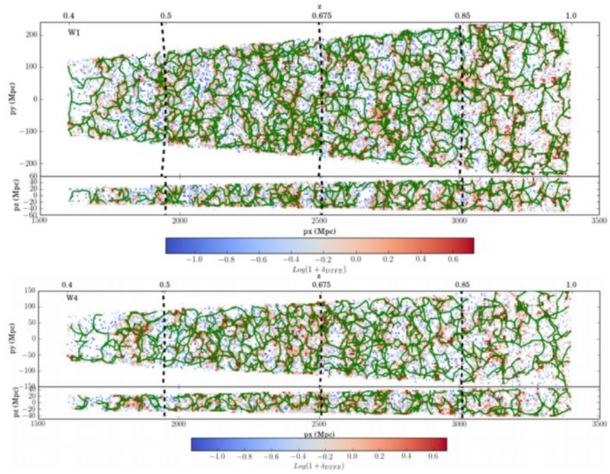

Fig. 2: Projected distribution of the filaments reconstructed in the VIPERS W1 (upper panel) and W4 cones (lower panel). The density of galaxies is represented by colours: the most dense areas: clusters and superclusters are marked in red; green lines represent filaments. [7]

Properties of dark energy were probed with measurements of the growth of structure [7, 8, 9, 10, 11]. The "standard" λ Cold Dark Mater cosmological model was found to describe the best our Universe, but the uncertainties of the measurements remained too large to choose only one model of dark energy. However, the cosmological constant remained the favourite.

The VIPERS data, obtained within the framework of an ESO Large Programme over the equivalent of just under 55 nights at the Very Large Telescope, will remain the largest legacy of the VIMOS spectrograph and its still unsurpassed ability to reach target densities close to 10 000 spectra per square degree. The wealth of the derived VIPERS data is still under analysis.

Fig. 3: Members of the VIPERS team during the last meeting in Cernobbio, Italy). NCNR was represented by Anna Durkalec, Katarzyna Małek (first and second from the left, middle row, respectively) and Agnieszka Pollo (second from the right, upper row).

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Ultra High Energy Cosmic Ray measurements using EUSO detectors

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Cosmic Rays (CR) are very energetic particles coming from outer space. The final proof of extraterrestial radiation was provided by Victor Hess balloon flight in 1912 [1]. High energy CR particles, mostly protons, bombarding Earth's atmosphere induce secondary particle cascades called Extensive Air Showers (EAS). The highest energies observed in CR exceed 10^{20} eV per primary particle. The origin of most CR is unknown. Arrival directions of ultra high energy cosmic rays (UHECR; E>10^{19}eV) might point to CR sources. Observations of UHECR are difficult due the decrease of flux with energy, and above 10^{19}eV it is about 1 particle per 100 km^2 per year. This fact forces the bulding of very large detector arrays like the Telescope Array in the USA or the Pierre Auger Observatory (PAO) in Argentina (TA) where particle detectors are spread over an area of about 3000 km^2 for observations of UHECR. Another method is based on the observation of fluorescense in the atmosphere emitted by N_2 molecules excited by charged particles produced during EAS development. This technique of Earth atmosphere observation from the ground at night allows for estimation of the energies and direction of UHECR particles, but the number of detected particles is still relatively low.

The National Centre for Nuclear Research participates in the **JEM-EUSO Collaboration** [2]. The goal of the **EUSO** (Extreme Universal Space Observatory) detectors is to observe EAS development using the fluorescense method (like PAO or TA), but with a detector in space.

The Ultra fast EUSO detectors with time resolution of 2.5μs based on multianode photomultipliers (MAPMT) allow for observation of fast moving signals like EAS track. The goal is to observe the Earth's atmosphere from above – from stratospheric balloons and the International Space Station. This method increases the effective area of observation to about 300 000 km^2 and in future should allow for detection of about 1000 UHECR events during the 5-year satellite mission.

Fig. 1. EUSO-SPB detector during preparation (Wanaka - New Zeland). Detector mounted in gondola of statospheric balloon provided by NASA observed Earth's atmosphere during 12-days flight for searching of cosmic rays signals [5].

Currently the JEM-EUSO Collaboration is working on a smaller pathfinder and test experiments to confirm and improve the experimental method. NCBJ has participated in the data analysis and construction of all experiments so far, providing high voltage systems for MAPMTs.

The EUSO experimental method was succesfully used in 2014 during the first ballon flight – **EUSO-Balloon** experiment [3], when tracks of laser signals imitating EAS development were registered. On April 24th 2017 a second ballon flight – the **EUSO-SPB** experiment was launched from Wanaka in New Zeland (see Figures). The results of our data analysis from the ground test experiment **EUSO-TA** were presented at an Internatonal CR Conference in 2017 [4]. The JEM-EUSO programme, as a technology of the future, is one of the points on the APPEC road map of European Astroparticle Physics Strategy for the years 2017-2026 [6].

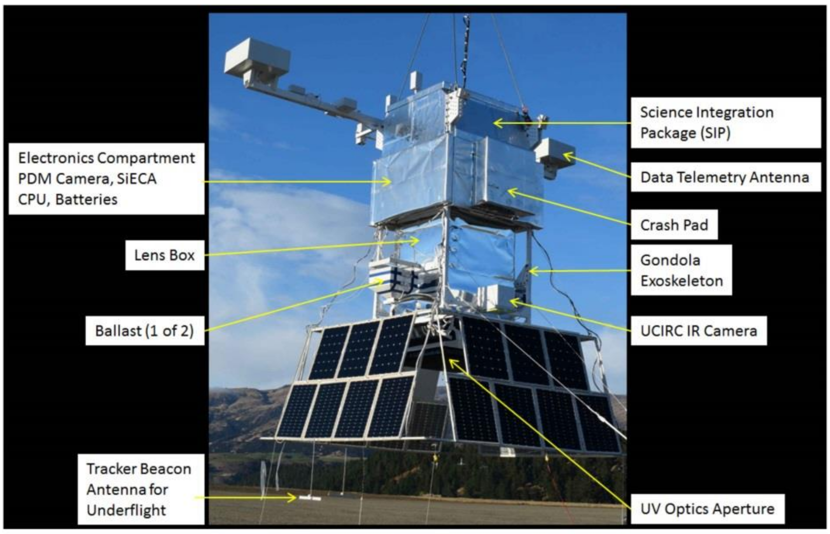

Fig.2.EUSO-SPB experiment.

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Internal clock formulation of quantum mechanics

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Quantum mechanics is based on an external and fixed parameter called time. According to general relativity no such entity exists. Thus, the evolution of gravitational systems is expressed in terms of internal degrees of freedom. In this work we have proposed a reformulation of quantum mechanics in such a way as to remove the absolute time from its formalism and replace it with an arbitrarily chosen internal degree of freedom, the internal clock.

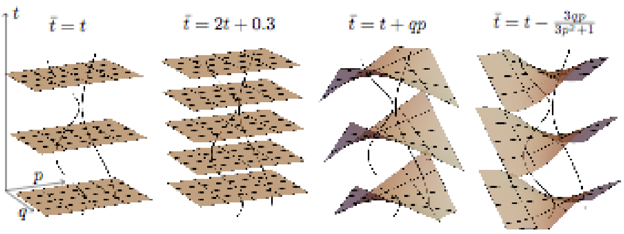

Fig. 1. The two curves (solid and dashed) represent the motion of a particle in a contact manifold (phase space × time manifold). The planes represent constant time surfaces which fix an abstract (from the point of view of classical mechanics) notion of simultaneity between states of a particle belonging to different solutions (represented here by two different curves). The second picture from the left illustrates a time transformation which merely changes time units and the zero-time point. The third and fourth pictures from the left illustrate time transformations which change simultaneity between states of the ``two" particles belonging to different curves.

We arrive at our formulation by first extending the symmetry of the canonical formalism of classical mechanics: canonical transformations are replaced by pseudocanonical transformations which include the former as a normal subgroup and which allow us to switch from one internal clock to another. Next, we lift the extended symmetry to the quantum level. Quantizations of canonical formalisms in all internal clocks satisfy the basic postulate of the new formulation: all Dirac observables are represented by the same quantum operators in a fixed Hilbert space irrespectively of the choice of clock. We then show that the choice of internal clock influences the dynamical properties of quantum states. This is so because dynamical observables are represented by different quantum operators for different internal clocks. The derived nonequivalence of different internal clock frames for a given quantum system is a distinctive and inevitable property of the internal clock formulation of quantum mechanics. Finally, we show that the new formulation contains the ordinary quantum mechanics as a special case. Our result should be useful for the quantization and interpretation of gravitational systems.

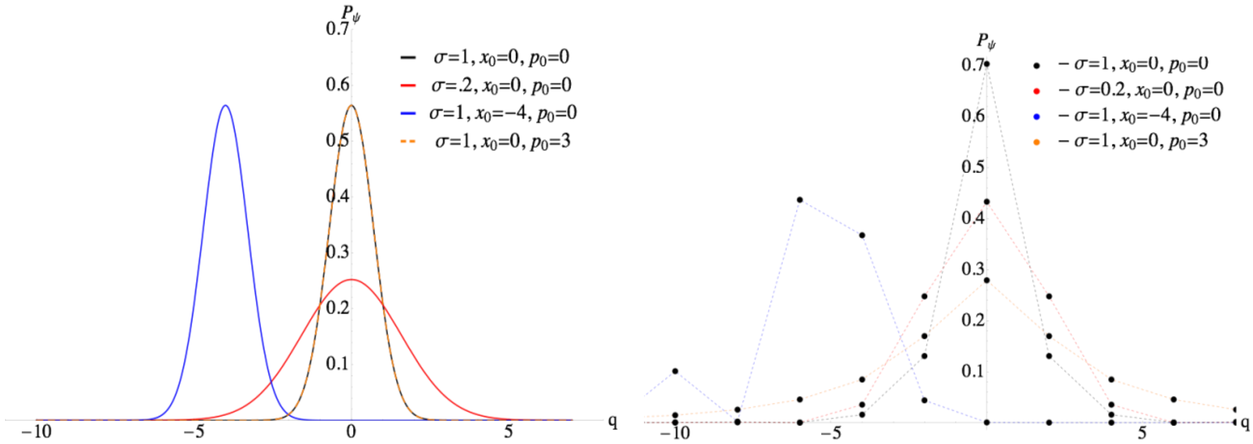

Fig. 2. Probability distribution $P_\psi|\langle q|\psi\rangle|^2$ of position eigenvalues for the Gaussian state $|\psi\rangle$ in the old clock t (upper) and in the new clock $\bar{t} = t + qp$ (lower). Upper: the usual continuous probability distribution. Lower: the probability for specific eigenvalues is marked with dots. The spectrum is discrete.

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What ξ? Cosmological constraints on the non-minimum coupling constant

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The total action integral for the theory under consideration consists of a gravitational part described by the standard Einstein-Hilbert action integral and a matter part composed of two substances. One is in the form of the scalar field non-minimally coupled with gravity

$$S_\phi = -\frac{1}{2}\int d^4x\,\sqrt{-g}\,(\varepsilon\nabla^\alpha\phi\nabla_\alpha\phi + \varepsilon\xi R\phi + 2V(\phi))$$

where the dimensionless constant ξ describes the coupling between gravity R and the scalar field ϕ, and the second substance is ordinary barotropic dust matter. Assuming a spatially flat Friedmann-Robertson-Walker metric and using dynamical systems theory one can reduce the dynamical behaviour of this model to a three-dimensional dynamical system. Additionally, this system is equipped with an invariant manifold corresponding to accelerated expansion of the Universe in the form of the de Sitter state. Exact solutions to the dynamics can easily be found on this invariant manifold. Then, using an invariant a manifold approximation we can integrate an acceleration equation to find modified Friedmann equation describing the background evolution of the Universe.

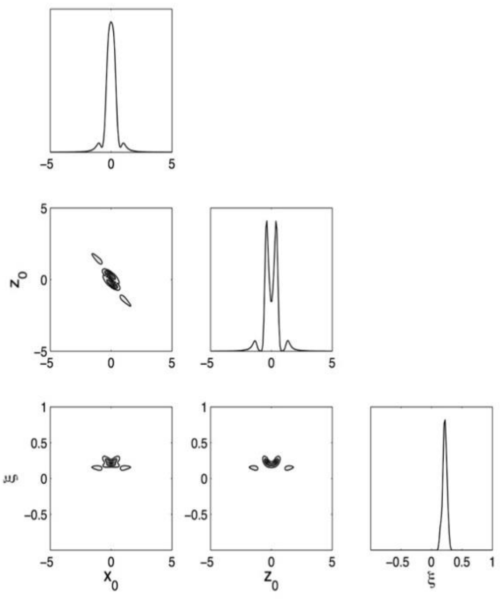

Fig. 1. Posterior constraint for the canonical scalar field with the fixed baryonic matter content and positive constant value of the scalar field potential function. On the one-dimensional plots fully marginalized probabilities for the given variable are presented, while the two-dimensional plots give 68% and 95% confidence intervals of the fully marginalized probabilities.

Using observational data from distant type Ia supernovae, Hubble function H(z) measurements and information coming from the Alcock–Paczyński test we find cosmological constraints on the non-minimum coupling constant ξ between the scalar curvature and the scalar field, see Fig. 1.

The 95% confidence intervals for the non-minimum coupling constant for the presented model $\boldsymbol{\xi} \in (\mathbf{0.1449}; \mathbf{0.2779})$.

Note that the equation of motion for the non-minimally coupled scalar field (the Klein-Gordon equation)

$$\nabla^{\alpha}\nabla_{\alpha}\phi - \xi R \phi = 0,$$

in $\boldsymbol{n} \geq \mathbf{2}$ space-time dimensions can be conformally invariant only if the non-minimaum coupling constant is

$$\xi = \frac{1}{4}\frac{n-2}{n-1},$$

and it suggests a discrete set of theoretically allowed values of the non-minimaum coupling constant imposed by the conformal invariance condition of the scalar field in n ≥ 2 space-time dimensions. We observe that these theoretically motivated values of the non-minimum coupling constant are contained in the intervals obtained using the observational data.

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Renormalization group equations in the limit of large *N*

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We provide a closed analytical form for the gauge contribution to the beta function of a generic Yukawa coupling in the limit of large *N*, where *N* is the number of heavy vector-like fermions charged under an abelian or non-abelian gauge group. To this end, we summed an infinite series of loop diagrams with ever increasing number of vacuum-polarization bubbles. The resummed expression is finite and for the abelian case presents a pole at the same location as for the corresponding gauge beta function.

When applied to new physics scenarios characterized by large Yukawa couplings, the contribution calculated here can cure their pathological

UV behavior and make the couplings asymptotically free. We present an example of this kind in Fig.1, where we show the RG running of the hypercharge and Yukawa couplings for the Standard Model and for an sample model of New Physics in which we assume there exists a new Yukawa coupling between the SM muon, with U(1) charge -1/2, a new inert SU(2) scalar doublet with charge 1/2, and an SU(2)-singlet fermion with U(1) charge -1, all of them color-neutral.

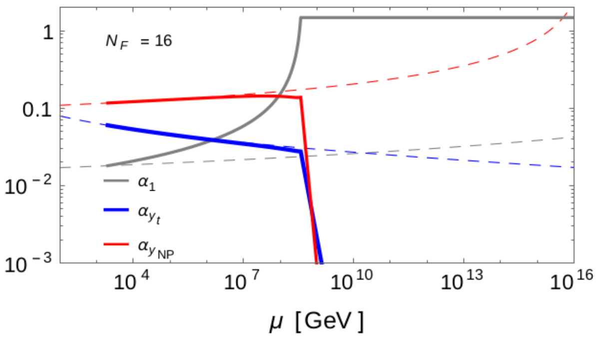

Fig. 1. Modified running of the hypercharge coupling (grey solid), top Yukawa coupling (blue solid), and the Yukawa coupling of a model of new physics defined in the text (red solid) in the presence of N=16 vector-like fermions charged under U(1). The common mass of the vector-like fermions is set at 2 TeV. For each coupling, the corresponding 1-loop running without the large N enhancement is shown with a dashed line of the same color.

This feature turns out to be important in scenarios that aim to explain some of the experimental anomalies observed recently in flavor physics, by means of loop contributions from new scalar and fermion fields. In the most common scenarios large Yukawa couplings are required, which lead to the breaking of perturbativity at energy scales as low as 10-100 TeV. However, when the proper resummation in the limit of large *N* is performed, much larger values of the Yukawa couplings become allowed and the parameter space opens up significantly. This is illustrated in Fig.2.

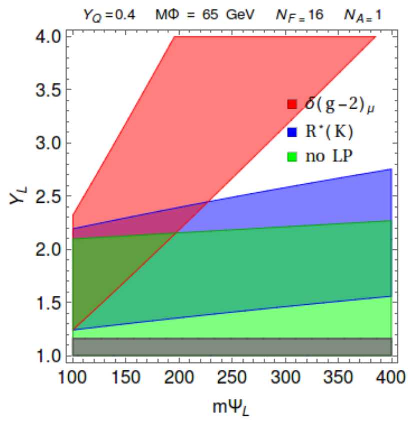

Fig. 2. Parameter space allowed by the measurement of the g-2 anomaly (light red) and the R_K anomaly (light blue). Values of the Yukawa coupling allowed by perturbativity up to the Planck scale are shown in grey for a scenario with no resummation, and in light green for a scenario with resummation in the limit of large N (N=16).

We find it encouraging that already at the level of the pure gauge coupling contributions presented here, the resummation can lead to novel phenomenological applications.

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Nuclear Physics

Direct reactions induced by light nuclei

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The article entitled: "Influence of single-neutron stripping on near-barrier ^{6}He + ^{208}Pb and ^{8}He + ^{208}Pb elastic scattering" by G. Marquínez-Durán *et al.*, Phys. Rev. C **95**, 024602 (2017) was presented as a highlight of the work published during 2017. This study formed part of the doctoral thesis of Dr. G. Marquínez-Durán at the University of Huelva, Spain and describes a comparison of the effects of coupling to the ^{208}Pb(^{6}He,^{5}He)^{209}Pb and ^{208}Pb(^{8}He,^{7}He)^{209}Pb single-neutron transfer reactions on the respective elastic scattering at incident He energies of 22 MeV. The exceptional quality of the ^{8}He + ^{208}Pb elastic scattering data made such a study possible (there are existing data in the literature for the corresponding ^{6}He + ^{208}Pb elastic scattering). Since most of the other conditions governing the reaction are similar for the two He isotopes it was anticipated that the larger spectroscopic factor for the <^{8}He | ^{7}He + n> overlap compared to that for <^{6}He | ^{5}He + n> — it is approximately a factor of two larger — would give rise to a more important coupling effect on the ^{8}He + ^{208}Pb elastic scattering.

This does seem to be the case since the qualitative differences in the shapes of the elastic scattering angular distributions for the two systems (when divided by the Rutherford cross section, see Fig. 1) are linked to the observed differences in the single-neutron transfer coupling effects. However, the calculated cross sections for this reaction are not directly correlated to the difference in spectroscopic factors for the two He isotopes and depend on the choice of distorting potential in the exit channel. Fortunately, the coupling effect is essentially independent of this choice, providing an additional demonstration that the coupling effect of a given channel or set of channels is not always linked to the cross section for populating those channels.

Finally, the contributions of the single-neutron transfer couplings to the effective optical potentials describing the elastic scattering in the two systems (the dynamic polarisation potential or DPP) were obtained via inversion of the scattering matrices obtained from the calculations explicitly including these couplings. It was found that the absorption due to the single-neutron stripping takes place at a larger radius for ^{8}He than for ^{6}He, in contrast to what was found for the total absorption. This is consistent with the dominant contribution to the absorption coming from breakup of the projectile, known to be strong and long-ranged for ^{6}He. The DPP also indicated a significant contribution to the real part of the effective optical potential from the stripping couplings but the data are not sensitive to this, the real potential being somehow "masked" by the strong, long-range absorptive imaginary part.

These data demonstrate that it is feasible to obtain accurate elastic scattering data near the Coulomb barrier with beam intensities as low as 10^{5} pps on target and that such data can reveal significant effects linked to the specific nuclear structure of the projectile.

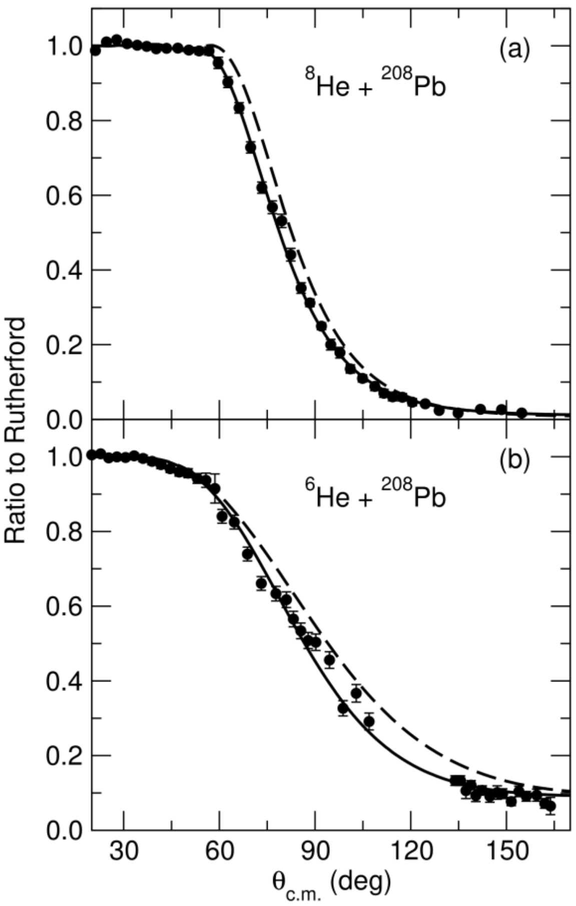

Fig. 1. (a) 22 MeV ^{8}He + ^{208}Pb elastic scattering angular distribution. (b) 22 MeV ^{6}He + ^{208}Pb elastic scattering angular distribution. The solid and dashed curves denote full CRC and no-coupling calculations respectively.

First measurement of the g-factor in a chiral band

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The ^{128}Cs nucleus belongs to a group of nuclei around A≈130 in which the phenomenon of nuclear chirality has been reported through observation of chiral doublet states [1] and the specific selection rules of the gamma transitions between these states[2,3]. The chiral partner bands in ^{128}Cs are described by the coupling of three components: an even-even core with angular momentum **jR** and two odd nucleons in the $\pi h_{11/2} \otimes \nu^{-1} h_{11/2}$ configuration with angular momentum **jp** and **jn** , respectively. The reported observables serve as an indirect sign of a chiral geometry formed in ^{128}Cs nucleus that is the three angular momentum vectors **jp**, **jn**, **jR** span the three dimensional space. However, these indirect observables cannot serve as an ultimate proof for the chiralilty in atomic nuclei, therefore it was necessary to develop a method for the direct measurement of the geometry formed by the three angular momentum vectors. This was a challenging task due to fundamental limitations imposed by the quantum properties of such nuclei.

In the chiral geometry the **jR** , **jp** and **jn** vectors span the three dimensional space and therefore can form either a right- or left-handed reference frame corresponding to left |L> and right-handed |R> intrinsic nuclear states.

This is called spontaneous chiral symmetry breaking in nuclear systems and occurs when an excited nucleus cools down and at some point chooses spontaneously one of the two intrinsic states. The major complication is that the |L> and |R> are not eigenstates of the nuclear system. Tunnelling between |L> and |R> takes place with a period much shorter than the gamma emission times which are equal to the lifetimes of the observed levels. This is why none of the gamma quanta carries information about the handedness of the intrinsic states which seemingly makes the measurement of the geometry formed by the three angular momentum vectors impossible. Indeed, it is not possible to distinguish the |L> and |L> states in a measurement, however the chiral geometry can still be investigated even without making such a distinction. Measurement of the magnetic dipole moment and the resulting g-factor value gives the way out. As presented in Ref. [4] the g-factor value depends on the scalar products of the angular momentum vectors in question. Therefore, the g-factor value strongly depends on the mutual orientation of the three vectors, although it does not distinguish the handedness, as required by the fundamental limitations.

The g-factor of the I=9+ chiral bandhead in ^{128}Cs was the subject of a Time Dependent Perturbed Angular Distribution Method (TDPAD) measurement with an external magnetic field produced by an electromagnet at IPN Orsay. The magnetic field of around 7 kG attainable at the electromagnet was magnified with the help of the GAMIPE reaction chamber of NIPNE (Romania). The ^{128}Cs nucleus was produced in the ^{122}Sn(^{10}B,4n)^{128}Cs fusion-evaporation reaction at 55 MeV beam energy. Single gamma quanta were registered by two LEPS detectors placed at ±45 degrees with respect to the beam axis. Interaction of the external magnetic field and the magnetic moment associated with the nuclear state leads to precession of the nuclear angular momentum vector which is observed by intensity oscillations of the gamma radiation – see Figure 1.

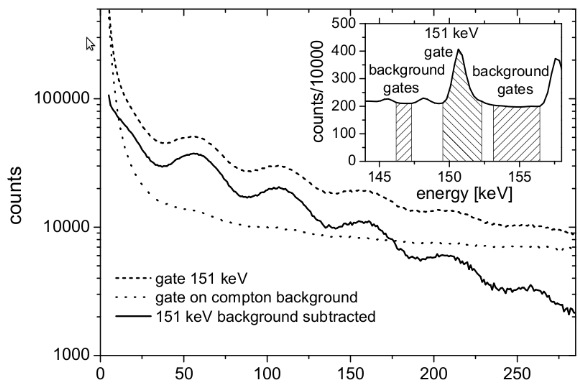

Fig. 1. Oscillating gamma radiation intensity observed by LEPS detectors.

The measured g factor g= +0.59(1) shows that there is an important contribution of the core rotation in the total angular momentum of the isomeric state [4]. Moreover, a quantitative theoretical analysis supports the conclusion that the three angular momentum vectors lie almost in one plane, which suggests that the chiral configuration in ^{128}Cs demonstrated in previous work by characteristic patterns of electromagnetic transitions appears only above some value of the total nuclear spin.

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An instanton-motivated approach to the spontaneous fission of odd nuclei

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It is known that the spontaneous fission (SF) half-lives of odd nuclei are 3-5 orders of magnitude longer than those of their even-even neighbours - see e.g. the recent review [1]. This phenomenon is related to the blocking of orbital(s); occupied by the odd nucleon(s), the details of the hindrance mechanism are, however, far from being understood. In particular, dynamical effects must be taken into account. The usual approach based on the adiabatic approximation breaks down in the case of odd nuclei, which is due to the presence of the avoided level crossing between the state occupied by the unpaired nucleon and other levels. Therefore, a more suitable method which goes beyond the adiabatic approximation is needed. Our approach is based on the instanton formalism formulated for the mean-field setting in Ref. [2,3] and further investigated in Ref. [4]. The instanton equations given there involve a selfconsistent Hamiltonian, which we approximate by the phenomenological Hamiltonian with a Woods-Saxon potential. We first tested our method in the simple case of a two-level model and compared the action values obtained from the instanton solution with the action calculated within the adiabatic approximation – results are shown in Table 1.

$\hbar\dot{q}/(E_2-E_1)$	0.16	0.08	0.05
$V_{int}[MeV]$		0.5	
$S_{inst}/\hbar$	1.183	0.770	0.569
$S_{adiab}/\hbar$	2.015	1.007	0.672

Table 1. Instanton action values compared with the adiabatic ones in a 2-level system for different maximal velocities $\dot{q}$.

One can see that the adiabatic action is generally higher than that obtained from the instanton, but with decreasing velocity $\dot{q}$ both values converge to each other, as one would expect.

Results for a more realistic case, namely four neutron states taken from the deformed W-S potential (Fig.1) for ^{272}Mt along the fission path are presented in Table 2. Three values of collective velocity have been considered, one obtained using the potential energy landscape for ^{272}Mt and the mass parameter for the neighbouring even-even nuclei (108,162), and the other two scaled down by a constant factor.

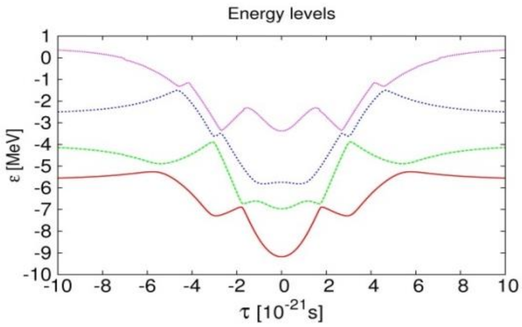

Fig. 1. Energy levels of 1/2+ neutron states against imaginary time.

$\hbar\dot{q}_{max}$ [MeV]	$S_{inst}/\hbar$	$S_{adiab}/\hbar$
0.14	2.6818	55.048
0.09	2.4892	36.699
0.06	2.3492	25.689

Table 2. Comparison of the action corresponding to the lowest state obtained from the instanton solution (S_{inst}) and in the adiabatic approximation (S_{adiab}) for a few values of the maximum collective velocity $\dot{q}_{max}$.

From the comparison of both action values given in Table 2 we see that the adiabatic approach overestimates the action, giving values more than an order of magnitude larger. This shows how far from the adiabatic limit we actually are in the case of the unpaired level undergoing sharp avoided crossings.

On the other hand, the instanton method does not break down around level crossings and, as we have seen, gives the correct action value in the adiabatic limit. It may, therefore, provide a basis for a more realistic estimate of the action values and the corresponding SF half-lives. This would contribute to the present research in the superheavy nuclei region allowing the prediction of where especially long-lived systems could be expected. Further investigations are under way.

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Plasma Physics and Technology

Eurofusion_NCBJ_JET4 project for gamma-ray detectors in plasma experiments

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The EUROfusion_NCBJ_JET4 Project for Gamma-Ray Detectors in Plasma Experiments is a four-year project realized within the European Joint Programme, co-financed by EUROATOM, the Research and Training Programme of the European Atomic Community (2014 - 2018), complementing Horizon 2020 - The Framework Programme for Research and Innovation, and partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of international co-financed projects. The project was prolonged in 2017 to the end of 2018.

Since 2012 NCBJ has been involved in work on gamma-ray diagnostics for plasmas. The main objective of our activities is participation in long term projects carried out at the Joint European Torus (JET), then to prepare detectors for the International Thermonuclear Experimental Reactor (ITER) as well as for the DEMOnstration Power Plant (DEMO), see www.euro-fusion.org.

At JET the α particle diagnostics are based on the $^{9}Be(\alpha,n\gamma)^{12}C$ nuclear reaction occurring between confined α-particles and beryllium impurity ions typically present in the plasma. A 4.4 MeV gamma line is emitted in the reaction:

$$^{9}Be + \alpha \longrightarrow {}^{13}C \xrightarrow{n} {}^{12}C^{*} \xrightarrow{\gamma(4.44MeV)} {}^{12}C_{g.s.}$$

Gamma-ray diagnostics of magnetically confined plasmas provide information on runaway electrons (fast electrons that often appear during plasma disruptions), fusion products and other fast ions due to nuclear reactions on fuel ions or main plasma impurities such as carbon and beryllium.

Two projects are currently being carried out by NCBJ within JET4 Enhancements Projects: modernization of two detector systems at JET, the Gamma-ray Camera (GCU) and Gamma-ray Spectrometer (GSU).

The Gamma-ray Camera is a very useful diagnostic tool to study confined α particles as well as fast ions. The information provided by the upgraded Gamma-ray Camera will complement the high resolution spectroscopy measurements with the Gamma-ray Spectrometer. An upgrade of the gamma-ray diagnostics is necessary because in planned deuterium-tritium campaigns measurements at high count rates are expected.

Our special interest is in measurements at high count rates and for this purpose $CeBr_3$ and $LaBr_3$:Ce scintillators were used with a decay time of about 20 ns.

The multi Pixel Photon Counter (MPPC) is one of these devices known as silicon photomultipliers. It is characterized by a fast response time, high gain coefficient, high photon detection efficiency resulting in good energy resolution, low voltage operation, resistance to mechanical shocks, compactness and immunity to a magnetic field. The MPPC gain is temperature dependent, so it is necessary to use a device which will allow itto be maintained at a constant value. For the upgraded Gamma-ray Camera, a detector based on a $LaBr_3$:Ce scintillator is equipped with MTCD@NCBJ, an MPPC Temperature Compensation Device to stabilize the MPPC gain. In addition, the basic performance of a photomultiplier tube (PMT) was determined and compared with an MPPC. 19 detector systems consisting of an MPPC, MTCD@NCBJ and a $LaBr_3$:Ce scintillator were delivered to JET and laboratory tests were performed there with radioactive sources.

A new detector for the Gamma-ray Spectrometer based on a 3″×3″ $CeBr_3$ scintillator coupled to a photomultiplier tube will be installed in the JET hall in 2018. The results of laboratory tests already performed have shown that this detector based on $CeBr_3$ with an active voltage divider is well suited for measurements at rates up to ~1 Mcps.

Monte Carlo simulations were performed with the Geant4 code to determine a response function for modernized detectors.

We started to analyse runaway electrons observed with the Gamma-ray Camera.

An upgraded version of the Digital Neutron Gamma@NCBJ (DNG@NCBJ) data acquisition system for high resolution spectrometry measurements at Mcps rates was prepared.

Measurement results of activation of aluminium capsules by 14 MeV neutrons are presented.

A dedicated program used for a determination of peak parameters registered with scintillators was developed and tested.

Our activities are presented in more detail in subsequent articles of the NCBJ Annual Report 2017 and in 7 publications in peer-reviewed journals.

This scientific work was partly supported by Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2018 allocated for the realization of the international co-financed project.

Response function calculations for JET Detectors

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At JET the α-particle diagnostics are based on the $^{9}Be(\alpha,n\gamma)^{12}C$ nuclear reaction occurring between confined α-particles and beryllium impurity ions typically present in plasmas. The 4.4 MeV gamma line is emitted in the reaction:

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Gamma-ray diagnostics of magnetically confined plasmas provide information on runaway electrons (fast electrons that often appear during plasma disruptions), fusion products and other fast ions due to nuclear reactions on fuel ions or main plasma impurities such as carbon and beryllium. The upgraded JET Gamma-ray Camera is now equipped with new detectors, based on fast $LaBr_3$:Ce scintillators.

To determine an output of detectors when they are exposed to radiation sources, e.g., gamma-rays or neutrons, a detector response function is used. Such a function is needed to get a response of a detector to a known radiation source or to perform a spectrum analysis to find a type and quantity of a source irradiated a detector. In case if it is possible, experimentally determined response functions should be used but Monte Carlo simulated distributions could be used as well.

We performed Monte Carlo simulations to evaluate a detector response to gamma radiation which allows to reconstruct spectra measured with a ϕ25.4×16.9 mm $LaBr_3$:Ce scintillator, installed at the upgraded Gamma-ray Camera. For all simulations, we used the Geant4 code due to its well-defined physics, flexibility and good reliability. A point-like gamma-ray source was put at a fixed distance from the face of the detector.

We compared measured and simulated gamma-ray spectra registered with a $LaBr_3$:Ce scintillator. Measurements were done with PuBe and PuC sources, emitting 4.4 MeV and 6.1 MeV gamma-rays, respectively. The geometry used in simulations was the same as in measurements. For both sources a distance from the scintillator face to the source was 40 mm. 10^6 events were simulated in all presented results.

In Fig. 1 a comparison of measured and simulated gamma-ray spectra is shown: in the upper part for the PuBe and in the lower part for PuC source. A total energy deposited in the scintillator is presented in all spectra. Simulated spectra were normalized to experimental ones. FWHM equal to 3% was assumed in simulations. Since in Monte Carlo calculations no gamma lines from natural sources were included, a discrepancy at lower energies is observed. A good agreement between experimental and measured spectra for gamma-ray energies up to ~6 MeV allows to predict a response function for higher energies. In Fig. 2 a simulated spectrum for 10 MeV gamma-rays is shown.

From three spectra simulated for 4.4, 6.1 and 10 MeV gamma-rays a conclusion is drawn that a scintillator efficiency drops drastically with an increasing gamma-ray energy and a scintillator with a diameter of 25.4 mm and a height of 16.9 mm is not suited for measurements of gamma-ray energies higher than a few MeV.

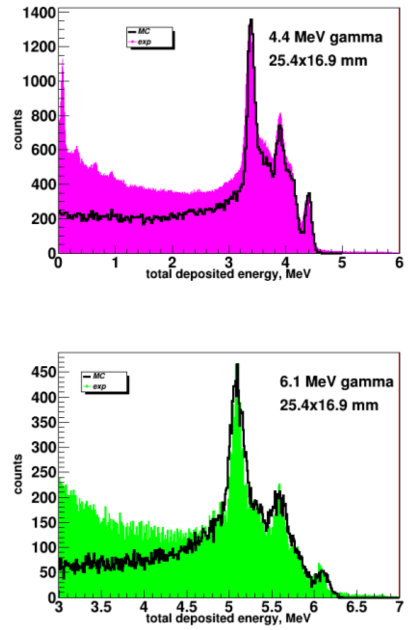

Fig. 1. Measured (non black) and simulated (black) gamma-ray spectra for PuBe (upper) and PuC (lower) sources.

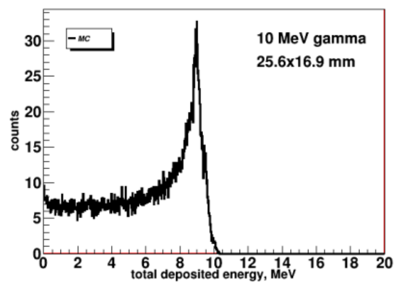

Fig. 2. Monte Carlo simulated gamma-ray spectrum for 10 MeV gamma-rays.

This scientific work was partly supported by Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2018 allocated for the realization of the international co-financed project.

Preliminary analysis of Runaway Electrons at JET

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Runaway electrons (RE) are electrons that undergo free fall acceleration of relativistic particles. The understanding of the RE generation processes and methods to suppress them is necessary to ensure safe and reliable operation of future tokamaks [1].

RE generation processes are studied at the JET facility using different diagnostics, in particular with the Gamma-ray Camera (GC). In 2016 two new detectors based on fast $CeBr_3$ scintillators were installed in channels 9 and 10, replacing those based on CsI crystals [2]. The new setup was tested during the experimental campaigns in July and November 2016. Experiment goals were to determine the efficiency of high Z impurity injection in a RE beam.

Dedicated software, JET_SHOT_PILEUP, created in C++ is language, was prepared to analyse data from JET shots. The flowchart of this program is shown in Fig. 1.

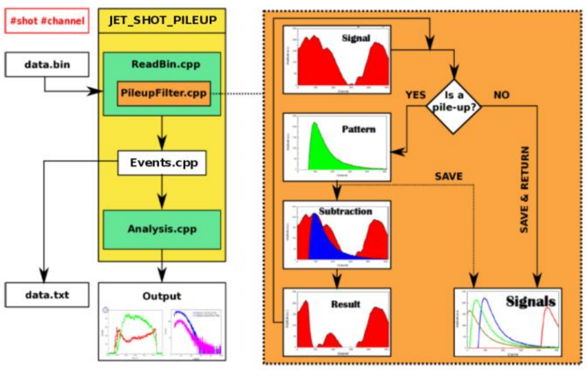

Fig. 1. Flowchart of the JET_SHOT_PILEUP program used for analysis of Runaway Electrons.

JET_SHOT_PILEUP consists of four classes: ReadBin, PileupFilter, Events and Analysis. The JET_SHOT_PILEUP program is analyses event-by-event and the returns time and shape of the signal.

The data acquisition (DAQ) time to start acquisition is provided by the JET absolute time with a precision of 1 MHz. The data file is composed of events and each event corresponds to an occurrence time and a pulse amplitude.

The class Events contains elements with time and amplitude of each signal. The object of this class is created by the readEventsFromBin() function called by the ReadBin class which is used to read a binary output file generated by the DAQ dedicated to GC. The PileupFilter class is used to unfold pile-up events. Pile-up events occur for high count rate measurements when the signal length is longer than the data acquisition time.

In the case of pile-up events, more than one signal is registered and a special formula is needed to obtain the time and amplitude of each component signal. The *Analysis* class is used to load an Events object. It builds an energy spectrum and calculates how many events were recorded during a shot.

Results from shots #91066 - #91081 and #92448 - #92461 were analysed with the JET_SHOT_PILEUP program.

As a result of the analysis we obtain a gamma-ray energy spectrum and a distribution of counts in time computed for two energy ranges, below and above 520 keV. The number of registered gamma-rays in the GC rises when the disruption happens, see the green line in Fig. 2. The start time of the JET plasma disruption obtained from theGC consistent with that obtained by other JET diagnostics.

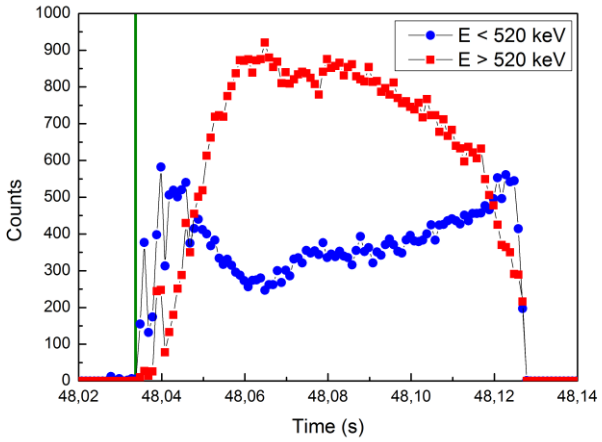

Fig. 2. Number of gamma photons registered with the $CeBr_3$ detector in the GC during shot #92449. The solid green line indicates the start of JET plasma disruption.

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This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of scientific financial resources in the years 2015-2017 allocated for the realization of the international co-financed projects.

Fast neutron activation of aluminum samples

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Each scintillator which is part of the detector in the Gamma-ray Camera (GC) at JET is placed in an aluminium capsule. Due to the strong neutron and gamma fluxes produced during experiments performed at JET the capsule material is activated by neutrons. It is then necessary to check which radioactive nuclei are present by registering their gamma lines.

At NCBJ we used a *Genie 16D* neutron generator which emita a neutron flux equal to 10^8 n/s with an average energy of 14 MeV [1]. Spectra registered with a HPGe detector were analysed with a TUKAN analyser. Two samples of PA6 aluminium were used: a solid aluminium cylinder with dimensions of ϕ30×7 mm and an aluminium capsule with dimensions of ϕ35×34 mm and a wall thickness of 1.2 mm [2],

Irradiation time of each sample was 600 s and after a pause of 60 s a gamma spectrum was measured for 1200 s (40×30 s). Measurements without any aluminium material were performed as well to determine the laboratory background.

Natural aluminium contains only one stable isotope ^{27}Al. In Fig. 1 cross section values for selected reactions induced by neutrons on ^{27}Al are shown.

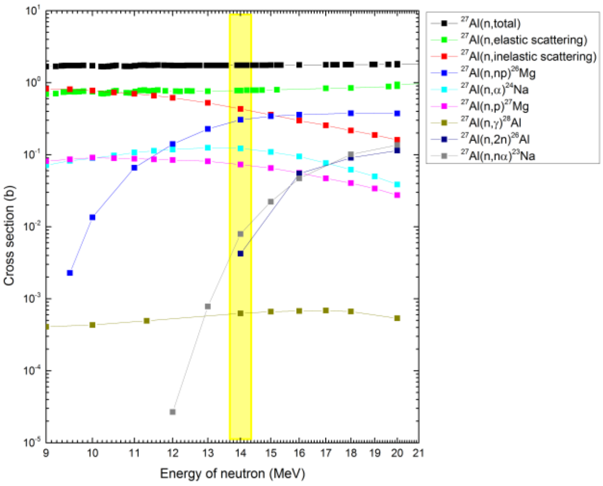

Fig. 1. Cross section for selected reactions induced by neutrons on ^{27}Al [3].

In Table 1 a short summary of the most pronounced gamma lines observed during aluminium activation by fast neutrons is presented.

Table 1. Summary of isotopes activated by fast neutrons in aluminium [3].

Reaction	Half-life of product	Emitted gamma lines
^{27}Al(n, γ)^{28}Al	2.24 m	1779 keV
^{27}Al(n,p)^{27}Mg	9.46 m	170, 844, 1014 keV
^{27}Al(n,α)^{24}Na	14.96 h	1369, 2754 keV

Sample gamma spectra from the performed irradiations are presented in Fig. 2. Two naturally occurring peaks are seen at 1461 keV caused by gammas from ^{40}K and at 2615 keV from ^{208}Tl.

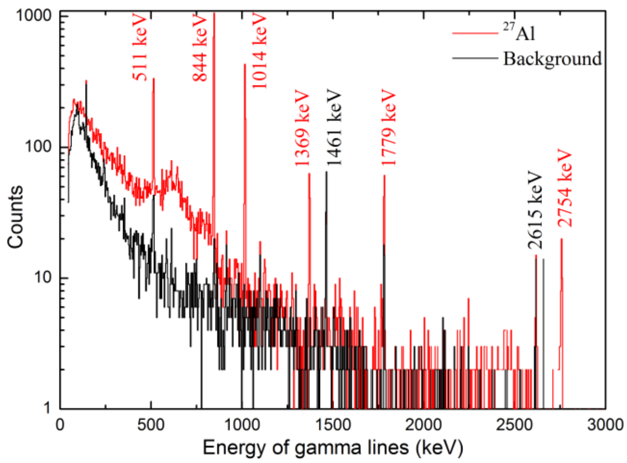

Fig. 2. Sample of gamma spectra from an irradiated ^{27}Al sample (red) and background after irradiation without a sample (black).

The observed gamma lines could be used to obtain an energy calibration of the detector setup.

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This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2018 allocated for the realization of international co-financed projects.

Research on runaway electrons in the COMPASS Tokamak

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[2]Institute of Plasma Physics, Prague, Czech Republic

Runaway electrons (REs) are generated in tokamaks when the friction of electron collisions with the plasma does not compensate the electrical force induced externally. Such REs may reach energies up to several MeV. Intense RE beams can significantly damage components of the first wall of a tokamak vacuum chamber. Therefore, control and mitigation of REs, based on credible measuring methods, should be developed in currently operating tokamaks.

In 2017 extensive research on REs was carried out during two dedicated experimental campaigns within the COMPASS tokamak at the Institute of Plasma Physics AS CR in Prague. It was performed by means of a three channel detection system of the Cherenkov-type,equipped with radiators made of CVD-type diamonds. The NCBJ team proposed to study REs by means of the Cherenkov-type detectors several years ago, and the measurements by means of the three channel detection system in the COMPASS tokamak were initiated in 2015. The applied probe radiators were covered by thin molybdenum filters of different thickness, which established different low-energy thresholds for RE detection. This made it possible to determine the characteristics of the low-energy part of the RE energy spectrum. The low energy thresholds of the three-channel probe were as follows: 58 keV, 145 keV and 221 keV during the first 2017 experimental campaign, and 109 keV, 145 keV and 221 keV during the second one.

In 2017 research on REs was performed within the framework of the EUROfusion Work Package MST2 “Preparation of Exploitation of Medium-Size Tokamaks”. The main objective of the NCBJ team is activities was improvement of the Cherenkov detectors, as a diagnostic technique helpful for studies of the generation and mitigation of REs in tokamaks. An example of signals recorded in measurements performed during the first RE campaign of 2017 (June), is shown in Fig.1. This example presents waveforms from a circular plasma discharge with massive argon–puffing, and is interesting for studies of post-disruptive REs often observed under such circumstances within the COMPASS facility.

The application of Cherenkov-type detectors within the COMPASS tokamak enabled monitoring of REs, studies on the correlation of Cherenkov signals with MHD activity of the plasma, and estimation of RE losses due to MHD perturbations. It can also be treated as support of research on the mitigation of REs and validation of their generation models in the COMPASS tokamak.

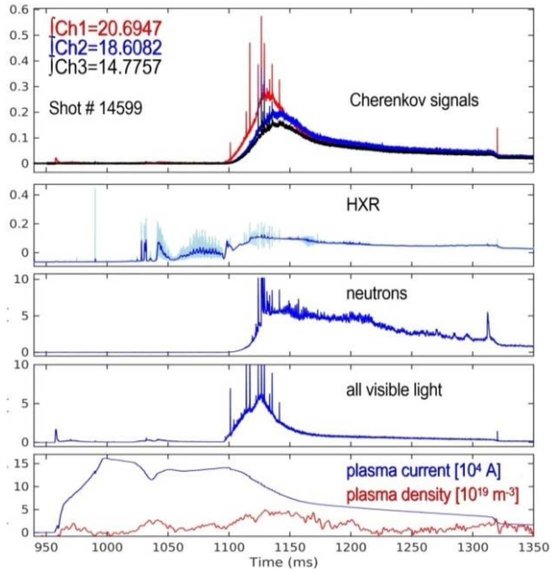

Fig. 1. Comparison of electron-induced signals (obtained from the three-channel Cherenkov probe) with the basic plasma signals: hard X rays (HXR), photo neutrons, visible light emission, plasma current and line-averaged electron density for COMPASS shot #14599 performed at the deuterium fuelling, massive argon gas injection and circular plasma. The measuring head was at R = 0.805 m (15 mm outside the tokamak vessel and 65 mm outside the mid-plane separatrix radius).

The results of both COMPASS RE campaigns in 2017 proved that Cherenkov detectors are able to detect prompt losses of low energy REs accompanying the current quench phenomena.

Acknowledgements: This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources allocated for the realization of international co-financed projects during 2017.

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Fabrication of advanced targets for laser driven nuclear fusion reactions through standard microelectronics technology approaches

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Measurements were mainly focused on microfabrication techniques and processes optimized for the fabrication of silicon targets enriched with hydrogen and doped with boron at high atomic concentration 10^{20}–10^{22}cm^{-3} and on a comparison of the key results achieved with the different targets used in the experiment. Hydrodynamic simulations were also performed using the 2D code PALE [1]. The experiment was performed at the Asterix Laser System (PALS) facility at the AS CR, Prague, Czech Republic, where a kJ-class, sub nanosecond (0.3-ns FWHM), linearly polarized laser was used to irradiate massive silicon targets. The laser pulse was focused in vacuum down to 80-µm (focal spot diameter) by an f = 2 aspherical lens, thus reaching a nominal intensity of 3×10^{16} W/cm^{-2} on target, shown in Figure 1.

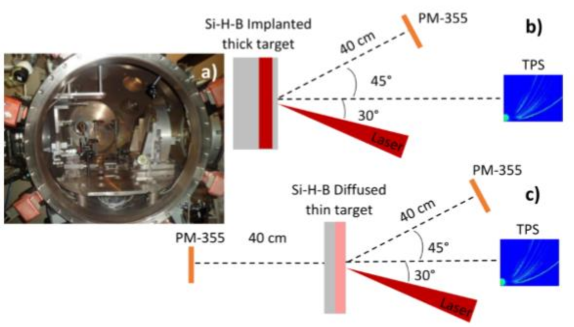

Fig. 1. a) The PALS laboratory interaction chamber, b) Experimental set-up for the silicon implanted thick target, c) Experimental set-up for the silicon diffused thin target.

The incidence angle between the laser-beam axis and the target normal was 30°. CR-39/PM-355 nuclear track detectors were placed in front of two targets at a distance of 40 cm and at an angle of 45° with respect to the target normal to detect the alpha particles produced in the nuclear reaction. Ions hitting the CR-39/PM-355 detectors were filtered by aluminium foils with a range of thicknesses varying from 10 - 20 µm to cut the signal coming from other ions produced during the laser-target interaction. Track detectors were also placed behind the target, at the same distance (40cm) to detect particles expanding in the forward configuration, as shown in Figure 1c.

From an accurate analysis of the nuclear track detectors irradiated by the ions it was possible to estimate the particle yield per unit area. Figure 2 shows the histograms of the generated alpha particle density resulting in a higher value for the B-implanted hydrogenated silicon target (2×10^5cm^{-2}) compared to the B-diffused ones (1.6×10^4cm^{-2} and 1.4×10^4cm^{-2} in the backward and forward configuration, respectively). Since CR-39/PM-355 detectors were placed at different angles, it was possible to estimate the total number of alpha particles produced, which resulted in about 5×10^8 particles per pulse for the implanted samples and 4×10^7 particles per pulse for the diffused ones.

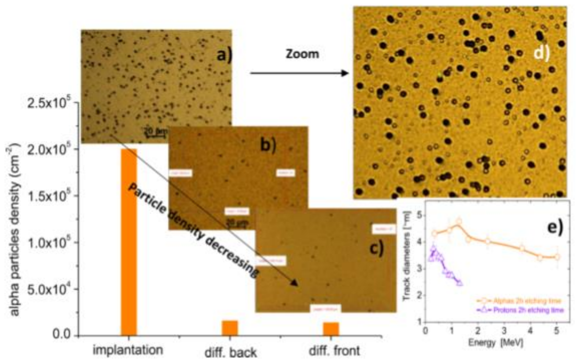

Fig. 2. CR-39/PM-355 detector alpha particle track image from the three targets considered and related yield histograms for: a) the implanted target, b) the diffused target in the backward configuration, c) the diffused target in forward configuration, d) Zoom of the detector area covered with alpha particle tracks (large dark spots) and proton tracks (small light coloured spots), e) CR-39/PM-355 calibration curves for alpha particles (yellow) and protons (violet).

Both values are in good agreement with the theoretical estimates. Hydrodynamic simulations were also performed by using a 2D cylindrical r-z geometry code (PALE). The results of the hydrodynamic simulations are summarized in Figure 3, which shows the boron plasma density (cm^{-3}) as a function of the distance from the target. In this case of a thick implanted target the plasma expansion configuration was considered only in the backward direction, in the opposite direction to the incoming laser pulse i.e.

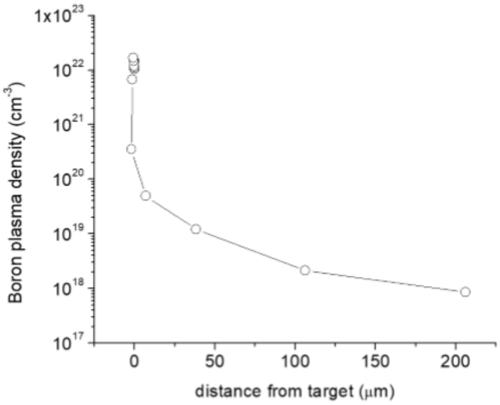

Fig. 3. Hydrodynamic simulation of Boron plasma density vs distance from target by for case of a thick Si-H-B target.

A typical proton energy distribution measured by the Thomson Parabola Spectrometer is shown in Figure 4, the laser-accelerated proton number is clearly a key parameter to enhance the generated alpha particle number along with the boron concentration in the target material, as already pointed out. Thus, the achieved record results in terms of alpha particle number come mainly from the combination of specific chemical-physical parameters of the target used and the given laser features (e.g. pulse temporal profile). In comparison, in terms of the number of particles per solid angle obtained in recent experiments of laser driven fusion is approximately 10^7 alphas/sr, however 5×10^{18} W/cm^2 was used. In our case 10^9 alpha particles per steradian was achieved using only 3×10^{16} W/cm^2.

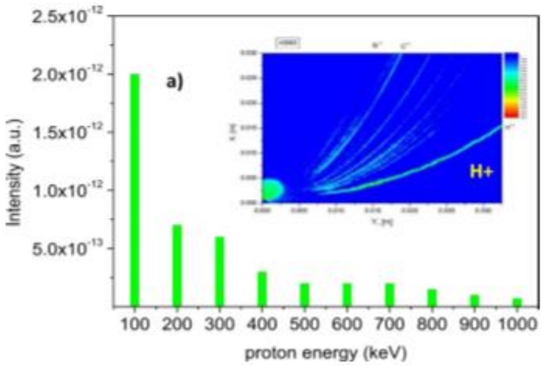

Fig. 4. Proton energy distribution histogram. The yellow arrow in the inset indicates the proton' parabola signal.

Reference

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Research on physical phenomena in high-current discharges of the plasma-focus type*

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In the first quarter of 2017 the NCBJ-TJ5 team, in collaboration with several researchers from IFPiLM in Warsaw and CVUT in Prague, prepared a revised paper on studies of plasma-current filaments in a pinch column of pulse discharges in the PF-1000U facility. On the basis of images of the XUV radiation it was proved that numerous tiny plasma-filaments and hot-spots can be formed inside and near the pinch column during radial compression and the quasi-stable phase of the discharge. Some examples are shown in Fig. 1.

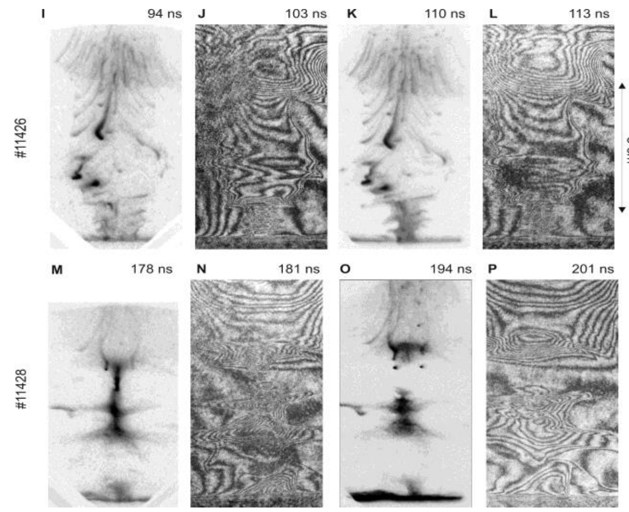

Fig. 1. XUV and interferometric images recorded during the stagnation and disruption of the pinch column at different instants after maximum compression.

These plasma-filaments moved together with the plasma stream and their life-time amounted to about 50 ns. An interesting phenomenon was the formation of very small quasi-spherical regions of dense plasma outside the main pinch column [1].

In the framework of the same collaboration studies of transformations of the ordered internal structures during the acceleration of fast charged particles in a dense plasma focus discharge were performed. Different waveforms characterizing the investigated discharges and corresponding interferometric images were recorded. Some examples are presented in Fig. 2.

It was found that the first neutron pulse is generated due to acceleration of deuterons during the plasmoid's formation, while the subsequent neutron pulses are emitted during development of strong plasma instabilities [2].

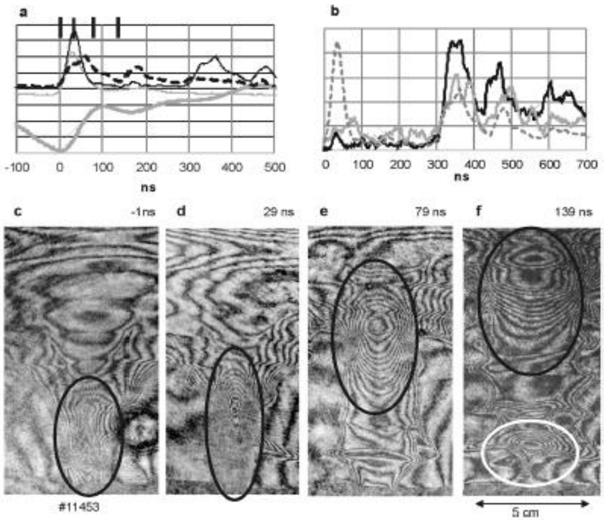

Fig. 2. Data from shot #11453: (a) Waveforms of the current derivative (thick grey), SXR (thin grey), HXR (thin black) and neutrons (dashed); (b) Waveforms from scintillation detectors recorded along the axis (black), upstream (grey) and side-on (dashed); (c-f) Interferometric images recorded at different instants.

The main aim of the next experimental campaign was to increase the neutron yield from a dense plasma focus discharge by the use of an additional conical tip located in the centre of the anode end-plate. Such a tip changed the discharge form considerably, as shown in Fig. 3.

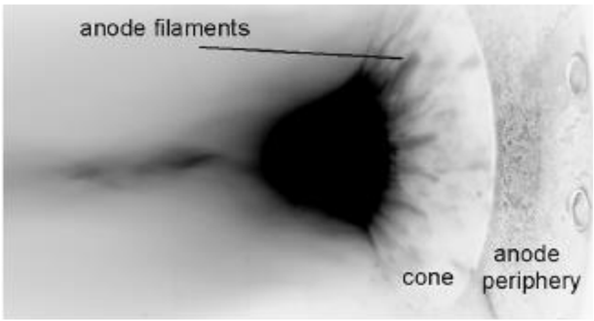

Fig. 3. Time-integrated VR picture of discharge #11857, taken side-on, which shows the quasi-stable positions of the current filaments traces upon the electrode surface.

A detailed analysis of the recorded waveforms and interferometric images was performed and noticeable differences in the pinch were observed, as shown in Fig. 4.

On the basis of the experiments performed it was found that the use of the conical tip eliminated plasma penetration into the anode interior, and shortened the length and diameter of the dense plasma column. It enabled the average neutron yield Y_n to be increased by one order of magnitude (up to 10^{11} neutrons/shot) [3].

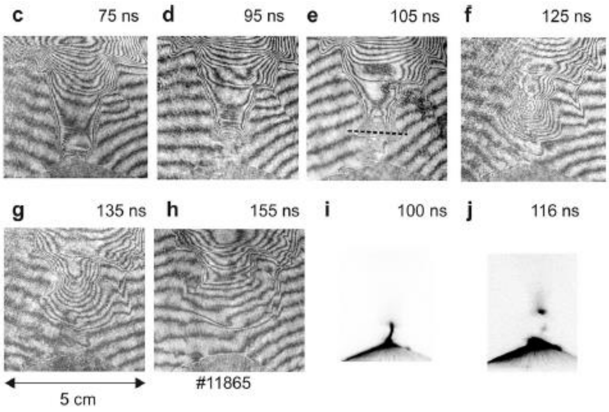

Fig. 4. Interferometric images recorded during the pinch implosion (c-e), after its interruption, i.e. during decay of the secondary plasmoids (f-g). Two XUV frames were recorded (i) before and (j) after the constriction disruption.

Another series of PF-1000U discharges was carried out in order to study the visible and X ray emission, and to determine the values of the local electron temperature in the pinch column [4]. Pictures of VR and SXR emission were recorded and compared, as shown in Fig. 5.

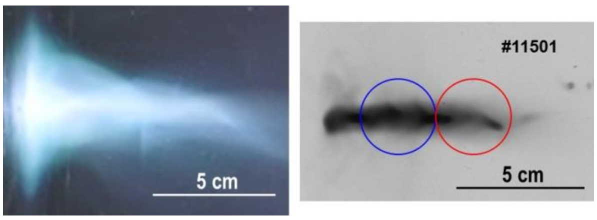

Fig. 5. Comparison of time-integrated VR and SXR images of a discharge performed at p_0 = 1.2 hPa (D_2+1%Ne) with additional D_2-puffing.

Time-resolved SXR signals, obtained from PIN diodes equipped with different Be-filters and observing various regions (see Fig. 5), were analyzed. A strong correlation between the appearance of hot-spots and sharp SXR peaks was observed [4]. From the ratio of these peak intensities it was possible to estimate local values of the electron temperature Te, as shown in Fig. 6.

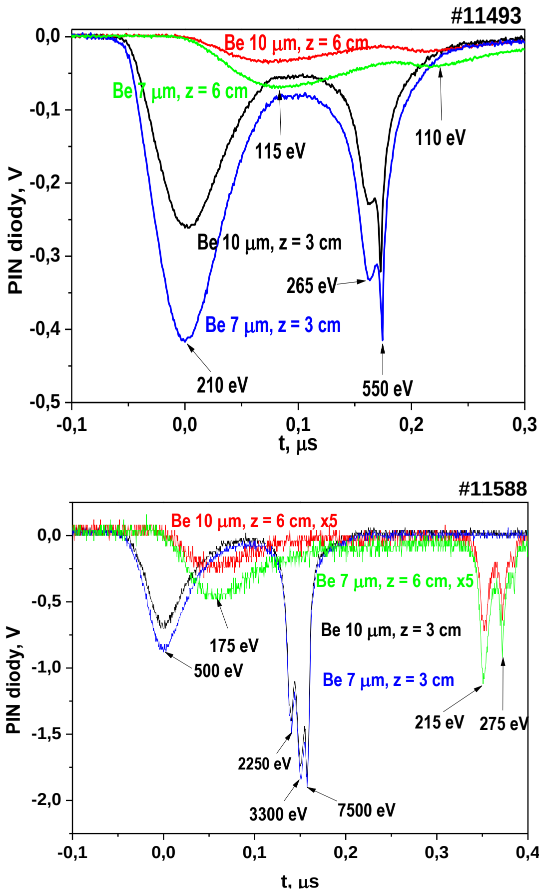

Fig. 6. SXR signals from shot #11493 performed at p_0 = 1.2 hPa D_2 with additional D_2-puffing, and those from shot #11588 performed at p_0 = 1.2 hPa (90%D_2 + 10% Ne) with puffing of a (75% D_2 + 25% Ne)-mixture.

Other experiments at the PF-1000U facility concerned laboratory simulations of astrophysical plasma jets, as shown in Fig. 7.

Measurements were performed by means of a high-speed camera, optical spectrometer and small magnetic probes. Results obtained from experiments performed at the PF-3 in Moscow, the PF-1000 in Warsaw, and the KPF-4 in Sukhumi were compared and summarized [5].

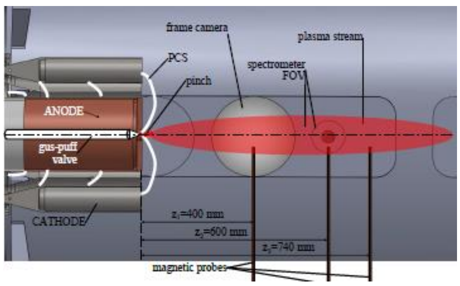

Fig. 7. Scheme of the PF-1000U experiment for laboratory simulation of astrophysical plasma jets.

It was proved that PF-type facilities can generate intense plasma streams, which contain plasma jets characterized by dimensionless parameters, e.g. Mach-, Reynolds- and Péclet-numbers, and so-called contrast, corresponding to those observed in cosmic space. This makes it possible to perform simulations of astrophysical phenomena in the laboratory [5].

The recent series of experiments carried out at the PF-1000U facility concerned studies of gas conditions needed to generate long plasma jets, as shown in Fig. 7.

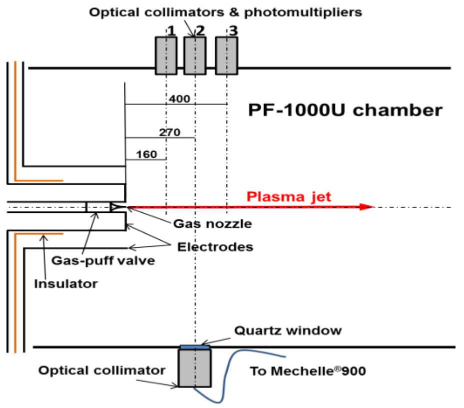

Fig. 7. Scheme of the measuring system used for the determination of the optimal gas conditions.

Results obtained from these studies are still under quantitative and editorial elaboration [6].

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*Scientific collaboration of the NCBJ, IFPiLM, CVUT, and Kurchatov Institute

Investigation of the interactions of intense plasma streams with different solid materials*

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In the first quarter of 2017 the NCBJ-TJ5 team participated in the preparation of a review paper on damage and modification of materials under high power plasma exposures [1]. Particular attention was focused on experimental studies performed with the MPC and QSPA Kh-50 facilities operated at the IPP KIPT in Kharkov. The latter is shown in Fig. 1.

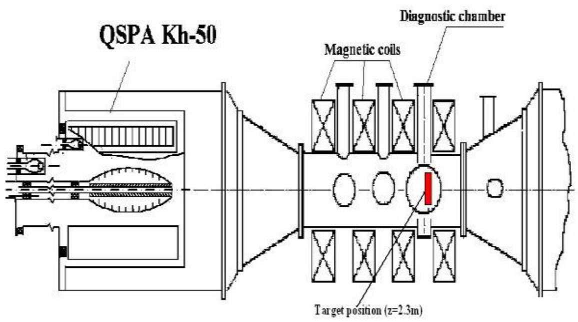

Fig. 1. Scheme of the QSPA Kh-50 facility used for materials studies.

The behaviour of tungsten samples exposed to intense plasma pulses was studied. Examples are shown in Fig. 2.

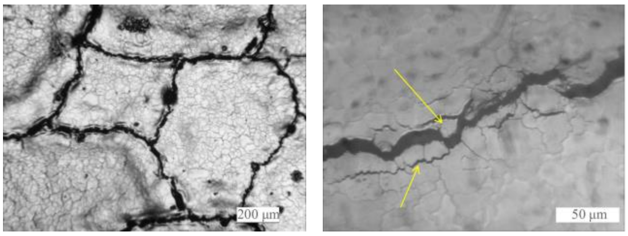

Fig. 2. Micro-cracks and slits formed between tungsten grains.

Attention was also paid to research on modification of Cr18Ni10Ti-steel and Eurofer-alloy samples by intense plasma streams. Changes upon the irradiated Eurofer surfaces are presented in Fig. 3.

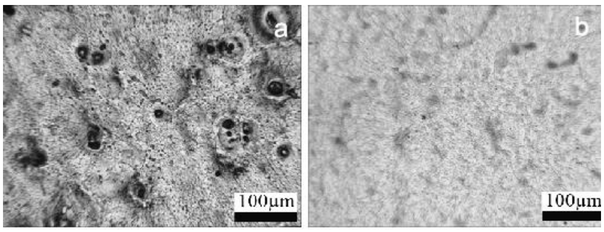

Fig. 3. Optical microscope images of a Eurofer-alloy surface exposed to 5 plasma pulses within the MPC (a) and QSPA (b) facilities.

Another research topic was the modification of tungsten coatings deposited on steel substrates. Some examples are presented in Fig. 4.

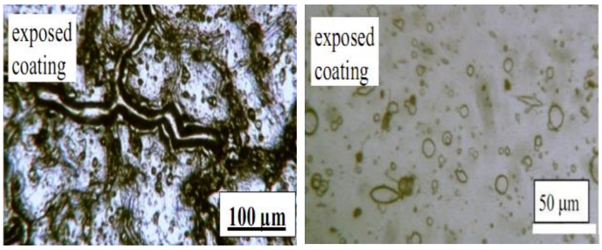

Fig. 4. Optical microscope images of a Eurofer-alloy surface coated witch a W-layer and exposed to 5 plasma pulses within the MPC (left) and QSPA (right) facilities.

Sputtering tests of the Cr18Ni10Ti and Eurofer samples were also been carried out for virgin surfaces, as well as for those coated by a W-layer and those modified by plasma streams with different pulse lengths. Use was made of an Ar+ ion-beam. It was shown that the roughness of the initial surfaces could be increased noticeably due to the sputtering of the grains boundaries [1].

In the framework of the same collaboration studies of the optical spectra of plasma produced from stainless-steel (SS) samples exposed to pulsed plasma streams were also performed [2]. Detailed investigation was carried out on SW7 and S316/316L samples. They were first exposed to pulses from a Nd:YAG laser, which was operated at $\lambda L = 1064$ nm and produced 3 ns-pulses of energy ranging up to 0.5 J. Since the samples were irradiated under vacuum conditions (at $p0 = 6.8 \times 10^{-5}$ hPa), the radiation of laser-produced plasma had an optical spectrum composed of spectral lines originating from components of the irradiated target only, a shown in Fig. 5.

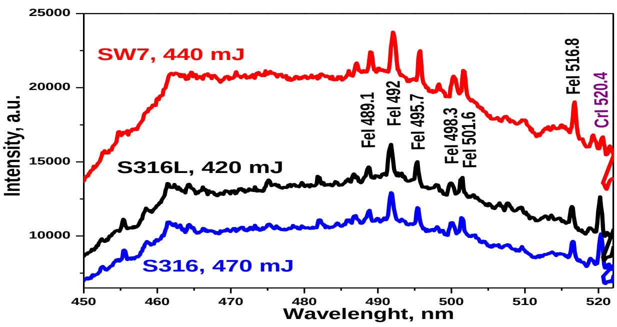

Fig. 5. Optical spectra obtained from different SS samples irradiated by laser pulses of similar energy.

The main experiments on erosion of SS samples were performed within the RPI-IBIS facility, which is shown in Fig. 6.

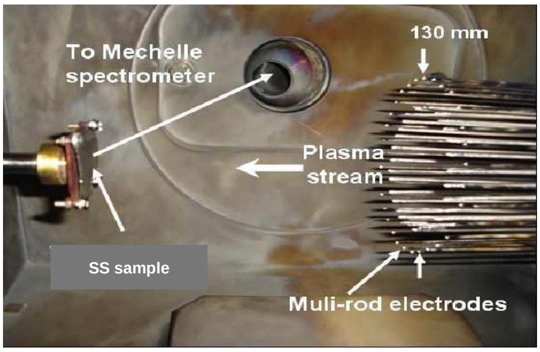

Fig. 6. Experimental arrangement for studies of erosion of the SS samples in the RPI-IBIS device.

The optimal operational mode of this device was determined on the basis of the optical emission spectra. Behaviour of SW7 and S316 samples was studied at the same energy flux density of the applied plasma streams, as shown in Fig. 7.

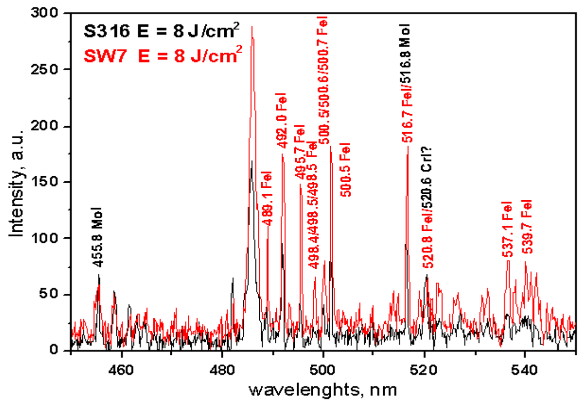

Fig. 7. Comparison of the erosion of two different SS samples under the same conditions of exposition.

It was found that the S316 samples showed higher resistance to erosion than the SW7 samples. Subsequently, a study of the erosion of the chosen material at different thermal loads was performed, as shown in Fig. 8.

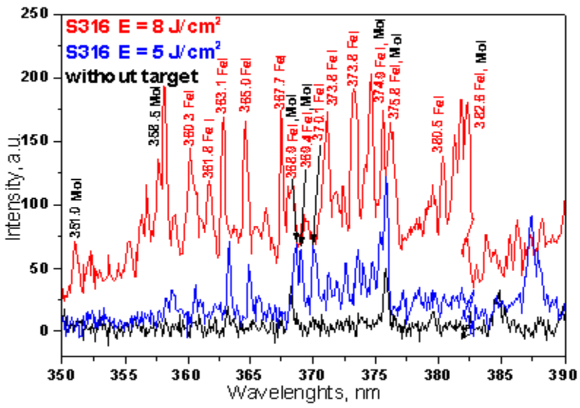

Fig. 8. Erosion of S316 samples at different energy flux densities of the plasma stream.

The described studies enabled us to select the most resistive steel and to estimate the maximum thermal loads [2].

The joint Polish-Ukrainian team also performed surface analyse of different steel samples irradiated by laser beams and pulsed plasma streams [3]. During the first experimental session the samples were exposed to different numbers of Nd:YAG laser pulses of 50-150 MW power and the erosion craters were investigated by means of a microscope and profilometer, as shown in Fig. 9.

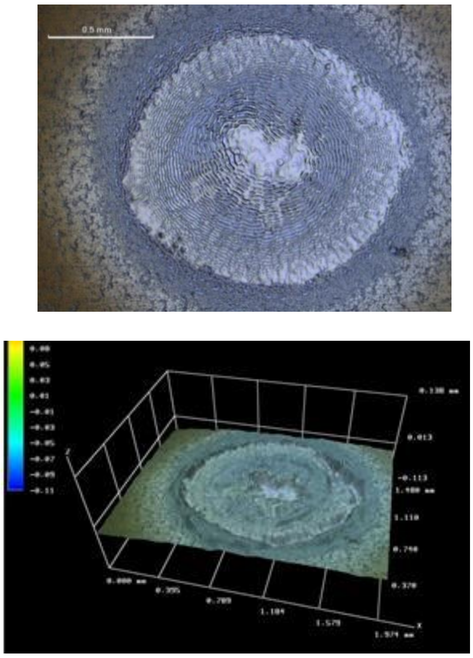

Fig. 9. Macro-photography and profiles of the erosion crater formed upon an SS316 sample surface after bombardment by 20 laser pulses of 150 MW /3 ns.

During the second experimental session the SS samples were placed in the chamber of the RPI-IBIS facility operated with deuterium filling and the energy flux density of the plasma stream bombarding the sample surface was varied from 5 to 8 J/cm^2. Morphological changes of the samples were analysed, and the dependence of the surface changes on the number and power of laser or plasma pulses was found [3].

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*Scientific collaboration of NCBJ, IFPiLM, and IPP KIPT.

Reliability, Availability, Maintainability and Inspectability (RAMI) studies for selected systems of the DEMO Oriented Neutron Source

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The mission of the DEMO Oriented Neutron Source (DONES) is to provide a high energy neutron beam with sufficient intensity and irradiation volume for the following purposes:

- investigation of materials behaviour under asimulated fusion environment during operation of the fusion demonstration power reactor (DEMO),
- elaboration of a database for benchmarking of the radiation response of materials hand in hand with computational materials science.

Reliability, Availability, Maintainability and Inspectability (RAMI) studies are crucial to ensure the safety and adequate efficiency of this installation:

- Reliability (R) means the system's ability to perform a specific function at specified level of efficiency without interruptions or failures;
- Availability (A) is the system's ability to stay continuously in an operational state;
- Maintainability (M) is the system's ability to restart operations after unplanned outages.

All the aforementioned attributes can be quantitatively measured with a variety of well-defined RAMI metrics, but the appropriate approach must be adopted in order adequately to reflect the functional structure of the systems being analyzed. In this work the block-wise approach has been chosen in which the systems are broken down into smaller parts (subsystems/components), while the dependencies between these structures are maintained via logical connections defined by the functional relations between subsystems. When the blocks are statistically independent, RAMI metrics can be evaluated in a closed form. However, for the complex systems analyzed under this study, the statistical independence assumption is violated due to the time-varying characteristics and sequence-dependencies. Therefore, more complex modelling (Dynamic Reliability Block Diagram – DRBD) has been applied (Fig. 1). In this approach the blocks were modelled by associating the state evolution of each block with an event, or a series of events, whose occurrence triggers some changes in the block's characteristics.

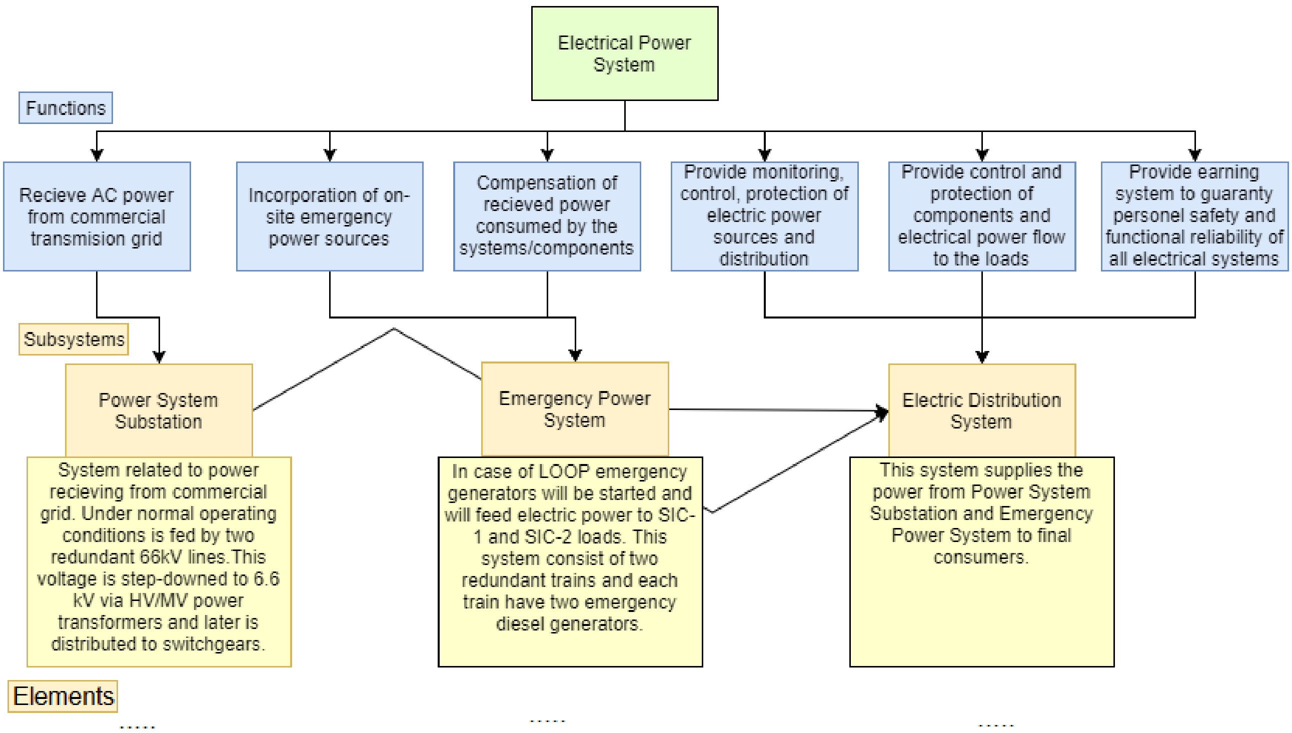

Fig. 1. The figure depicts the DRBD for the Electrical Power System (green box) that has to maintain six functions (blue boxes), which are realized by three subsystems (orange boxes) whose operations are described in the yellow boxes.

Accelerators, Detectors & Electronics

Tests of the upgraded JET gamma camera detectors

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In 2017 tests of upgraded detectors installed at the JET Gamma Camera (GC) were performed at both NCBJ and JET.

19 detector systems consisting of a silicon photomultiplier MPPC placed on an RC passive base and a ϕ25.4×16.9 mm $LaBr_3$:Ce scintillator were assembled at NCBJ. The MPPC was glued to a scintillator with a Cargille glue (MELTMOUNT 1.539 Code 53). The climate chamber available at Świerk Science & Technology Park was used for this procedure. The operational voltage of the MPPC was set to 54.6 V.

Sample test results are shown in Fig. 1.

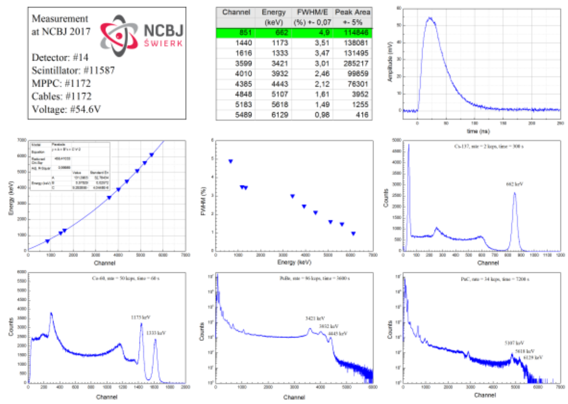

Fig. 1. Datasheet for detector #14 from tests conducted at NCBJ.

The amplitude of each detector (top right) was observed on an oscilloscope. Afterwards measurements with radioactive sources were conducted: 137Cs (middle right), 60Co (bottom left), PuBe (bottom middle), PuC (bottom right). An energy calibration of the detectors (middle left) was performed and the energy resolution was evaluated (middle). A CAEN DT5730 digitizer was used in the measurements.

The detectors were then sent to the JET laboratory with their auxiliary equipment, including the MTCD@NCBJ and the FilterBox@NCBJ [1].

At JET, measurements were conducted with a ^{22}Na source (right part in Fig. 2), placed permanently inside the GC construction, and with an external 137Cs source (left part) placed in front of each detector. These measurements were carried out with a CAEN DT 5730 digitizer (bottom), and the dedicated acquisition system from the Instituto de Plasmas e Fusão Nuclear (IST) (top).

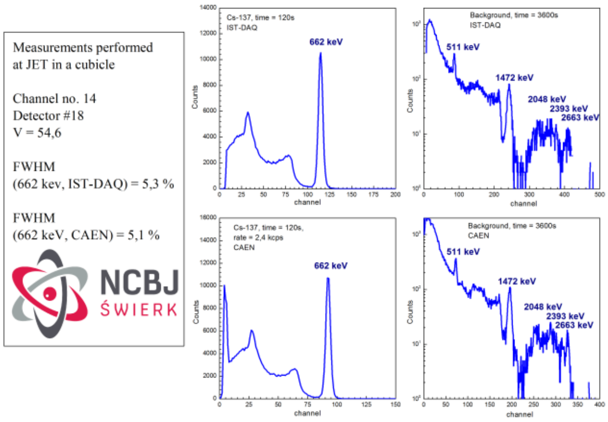

Fig. 2. Datasheet for detector #14 from tests conducted at JET.

In Fig. 3 a comparison of measured energy resolution values obtained at NCBJ and JET is shown.

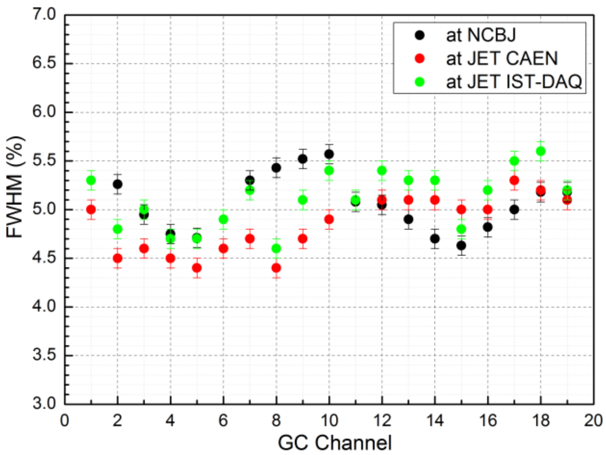

Fig. 3. Energy resolutions of the 0.662 MeV line for each detector in the Gamma Camera.

In 2018 tests will be carried out at JET with the Gamma-ray Camera installed in the tokamak hall.

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Novel detectors based on SiC structures for mixed radiation fields

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Silicon carbide (SiC) is a semiconductor material with good alpha and neutron radiation detection properties [1-3]. Due to its high radiation hardness and the large number of possible neutron nuclear reactions with carbon and silicon atoms, it is suitable for utilization in fast neutron spectrometry, in particular in nuclear reactors [2-3]. A literature review demonstrates that detectors based on silicon carbide are sensitive to gamma radiation and show unique possibility of discrimination of neutron and gamma radiation [3]. Such properties are important in a number of technical and scientific fields in radiological protection e.g. in dosimetry of mixed radiation fields. It was shown that SiC detectors with built-in converters extend the operation energy range to thermal and epithermal neutrons [2].

Due to the above mentioned properties silicon carbide detectors can be designed with a built-in neutron converter layer allowing the utilization of silicon carbide sensors in dosimetry of mixed fields with a broad energy spectrum, and in particular in the low neutron energy range. Due to technological reasons, tested moderator layers mainly based on lithium (Li) and its compounds are not compatible with modern semiconductor technology because of the high diffusivity of lithium. It has been shown that lithium causes leakage in the dielectric layers that are one of the most important parts of any semiconductor device [4].

The specific objectives of these studies are: (1) Preparation of SiC detectors with good electrical parameters with different types of neutron converters based on boron and gadolinium and also without a converter. (2) Characterization of the response of detectors with neutron converters and without converters with the same structural parameters in different fields of radiation. (3) Characterization of the long-term effectiveness of a neutron converter in high-flux radiation fields. (4) Analysis of the results obtained and proposal of a construction of a detector that will be the most versatile in terms of mixed radiation detection and PSD (Pulse Shape Discrimination) of the detected particles. It has been hypothesized that it is possible to implement a sensor that will be sensitive to mixed radiation, in particular a neutron radiation component with a broad energy spectrum, with the unique feature of the possibility of particle discrimination. It is expected that this kind of detector can distinguish types of interaction and consequently will allow the spectra into to be divided components (type of radiation, energy).

During the previous research the alpha spectrum (fig. 1) from an isotopic open source of Cf-252 using test diodes fabricated at the Institute of Microelectronics and Optoelectronics at Warsaw University of Technology was obtained.

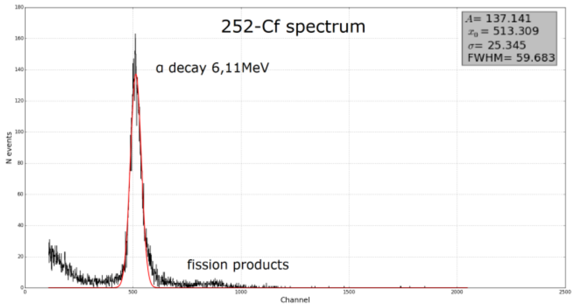

Fig. 1. Cf-252 isotopic open source spectrum from SiC test diodes.

For further work on the PSD method using SiC detectors a measuring set-up containing a fast digitizer, oscilloscope, charge preamplifier, laptop and dedicated software for acquisition and analysing pulses from the detector has been developed (Fig. 2).

As a first stage this measurement setup is used to measure silicon detectors for calibration and reference purposes using an open Cf-252 source to separate signals from fission products. The method is based on simultaneous determination of pulse rise-time and amplitude for each detected particle [5].

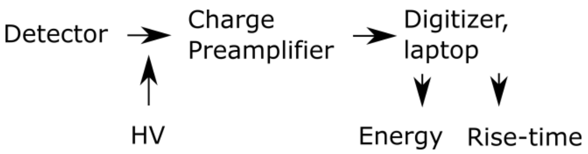

Fig. 2. Measuring set-up.

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NCBJ participation in the GBAR (Gravitational Behaviour of Antihydrogen at Rest) project at CERN

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In 2016 the electron linear accelerator for the GBAR experiment at CERN was manufactured at NCBJ. The linac was designed to deliver a 9 MeV, 300 mA peak current electron beam. With these parameterers it is the strongest radiation source in easy-accessible areas at CERN.

In February 2017 the installation of the device started. All the accelerator's units were located in place (see Fig.1.) and the electrical cabling and water connections were made. In parallel to the installation of the linac many additional, not previously required, safety and technical documents were being prepared. Before the start-up electrical and safety systems inspections were made. In Fig. 2 the accelerator head installed in the bunker is shown

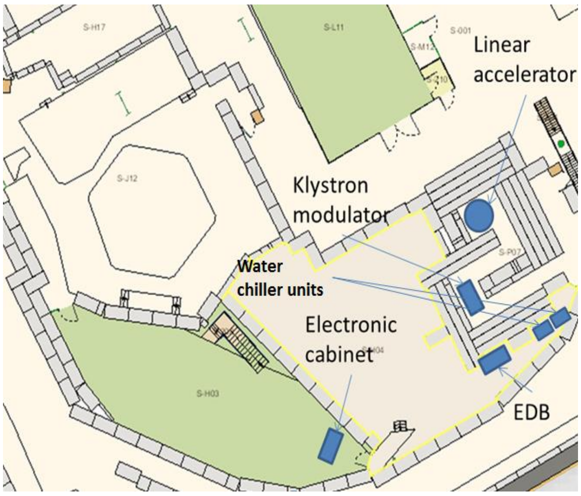

Fig. 1. Accelerator unit location in the experiment area.

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Fig. 2 .Accelerator head installed in the bunker.

After that the accelerator was started and electron beam energy measurements were made using a magnetic spectrometer. Later, the target was attached to the linac and the first positrons were observed. In Fig. 3 signals from positron detectors placed at the end of the positron transfer line are shown. GBAR experiment members were trained and started to use the device by themselves.

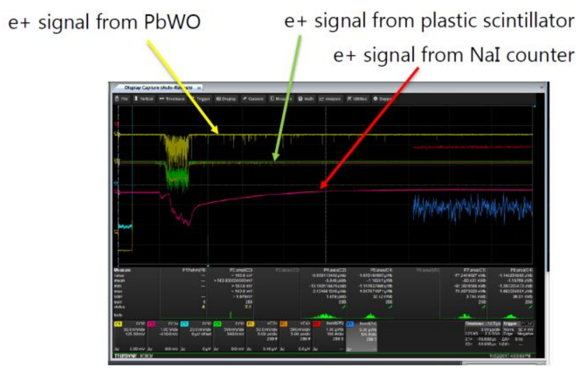

Fig. 3. Signals from positron beam detectors.

Light decay components of CsI:Tl

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Cesium iodides activated with thallium are widely used as gamma ray detectors for scientific, commercial and government purposes. Despite this widespread use there is ongoing work aimed at understanding the mechanism of light emission in these crystals. Different emission mechanisms inside the scintillators were activated by variable measurement conditions. The CsI:Tl crystals tested were grown in the Ukraine with thallium concentration from 0.03 to 0.08mol% [1]. XP 5212 photomultipliers from Photonics were used as light detectors. Light pulse decays from CsI:Tl excited by gamma-ray sources with energies 17-835keV were registered with digital techniques. Temperature treatments from 303K to 203K were made with the use of a climatic chamber.

The light pulse decays of CsI:Tl were analysed and described by an exponential function with three components. An increase of the decay times (τ_i) with decreasing temperature were observed (see table 1).

Table 1. Decay times of 3 components at different temperatures.

Temperature (K)	$\tau_1 \pm \Delta\tau_1$ (μs)	$\tau_2 \pm \Delta\tau_2$ (μs)	$\tau_3 \pm \Delta\tau_3$ (μs)
303	0.84±0.01	3.9±0.1	31.8±1.9
253	1.06±0.01	6.0±0.1	48.3±2.7
203	1.62±0.03	14.3±1.2	137.5±30.1

Following decay time prolongation with crystal cooling the authors decided to prolong the time of light pulse collection up to 500μs. It was at least 5 times longer than in a previous experiments [2]-[3]. This operation allows the effect of practically proportional CsI:Tl light answer to be obserwed (see the black points at fig. 1). This kind of CsI:Tl characteristic cannot be recorded with analogue systems, where the achievable peaking time is maximally close to 24μs. Note also the positive non-proportionality of the 1st and 2nd components (red and green points) and the negative curve deflection for the 3rd component (blue points). This observation was specified by A. Syntfeld et al. at room temperature [5]. What is interesting is that the 1st components have bigger positive non-proportionality than the second one at 303K and 253K. While reducing the temperature to 203K causes trend reversion. Measurements performed at 203K are burdened with large errors resulting from the bad peak-to-noise ratio dependent on the limitations of the photomultiplier and the low level of scintillation.

Experimental tests performed at NCBJ are supported by the theoretical models made by a group from the USA [4]-[5]. For more details read [6].

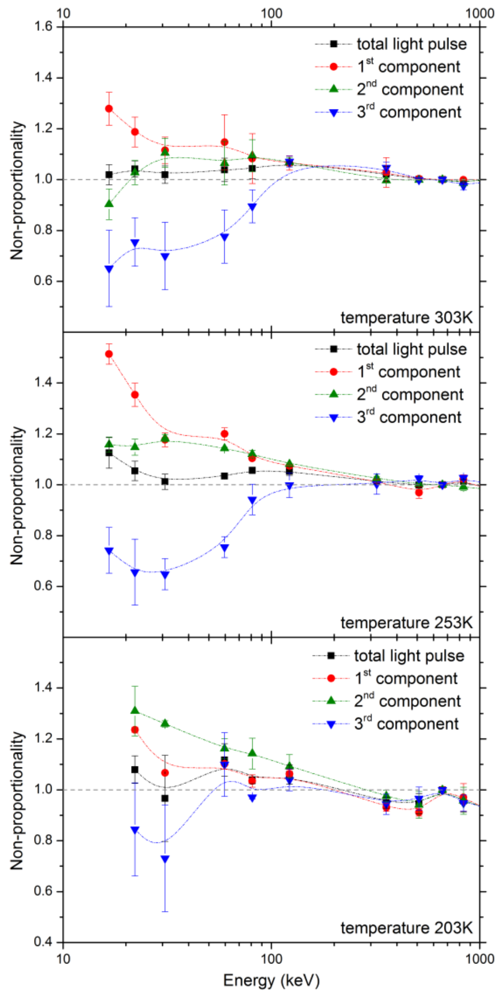

Fig. 1. Comparison of the non-proportionality characteristics of the 1st, 2nd and 3rd component at 303, 253 and 202K.

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Scintillation response to gamma-rays measured over a wide temperature range for CsI:Tl with a SiPM photodetector

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Continuing our studies from last year we developed a method to cover relative light yield curves over the temperature range between -185°C and +150°C. We used a custom designed liquid nitrogen (LN_2) cooled cryostat with specially constructed copper frames to allow mounting a scintillator and a photodetector separately. Light from a thallium doped CsI sample was collected by an HUV-HD SiPM from FBK with 6×6 mm^2 area and 25×25 μm^2 cell pitch [1]. Two voltage regulators were used to heat the crystal from nearly LN_2 boiling point to almost room temperature (RT). Once taken out from the dewar, the cryostat was used for crystal characterization between RT and +150°C.

We measured the relative light yield of CsI:Tl as a function of crystal temperature using two shaping time constants in the spectroscopy amplifier, 2 µs and 10 µs. Fig. 1 presents temperature dependences of CsI:Tl light yield measured during this experiment and reported by other groups.

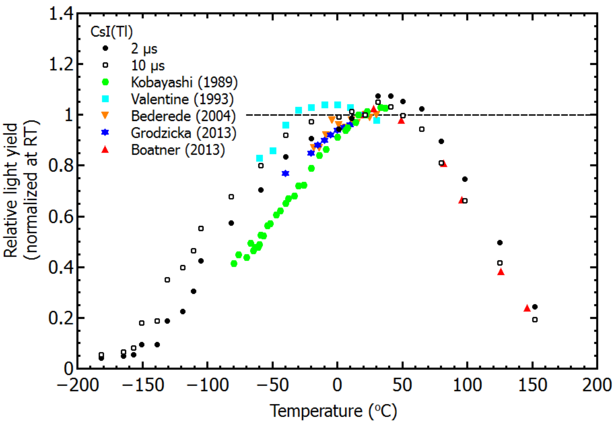

Fig. 1. Relative light yield of a CsI:Tl crystal as a function of sample temperature, recorded for 662 keV γ-rays.

In addition to sample-to-sample variations and the variety of experimental techniques used, the spread in the slopes of the measured curves arises due to differences in shaping (integration) times applied for pulse processing. The temperature dependence of each decay mode can be different. When long shaping times are used, the contribution of slow decay modes to the recorded scintillation yield is significantly larger. As a result, the light yield measured as a function of temperature for different shaping times also shows some variance.

To highlight the influence of long decay modes on the temperature dependence of the relative light yield we plotted the ratio of light output recorded with 10 µs and 2 µs shaping time constants (see Fig. 2). The ratio decreases monotonically with increasing temperature over the entire temperature range covered, except for temperatures between –160°C and –100°C, where a substantial rise appears.

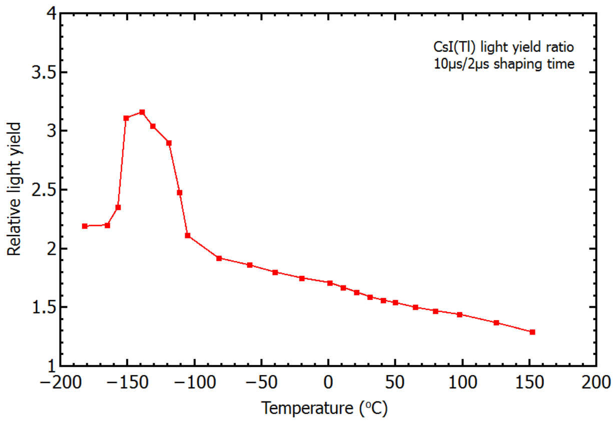

Fig. 2. The ratio of the relative light yield of a CsI:Tl crystal as a function of sample temperature, recorded using 10 µs and 2 µs shaping time constants in the amplifier.

This observation points to an increase of the long decay component related to a process, that is intense only in the mentioned temperature range. It can be explained with the thermally stimulated luminescence (TSL) glow curve measured for thallium doped CsI by Gridin et al. BŁĄD! NIE MOŻNA ODNALEŹĆ ŹRÓDŁA ODWOŁANIA., where a peak appears at 115 K.

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Silicon photomultiplier irradiation by neutron flux

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Multi-Pixel Photon Counters are novel silicon photodetectors made up of multiple avalanche photodiode (APD) cells operated in Geiger mode and connected toa common readout. The advantages of these photodetectors are: high gain of 10^5 to 10^7, fast response time, compact size, insensitivity to magnetic fields and low bias voltage, below 100 V. They can be used in many scientific and commercial applications, e.g. medicine, high-energy physics and astrophysics.

The goal of this paper was to study the evolution of MPPC properties during neutron irradiation. The PuBe neutron source used in this experiment is characterized by a continuous neutron energy spectrum with average energy about 4.6 MeV and internal activity of about $8\text{x}10^5$ n/s in 4π. In our work we investigate I-V characteristics. We pay close attention to determine the energy resolution of the irradiated photodetectors coupled to a non-irradiated scintillator.

In our set-up (Fig. 1) we used two types of MPPC photodetectors from Hamamatsu: S13360-3050CS and S13360-6050CS, which are characterized by different active areas: 3x3 mm^2 and 6x6 mm^2 respectively and 50 μm pixel pitch size. During the irradiation process, the geometry between the MPPC and the neutron source was chosen to keep the same neutron flux for each type of MPPC.

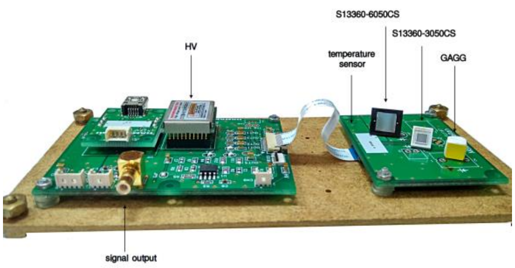

Fig. 1. Experimental set-up: MPPC photodetectors from Hamamatsu: S13360-3050CS and S13360-6050CS, GAGG scintillator and Hamamatsu evaluation board C12332-01.

To determine the current-voltage (I-V) characteristics of each MPPC a Keithley 2400 Series SourceMeter was used. This instrument can register currents starting from single picoampers. For safety reason upper current limit was set to 100 μA. All measurements were performed in remote mode, controlled by a PC.

As can be seen in Fig. 2, neutrons from the PuBe source cause a very fast increase of the current for the photodetector with 6x6 mm^2 area. Similar behaviour was observed for smaller MPPC. Assuming the same value of operating voltage, equal to the initial breakdown voltage (before irradiation), the relationship between current and neutron fluence deviates from the linear fit.

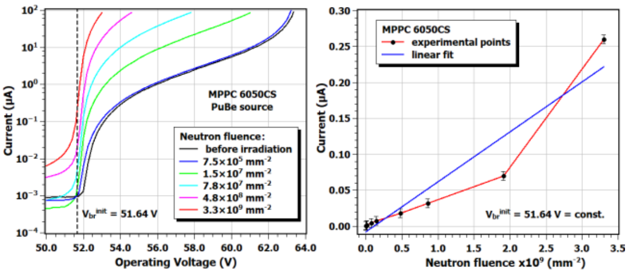

Fig. 2. Left – Example of the evolution of I-V characteristics measured for S13360-6050CS MPPC type induced by neutrons. Right - the current increase for constant breakdown voltage.

To observe energy resolution degradation caused by irradiation of the MPPCs, a 5x5x5 mm^3 GAGG scintillator was chosen. As a readout system CAEN digitizer DT5720 was used. Fig. 3 presents the evolution of the energy resolution of the 662 keV line from ^{137}Cs measured for a non-irradiated scintillator coupled to the MPPC before and after neutron irradiation. The initial energy resolution was about 7% and about 5% for 3x3 mm^2 and 6x6 mm^2 MPPCs, respectively. We observe a strong energy resolution degradation with saturation effect in the range of 10.5% for both MPPC types.

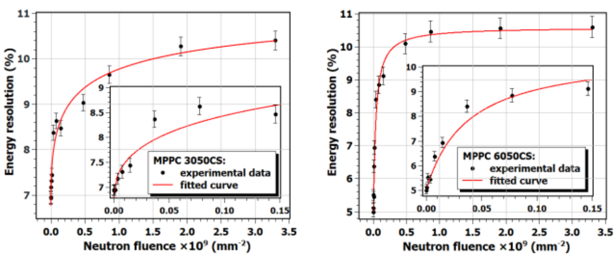

Fig. 3. Energy resolution of the 662 keV line from ^{137}Cs measured with GAGG scintillator before and after MPPC irradiation by neutrons. Left - 3x3 mm^2 and right - 6x6 mm^2 MPPC size.

The experimental results show that MPPC photodetectors are sensitive to neutrons. We observe a strong increase of the dark current rate with neutron fluence and strong energy resolution degradation with a saturation effect for high neutron fluence. In the latter case, a strong noise contribution to the measured energy resolution is responsible for the observed results.

Comparison of SensL and Hamamatsu 4x4 channel SiPM arrays in gamma spectrometry with scintillators

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The market of Silicon Photomultipliers (SiPMs) consists of many manufacturers that produce their detectors using different technologies. Hamamatsu (Japan) and SensL (Ireland) seems to be the most popular companies that produce large SiPM arrays. The aim of this work is the characterization and comparison of 4x4 channel SiPM arrays produced by these two producers. Both of the tested SiPMs are made in through-silicon via (TSV) technology, consist of 16, 3×3 mm avalanche photodiode (APD) cells and have a fill factor slightly above 60%. The largest difference is in the single APD cell size and hence the total number of APD cells (55 424 for Hamamatsu, 76 640 for SensL). In the case of the SensL SiPM, its spectral response characteristics are shifted slightly towards shorter wavelengths with a maximum at 420nm (450nm for Hamamatsu). The main parameters of the tested SiPM arrays are collected in Table 1.

Table 1. Main parameters of the testedSiPMs.

Manufacturer	Hamamatsu	SensL
Technology	TSV (through silicon via)	
Type	S12642 -0404PA	MicroFMV -30035-TSV
Number of channels	16 (4×4ch)	
Active area/channel	3×3 mm	
Effective active area (mm)	12×12	
Number of APD cells/channel	3 464	4 790
Total Number of APD cells	55 424	76 640
APD cell size [1)]	50×50 µm	44×44 µm
Fill factor (%)	62	64
Gain	1.25×10^6	6×10^6
Spectral resp. range (maximum sensitivity)	320-900 nm (450 nm)	300-800 nm (420 nm)
Capacitance/channel	342 pF	900 pF
Temperature coefficient	60 mV/°C	21.5 mV/°C

The pitch of the APD cell including dead space.

The presented measurements cover selection of the optimum SiPM operating voltage (with respect to energy resolution), verification of the excess noise factor and a check of the linearity characteristics. Moreover, gamma spectrometry with LSO, BGO and CsI:Tl scintillators together with the pulse characteristics for these crystals (rise time and full time) is reported, as well as the temperature dependence. The presented measurements show better performance of the SensL array compared to the Hamamatsu detector.

The study of gamma spectrometry with the three different scintillators showed comparable performance reflected in practically the same energy resolution (see Fig. 1), an essential parameter for most applications. However, some other performances, important for the user, like temperature stability, bias voltage and its influence on the SiPM gain are significantly better in the case of the SensL device. Moreover, the SensL array exhibits a better linearity due to the larger number of APD cells. The results of the measurements are collected in Table 2.

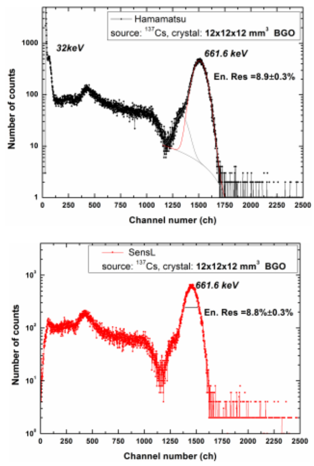

Fig. 1. The energy spectra of 661.6keV gamma rays, as measured with a12x12x12mm BGO crystal coupled to Hamamatsu (left) and SensL (right) SiPMs.

Table 2. The main parameters of both SiPMs as measured in the present studies.

	Hamamatsu	SensL
Optimum operating voltage	66.40V	28.25V
Overvoltage	2.10V	3.68V
Breakdown voltage	64.30V	24.57V
Energy resolution at 320keV measured with BGO scintillator 12x12x12mm	13.2±0.4%	12.2±0.4%
PHE number [1)] [phe/MeV]	2 420± 240	2 400± 400
Dark current for optimum operating voltage	19 500 nA ± 1 950	5 520 nA ±550
Temperature coefficient	60.2mV/0C	20.7 mV/°C
Change of Peak position	7,02%/°C	2,09%/°C
Change of peak position	1,12% per 10mV	0,49% per 10mV
ENF for optimum operating voltage	1.7±0.1	1.5±0.1

[1)]Measured at the optimum bias voltage.

Scintillation parameters of $Lu_xY_{1-x}AG$:Pr and LuAG:Pr,Mo crystals

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Recently, there has been an increased interest in scintillators belonging to the family of garnet crystals. Praseodymium activated LuAG (Lu3Al5O12:Pr) shows decent properties in terms of light output, energy resolution and fast emission originating from the 5d14f1 → 4f2 transitions in Pr3+, peaking at 310 nm. Since the material shows potential for application as a detector in PET imaging there have been attempts to improve the properties of this crystal.

Previously published results show that the aim of enhancing light yield and energy resolution has been successful and in our work we report an extended and detailed study of the influence of crystal composition on scintillation parametrs.

Two ways of achieving the enhancement were proposed:

- by applying a method of band gap engineering which was realized by partially substituting lutetium with yttrium in the crystal lattice,

- deliberate addition of impurities that were expected to introduce competitive trapping sites in the band gap of the material accomplished by the addition of small quantities of molybdenum.

A wide array of radiation sources emitting gamma radiation in the range between 14.4 to 1274 keV were used to perform measurements on a series of mixed (LuxY1-x)3Al5O12 crystals, where x = 0.00, 0.25, 0.50, 0.75, 1.00 and on LuAG:Pr co-doped with trace amounts of molybdenum (Mo at 0.005, 0.0009 and 0.0005 % mol.). The measurements were performed at various shaping times to study the impact of the material composition on the longer decay components of the pulse shape and on the linearity of the scintillation response.

Typical non-proportionality characteristics are presented in Fig. 1. Scintillator parameters such as energy resolution, intrinsic resolution, light output and scintillation decay times have been calculated based on the measured pulse height spectra. Some of the results are presented in Table 1 where it is clearly visible that the partial substitution of lutetium with yttrium in (Lu0.75Y0.25)3Al5O12:Pr results in an increase of the light output by 20% in comparison to the best available LuAG:Pr sample, despite the density decrease. Additionally, the energy resolution also exhibits improvement.

In Fig. 2. calculated decay times are shown. One may observe that the addition of yttrium elongates the fast component however the longer component is uniformly shortened in all of the yttrium containing samples.

The data also suggest that the influence of molybdenum addition is of the lesser importance since the co-doping does not introduce significant changes to the decay times and the improvement of the scintillation parameters is moderate.

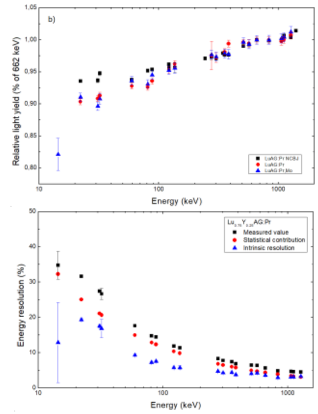

Fig. 1. Light yield (left) and energy resolution (right) non-proportionality.

Table 1. Properties of the investigated samples.

Formula	Light Output (ph/MeV)	Energy Resolution (%)
$Y_3Al_5O_{12}$:Pr	13 700	6.4
$Lu_3Al_5O_{12}$:Pr	9 400	11.5
$Lu_3Al_5O_{12}$:Pr NCBJ	14 200	5.7
$(Lu_{0.75}Y_{0.25})_3Al_5O_{12}$:Pr	17 100	5.6
$(Lu_{0.50}Y_{0.50})_3Al_5O_{12}$:Pr	13 800	6.6
$(Lu_{0.25}Y_{0.75})_3Al_5O_{12}$:Pr	14 900	7.2
$Lu_3Al_5O_{12}$:Pr,Mo (0.0005%)	12 700	5.2
$Lu_3Al_5O_{12}$:Pr,Mo (0.0009%)	14 500	6.1
$Lu_3Al_5O_{12}$:Pr,Mo (0.005%)	13 700	6.9

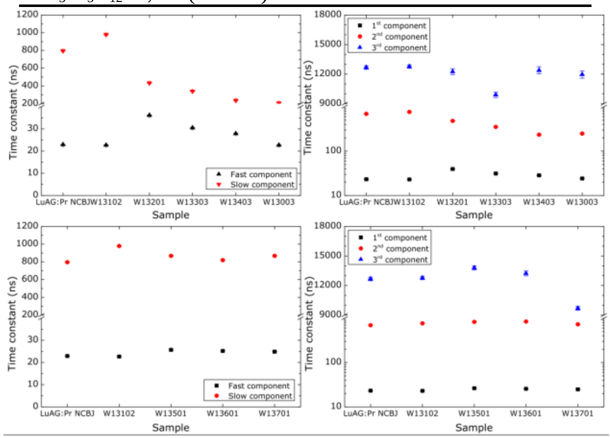

Fig. 2. Calculated values of decay time constants for all samples, measured at 2 (left) and 10 μs time scale (right).

Performance of 2 inch and 3 inch scintillation detectors with SiPM light readout

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The spectroscopic performance of 4 types of large detectors consisting of 3 different scintillators ($LaBr_3$, NaI(Tl) and BGO) coupled to a large MPPC array was studied. The measurements were made with a S12642-1616PB-50(X) Hamamatsu TSV MPPC array with a 50x50 μm^2 cell size and effective active area of 48x48 mm^2 (16x16 channels). In all the measurements common readout of all channels was used. The results obtained with the MPPC, such as energy resolution and linearity, were compared with measurements of the same crystals on a classic photomultiplier. An example of one of the studied detector configuration, consisting of the MPPC array and a 2 inch $LaBr_3$, is presented in Fig. 1.

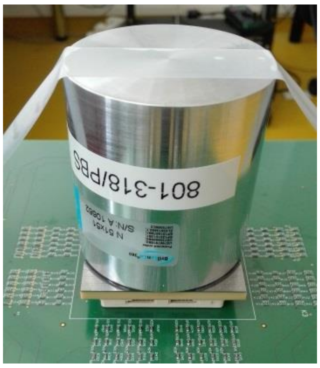

Fig. 1. One of the detector configurations used during the studies – a 2 inch $LaBr_3$ crystal coupled to a 48x48 mm^2 Hamamatsu TSV MPPC array S12642-1616PB-50(X).

The most common problem in the case of large area SiPM arrays is the high capacitance of the detector. However, in the case of spectroscopic measurements with large arrays this drawback may become an advantage. The very high capacitance together with the input resistance of the readout electronics creates an integrating circuit that changes the SiPM output signal. The resulting pulse is similar to that obtained after a charge preamplifier and hence the direct MPPC pulse can be send to a spectroscopy amplifier or digital MCA.

Because any SiPM is made of a finite number of photosensitive elements (micro-cells) its response to a high number of photons is always nonlinear. This is one of the main SiPM issues in spectrometric applications. Due to the very high number of 921 600 micro-cells the tested MPPC has excellent linearity. Even for high overvoltage and a fast $LaBr_3$ scintillator the deviation from the ideal line is at the level of only 4% for the 662keV line from ^{137}Cs.

Good energy resolution at a specific energy line or energy range is one of the key spectroscopic properties of a scintillation detector. The other important parameter is the low energy detection limit and dynamic range of the detector. In Fig. 2 low energy spectra of Mo-93, Am-57 and Cd-109 gamma sources for a 3 inch NaI(Tl) are presented. In the case of this detector, the peak at 16.6keV from Mo-93 is visible but slightly mixed with noise. Similar spectra obtained for 2 inch detectors showed good separation and energy resolution of the 16.6keV peak. Only in the case of 3 a inch BGO did the low energy threshold have to be set much higher, around 170keV.

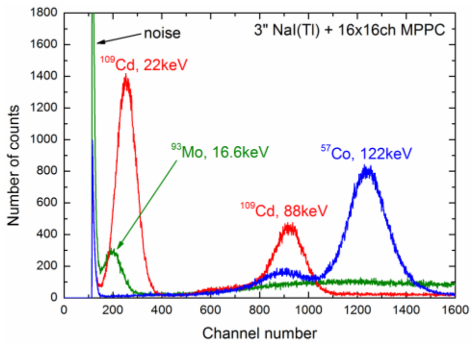

Fig. 2. Low energy spectra of Mo-93, Am-57 and Cd-109 gamma sources. The peak at 16.6keV from Mo-93 is visible but slightly mixed with noise.

In Table I the MPPC results are compared with measurements of the same crystals on a classic photomultiplier (XP5212B). The study proved that large MPPC arrays can be successfully used for spectrometry with 2 or 3 inch scintillators assuring very good energy resolution and linearity. For large MPPC arrays and slow scintillators the nonlinear response of these detectors is negligible due to the high number of micro-cells. The measurements showed that in the case of large MPPC (or SiPM) arrays characterized by large total capacitance the direct output signal from the detector can be used as an input to a spectroscopy amplifier or digital MCA.

Table 1. Comparison of results obtained with the tested 2 inch MPPC and classic PMT XP5212B

Crystal	En. Res. at 662keV [%] MPPC	En. Res. at 662keV [%] XP5212B PMT	Nonlinearity at 662keV [%]	Nonlinearity at 1275keV [%]
2″ $LaBr_3$	3.83 ± 0.05	3.53 ± 0.04	4.3	6.9
2″ NaI(Tl)	6.95 ± 0.09	6.94 ± 0.09	1.6	2.6
3″ NaI(Tl)	8.15 ± 0.10	6.5 ± 0.2	1.2	1.9
3″ BGO	13.41 ± 0.17	10.78 ± 0.13	1.1	1.3

Temperature dependence of scintillation properties of La-GPS(Ce)

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[2]*C&A corporation, Sendai, JAPAN*

In this work the scintillation response of La-GPS(Ce) scintillator is reported. The light output and energy resolution at temperatures up to 150 ˚C are reported. We also tested the basic properties of this scintillator at room temperature. The light output of La-GPS(Ce) samples is calculated to be about 12 000 phe/MeV, which gives about 30 000 ph/MeV.

1. Measurements at room temperature - non-proportionality and energy resolution

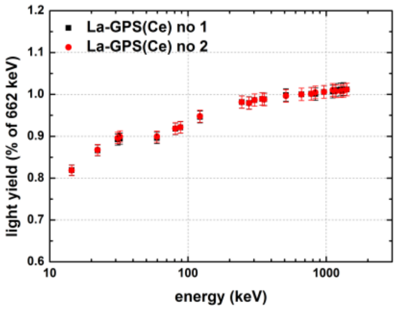

Fig. 1. Non-proportionality of La-GPS(Ce .

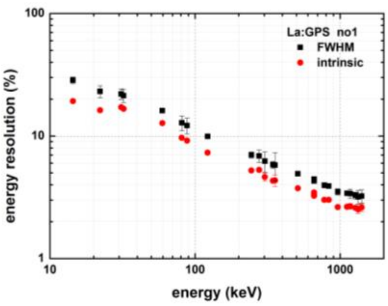

Fig. 2. Energy resolution as a function of the energy measured energyfor La-GPS(Ce).

The non-proportionality of the light yield is defined as the ratio of the photoelectron yield measured for a specific γ-ray energy to that measured for the 662 keV line from ^{137}Cs. Fig. 1 presents the non-proportionality for La-GPS(Ce). The FWHM for both La-GPS(Ce) samples irradiated with 662 keV γ rays from ^{137}Cs is 4.4% (see Fig. 2).

2. Measurements at high temperatures - light output and energy resolution

The temperature dependence of light output and energy resolution of La-GPS(Ce) were measured using atemperature-resistant 9110V02 ET Enterprises PMT. The measurements were performed in a Genviro climate chamber. The light yield of the La-GPS(Ce) sample decreases with increasing temperature. For 150 ˚C the light yield is approximately 50% of the yield at room temperature.

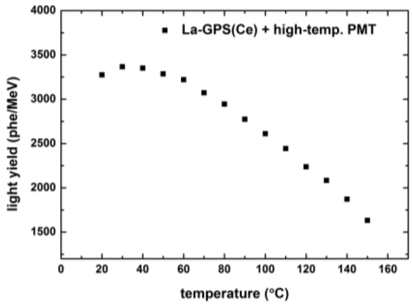

Fig. 3. Light yield as a function of temperature for La-GPS(Ce)

Energy resolution

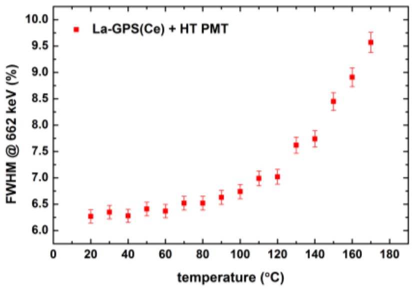

Fig. 4. Energy resolution of the 662-keV γ ray line as a function of temperature measured with La-GPS(Ce).

At room temperature, the energy resolution of 662-keV γ rays measured with an ET Enterprises 9110V02 PMT is about 6.5% (see Fig. 4). The ET Enterprises 9110V02 PMT has low quantum efficiency, therefore we observe lower light yield and worse energy resolution than that measured with a Hamamatsu R6231-100 PMT at room temperature.

La-GPS(Ce) is a very bright scintillator with good energy resolution and non-proportionality characteristics at room temperature. La-GPS(Ce) is proportional from several tens of keV up to the MeV-range. The light yield and energy resolution degraded at high temperatures.

Approximation of gamma-ray Peaks Registered with Scintillators

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Gamma-ray peaks, especially FEP, SEP and DEP, registered in scintillators are relatively broad and observed on a high non-linear background, see Fig. 1. Any program dealing with the analysis of gamma-ray spectrum has to find peaks, to estimate the peak location, centroid, height, width and peak integration. It could include data smoothing as well.

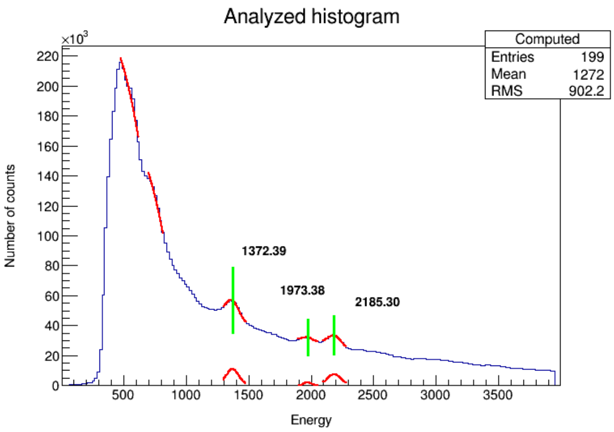

Fig. 1. Experimental spectrum (blue histogram) registered with a 20×15 mm $CeBr_3$ scintillator during 14 MeV neutron irradiation measurements performed with the Frascati Neutron Generator [SOFT_GCU]. Solid red line: results of the approximation.

A method is presented to analyse gamma-ray peaks registered in scintillators based on a Sensitive Nonlinear Iterative Peak (SNIP) algorithm [1]. Two types of SNIP algorithms are now implemented: Increasing Clipping Window and Decreasing Clipping Window but it is easy to include other SNIP methods. Due to the high sensitivity of the algorithm and possible false detection, a threshold mechanism was used.

The program is written in C++ in the Codeblocks environment using the CERN ROOT libraries. Compatibility with ROOT versions from 5.34.19 to 5.34.36 has been tested. The program can run on various hardware platforms. For testing purposes, the program was compiled and run in the Linux Debian 9 "stretch" and Windows 8.1 environments.

All parameters related to the approximation are set in the configuration file, which is loaded and analysed during program execution. A function for loading and analysing this configuration file allows easy addition of new functionalities to the program.

The results of the program are: a *text report* displayed on the console, a *text file* with a report containing the parameters of the detected peaks. In addition, an experimental histogram is displayed on the screen with the approximation results which can be saved to an image file, see Fig. 1.

A sum of linear and Gaussian functions is used to approximate the found peaks. The linear function depends on two parameters, the Gaussian function on thre. Because the sum of this function is non-linear, it has been implemented using iterative method to determine approximation parameters. The criteria ofmaximizing a likelihood function (Maximum Likelihood function) were implemented. The χ^2 test was used to verify the reliability of the approximation obtained. The iterative algorithm requires correct starting points to be foundfor an approximation - otherwise, an appropriate minimum will not be found.

The method of determining starting points is based on an analysis of the histogram data. The iterative algorithm also requires a proper stop criterion. The stop criterion was determined based on the following conditions: the algorithm must be convergent, the error must be small, the top of the Gaussian function (Gauss mean parameter) must have a value in the peak range. A vector of error parameters consists of variances of computed parameters. These variances depend on the quality of the adjustment of the sum of the Gaussian and linear functions to a given histogram. The following parameters are calculated: NDF (Number ofDegrees of Freedom) and χ^2 test results. These parameters depend on the quality of the fit of the function to the measurement data. Based on the above parameters, the best width of the histogram bins is calculated.

Reference

[1] C.G. Ryan et al., *SNIP, a statistics-sensitive background treatment for the quantitative analysis of PIXE spectra in geoscience applications*, Nucl. Instr. Meth. **B34** (1988) 396, https://doi.org/10.1016/0168-583X(88)90063-8

This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2018 allocated for the realization of international co-financed projects.

MTCD@NCBJ - MPPC Temperature Compensation Device

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Due to the strong Multi Pixel Photon Counter (MPPC) gain dependence on temperature, a prototype MPPC Temperature Compensation Device (MTCD@NCBJ) was designed and produced at NCBJ. It will be used at the Joint European Torus (JET), with the upgraded detectors during high count rate measurements.

In Fig. 1, the overall scheme of the electronics for the upgraded JET Gamma Camera is shown.

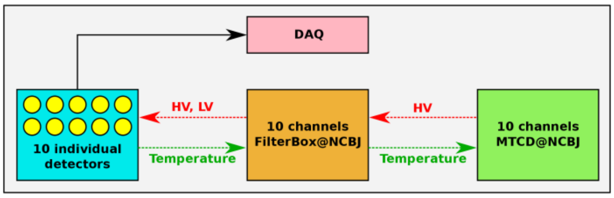

Fig. 1. Overall scheme of the detector system for the upgraded JET Gamma-ray Camera. HV denotes the MPPC voltage, LV – the power supply for temperature sensors and active elements.

The MTCD@NCBJ, with integrated power supplies, uses real-time temperature monitoring to maintain a constant value of the MPPC gain. It comprises two main parts: one connected with the adjustable MPPC voltage channels for each GC channel, the other used to determine an optimum value of the voltage which guarantees a constant gain. Each channel has its own isolated converter to eliminate ground loops, followed by a low-dropout regulator to minimize ripple on the output.

All functions are controlled from a personal computer with a communication based on Ethernet. In Fig. 2, the MTCD@NCBJ board is shown.

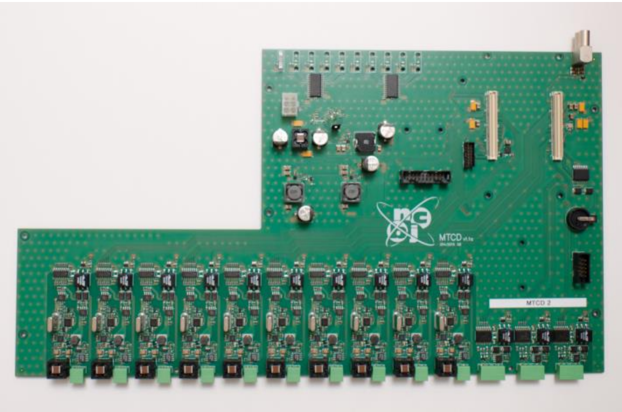

Fig. 2. Photo of MTCD@NCBJ with integrated power supplies.

A protection of overvoltage was implemented in the control part of the program to guarantee that the detectors will not be destroyed by applying too high a voltage.

A series of measurements was performed at NCBJ with a standard ^{137}Cs source, registered with a ϕ20×15 mm cylindrical $CeBr_3$ scintillator, MPPC from Hamamatsu and an active system based on a transimpedance amplifier (TIA) in order to check the MTCD@NCBJ performance.

The influence of the MPPC temperature change on gamma-ray spectra was checked in the temperature range between 10°C and 34°C as shown in Fig. 3.

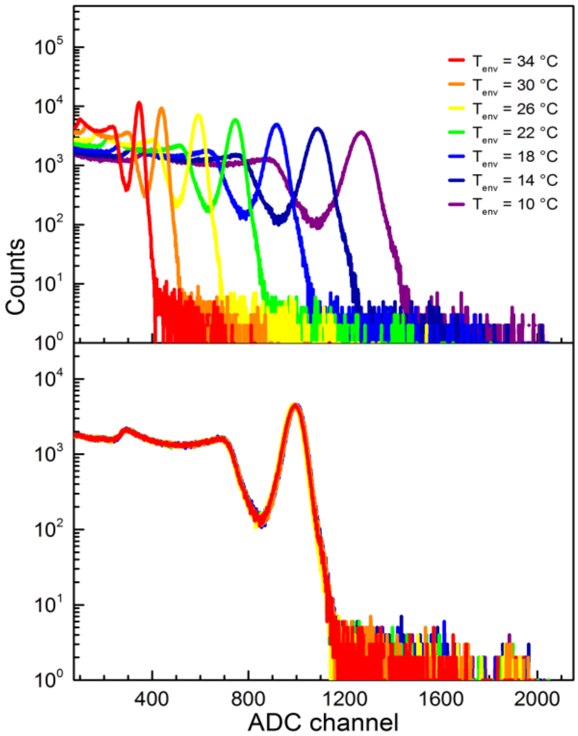

Fig. 3. Peak position as a function of MPPC temperature. Upper: without MTCD@NCBJ. Lower: with MTCD@NCBJ. Operational voltage: 57.5 V.

From the measurements performedwe conclude that MTCD@NCBJ is able to maintain a constant value of MPPC gain for both active and passive bases.

Reference

[1] A. Urban et al., *Detectors with a Compensation for MPPC Gain Dependence on Temperature*, sub. to IEEE Transactions on Nuclear Science (2018).

This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2018 allocated for the realization of international co-financed projects.

Basic performance of MPPCs and PMTs

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Upgrading an already existing detector system is usually a challenging task because of constraints in terms of, e.g., available space for a new device. In the case of the JET Gamma-ray Camera, limited space was the main reason to use, as a photodetector, a multi-pixel photon counter (MPPC), also known as a silicon photomultiplier or SiPM. If space were not a limiting factor, a photomultiplier tube (PMT) is a good alternative. We present a comparison of full width at half maximum (FWHM) values and overall detector efficiency for solutions based on MPPCs and PMTs.

In both detector setups ϕ25.4×16.9 mm $LaBr_3$:Ce scintillators were installed. One scintillator was coupled to an MPPC from Hamamatsu connected to a transimpedance amplifier (TIA), the MTCD@NCBJ and the FilterBox@NCBJ [1]. The other was coupled to a Hamamatsu photomultiplier tube with an active voltage divider.

Since the energy resolution of scintillators coupled to MPPCs is strongly dependent on the operational voltage, an optimum MPPC voltage was experimentally determined, see Fig. 1.

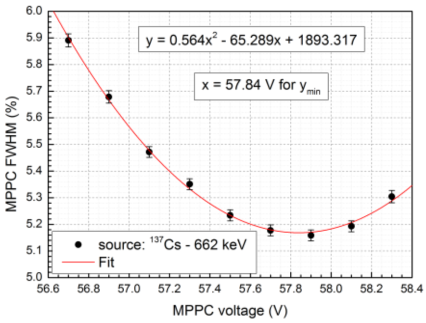

Fig. 1. Optimal operational voltage for the MPPC.

It was found that the optimum voltage of 57.84 V had to be decreased to 57.70 V to register gamma rays with an energy of about 6.1 MeV, see FEP (full energy peak) in Fig. 2.

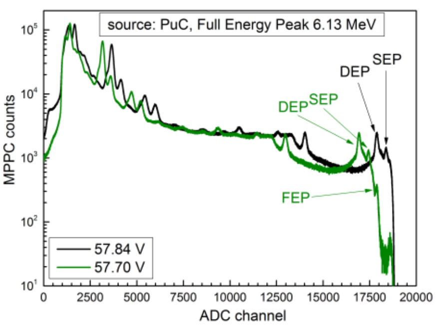

Fig. 2. Two operational voltages of the MPPC.

Both detectors were placed at the same distance from the source and measurements were performed at the same controlled room temperature. Spectra were registered with a CAEN DT5730 digitizer. For ^{137}Cs, ^{22}Na and ^{60}Co sources acquisition time was 5 minutes, for PuBe, and PuC – 16 hours. In Fig. 3 measured energy resolution values for eleven gamma-ray energies are shown.

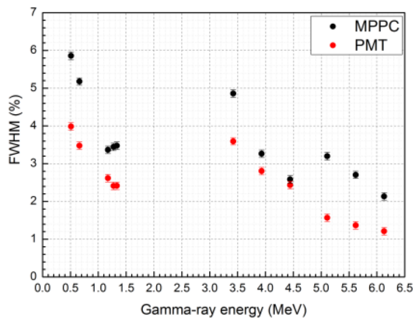

Fig. 3. Energy resolution for eleven measured gamma-ray energies.

A detector coupled to a PMT has a higher overall efficiency by a factor of ~30 than when coupled to an MPPC, see Fig. 4.

So, if space is not a limiting factor, a detector system solution with a photomultiplier tube is a better one, if FWHM and overall detector efficiency are important parameters.

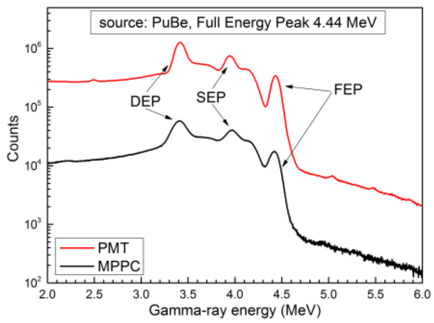

Fig. 4. Spectra registered in 16 h measurement with a PuBe source emitting a 4.44 MeV gamma line with both detectors.

Reference

[1] G. Boltruczyk et al., *Development of MPPC-based detectors for high count rate DT campaigns at JET*, Fus. Eng. Design **123** (2017) 940–944.

This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2018 allocated for the realization of international co-financed projects.

Digital acquisition in high count rate spectrometry - upgrade

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National Centre for Nuclear Research, Otwock-Świerk, Poland

A data acquisition system (DAQ) for high resolution spectrometry measurements at Mcps rates, DNG@NCBJ (Digital Neutron Gamma @NCBJ), was developed at NCBJ [1]. Data acquisition and signal processing operations are performed using an FPGA with an ARM9 processor on a Xilinx ZC706 evaluation board. The measurement system is based on direct sampling of the input signal. A high speed Texas Instruments ADS5400 (12-bit 1 GSPS) ADC is used. A dedicated IP core has been developed to fulfill the system requirements with a strong focus on high count rate pulse processing capability.

The upgrade of this system is divided into two parts. The digital board with the FPGA is replaced with a Mini ITX form factor board, see Fig. 1. A standard computer form factor allows a 19” size compact instrument to be built, ready to be mounted in a larger infrastructure. An Avnet AES-Mini-ITX-7Z045-G evaluation board was selected [2]. Both the architecture and specification of this board (FPGA part number, available memory, FMC connector, communication standards) are compatible with the previous board. This allows us to move all the IP cores and software between boards with only small changes in the board definitions files. Several scripts were added to simplify the measurement process. An option to use the Linaro Linux distribution with access to install software using a precompiled packet software data base instead of embedded Linux was added.

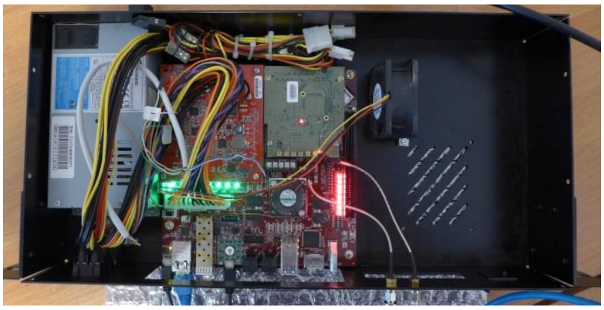

Fig. 1. Upgraded DNG@NCBJ digital acquisition system in a 19” case.

In the second part of the upgrade, a new FMC standard board with an analogue to digital converter was developed, see Fig. 2. The main goal was to develop a board using the same ADC as in the previous board and redesign the analogue signal chain to keep the software and IP core compatibility. Several changes were made to minimalize noise and reduce sampling clock jitter.

The main changes in the upgraded DNG@NCBJ may be summarized as follows:

- generation and distribution chip for low noise crystal clock,
- low noise voltage controlled oscillator,
- low-dropout regulators (LDO) characterized by low noise and high power supply rejection ratio (PSRR) for each crucial analogue chip.

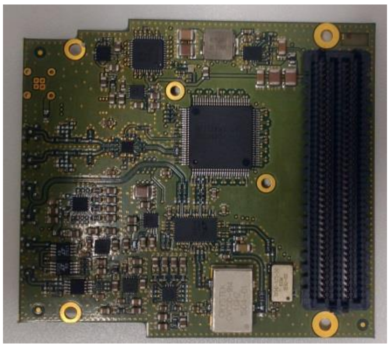

Fig. 2. Upgrade of the FMC standard board with analogue to digital converter.

In Fig. 3 an energy spectrum registered with the upgraded data acquisition system, a Photonis XP5500 photomultiplier and a 1”×1” $LaCl_3$:Ce scintillator is presented. A ^{60}Co source was used simultaneously with a strong ^{137}Cs source, with an activity of ~400 MBq, in order to increase the event rate.

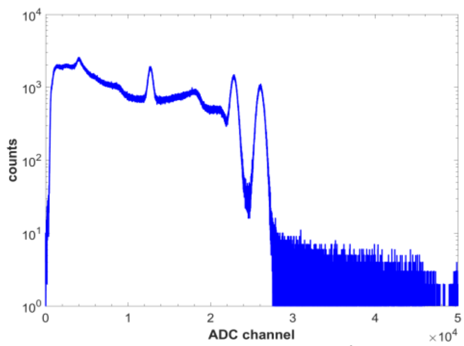

Fig. 3. Energy spectrum of ^{137}Cs and ^{60}Co measured with a 1”×1” $LaCl_3$:Ce and the upgraded DNG@NCBJ DAQ.

References

[1] *S Korolczuk et al,* Digital Acquisition in High Count Rate Gamma-Ray Spectrometry*, IEEE TNS, 63 (2016) 1668.*

[2] *http://*zedboard.org*/*product*/mini-itx-board*

This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2018 allocated for the realization of international co-financed projects.

Gamma-ray spectrometer for the MARIA nuclear reactor hot cell

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The electronics and Detection Systems Division has developed a gamma-ray spectrometer for the MARIA nuclear reactor hot cell. The instrument is a contribution to the larger diagnostics system which is being developed for the reactor under the Early Neutron Source project.

The seemingly simple task of identifying radioactive isotopes such as ^{137}Cs or ^{60}Co in spent nuclear fuel elements becomes challenging when their activity is of the order of 100 TBq. In radiation fields of this magnitude electronic devices tend to malfunction. Spectrometric detectors without appropriate shielding are flooded with events, and are no longer capable of distinguishing individual gamma rays from each other, see Fig. 1.

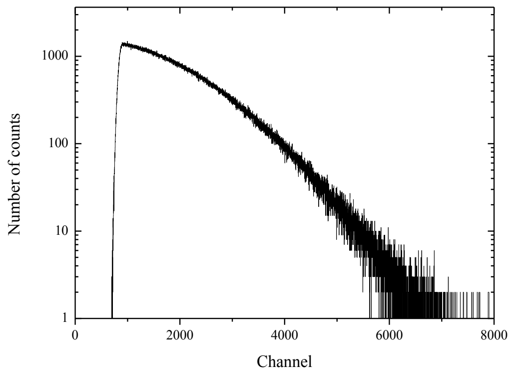

Fig. 1. Energy spectrum - the response of an overloaded detector. This particular spectrum was measured during initial tests, with an inadequately shielded $LaBr_3$ detector in the hot cell.

After a series of tests and market inquiry we have decided to use a 1″×1″ $LaBr_3$ scintillator, which was big enough to assure sufficient full energy absorption efficiency for high energy gamma quanta, and small enough to avoid extensive shielding. In order to comply with specific user requirements custom electronics and data acquisition systems have been designed and implemented.

Saint-Gobain Crystals, the only manufacturer of $LaBr_3$, has offered us the entire detector; a 1″×1″ $LaBr_3$ scintillator coupled with a 1.5″ Hamamatsu R9420 photomultiplier. For this detector a custom head was designed, including an active voltage divider, a HV supply, and a Cremat CR-113 preamplifier. The active voltage divider is necessary to prevent, or at least suppress, gain shifts due to changes of event rate. The head, along with the detector, was encapsulated in a single physical package, see Fig. 2.

Fig. 2. Gamma-ray spectrometer. The detector, plus its electronics, is inside the aluminum capsule.

The spectrometer, shielded from all directions by 10 cm lead bricks, may be positioned in a suitable location inside the hot cell. Power supply and communication is provided by means of two, 10 metre long cables from outside of the hot cell. The output is fed to a Tukan-DSP multichannel analyzer, see Fig. 3, connected to a PC via a USB cable.

Fig. 3. Tukan-DSP Digital Spectrometry Analyzer.

The analyzer has been provided with an Application Programming Interface in the form of a Dynamic Link Library. A dedicated User Graphics Interface is currently being developed by the instrument's end users.

This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of international co-financed projects.

Solid State Physics and Engineerin of Materials; Application

Asymmetric transfer hydrogenation in new N,N-diamine ligands derived from (-)-menthol

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Isolated molecules of enantiomerically pure diamines and amino alcohols are important mainly because of their range of applications such as organic synthesis as chiral ligands and organocatalysts, stereo-selective synthesis or applications in chemotherapeutics. They can also be used as chelators or organocatalysts to obtain enantiopure coordination compounds useful in homogeneous catalytic asymmetric synthesis.

Recently, a simple procedure for (+)-limonene and (+)-3-carene transformation into trans-1,2-diamine derivatives and their effectiveness as chiral ligands in the asymmetric transfer hydrogenation of aromatic ketones and imines was demonstrated [1,2].

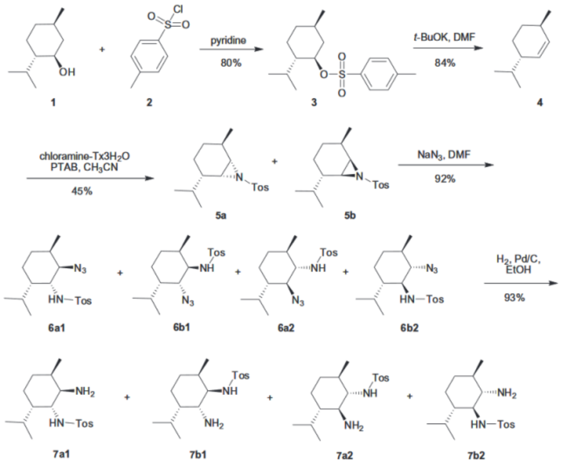

Fig. 1. Synthetic pathway of diamines 7a,b.

Table 1. Examples of studied atropisomers 6 obtained at different temperatures.

Entry	Temp. [°C]	Yield [%][b]			
		6a1	**6b1**	**6a2**	**6b2**
1	24	48	47	4	1
2	45	48	47	5	1
3	65	45	46	8	1
4	85	39	43	13	4
5	105	16	28	32	24
6	125	13	20	41	26
7	145[c]	16	21	27	23

This work [3] concentrated on using chiral ligands of monoterpenes and synthesis of new monotosylated diamines based on the (−)-menthol skeleton and their application in the asymmetric hydrogenation of selected acetophenones and 3,4-dihydro-ß-carboline (Fig. 1). Apart from the synthesis details, it was discovered that the distribution of azide **6** depends on the reaction temperature. As shown in Table 1, the contribution of isomers **6a2** and **6b2** to the reaction mixture increased together with the temperature and reached its maximum at 125°C. Therefore, changes of the temperature allow the propagation of the particular pair of isomers to be controlled.

Isomers **6a** and **6b** were isolated from the reaction mixture by column chromatography and crystallization from diethyl ether/hexane mixtures. The absolute stereochemistry and crystal structures of **6a1**, **6a2** and **6b1** were determined by the single crystal X-ray crystallography performed at NCBJ [3] (Figs. 2,3).

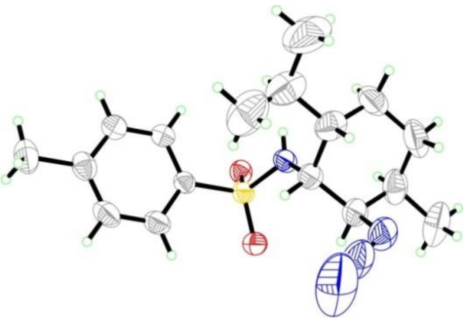

Fig. 2. Typical molecular conformations of 6a1 derived from X-ray structural studies.

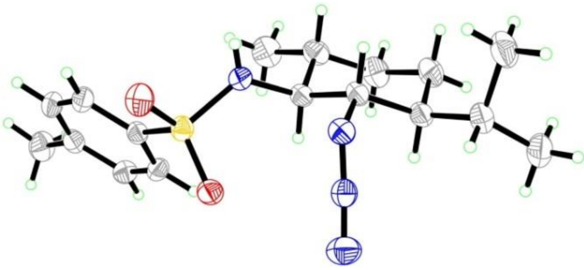

Fig. 3. Typical molecular conformations of 6a2 derived from X-ray structural studies.

References

[1] P. Roszkowski, J. K. Maurin, Z. Czarnocki; Tetrahedron-Asymmetry (2013) 24, 643-650.
[2] P. Roszkowski, P. Małecki, J. K. Maurin, Z. Czarnocki; Synthesis (2015) 47, 569-574.
[3] P. Roszkowski, J. K. Maurin, Z. Czarnocki; Tetrahedron-Asymmetry (2017) 28, 532-538.

Synthesis of selected meta- and ortho-substituted pentaarylpyridines

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Atropisomers are interesting stereoisomers possessing axial chirality resulting from restricted rotation around single bonds, and are found in many classes of compounds. Chiral ligands in supramolecular chemistry are important for the properties of compounds.

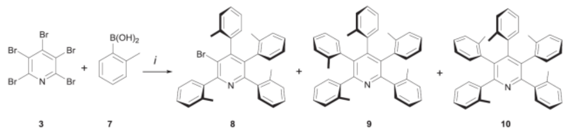

Fig. 1. Schematic synthesizes of 8-10 atropisomers.

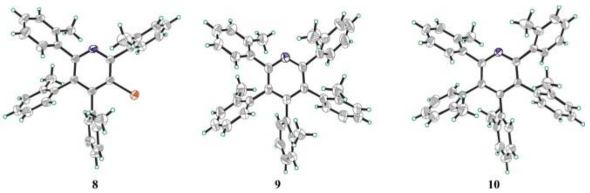

Fig. 2. Selected molecular structures derived from X-ray structural studies.

The phenomenon of atropisomerism occurring in ortho-substituted tri- and diarylpyridine derivatives was investigationed. Expecting that decoration of the pyridine core with five sterically demanding substituents would give rise to molecules of unique static and dynamic stereochemical properties, we considered the Suzuki-Miyaura cross-coupling reaction for this purpose. The first synthesis (Fig. 1) of sterically demanding, stable at room temperature atropisomeric derivatives of penta-(ortho-substituted phenyl) pyridines is described in Ref. [1]. Thermally stable atropisomers were isolated and characterized using X-ray diffraction (Fig 2.) and NMR methods. In the case of differently substituted 3,4,5-triaryl-2,6-dimethylpyridines and 2,3,5-triaryl-4,6-dimethylpyridines the optimized coupling conditions were found to be general for both isomeric tribromodimethylpyridines and a wide range of arylboronic acids substituted with electro-donating and electro-withdrawing groups [2]. In the case of compound **1m** we observed the presence of three components formed in 49% total yield and in approx. 1:1:1 molar ratio, having the same mass spectra and very similar NMR spectra. Components were separated using column chromatography and in two cases we performed an X-ray study at NCBJ. Although **1m** atropoisomers crystallize in the triclinic system, the crystal packing is different. This manifests itself in differences in unit cell volumes (1350.36(6) and 1374.68(14) Å^3, respectively) and because of the same unit cell contents result in different calculated crystal densities. The molecular geometries of the compounds are characterized by rotations of rigid fragments (rings) and flexible ethoxy groups.

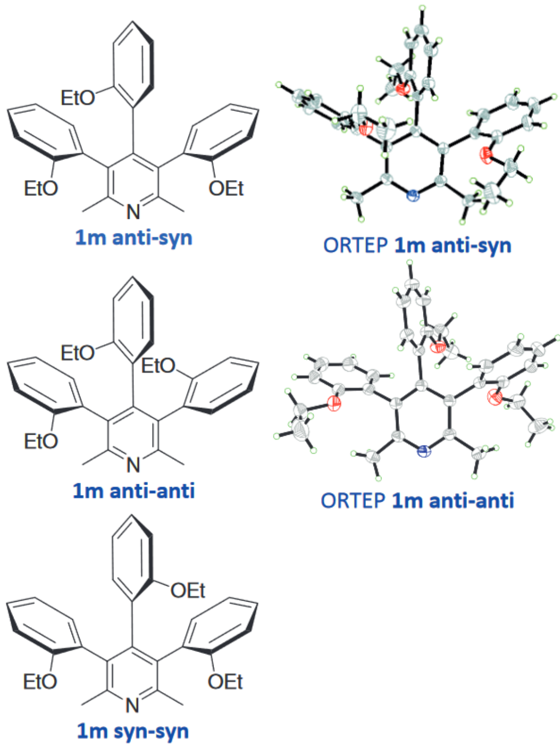

*Fig. 3. Studied stereochemistry of atropisomers **1m**.*

In **1m anti-syn** all three phenyl rings are not fully perpendicular to the pyridine ring plane. The ethoxy groups are almost co-planar with the respective phenyl rings and point towards the pyridine ring. Similarly in **1m anti-anti** all phenyl rings are inclined in one direction to the pyridine ring plane. The situation with the ethoxy groups looks a little bit different. Although two of them lie approximately in the respective phenyl ring planes the third one (on the left side of the ORTEP drawing) is out of plane. Such distortion is a result of the packing forces in the crystal.

References

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Unusual visible-light photolytic cleavage of tertiary amides during the synthesis of cyclolignans related to podophyllotoxin

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During the attempted photochemical cyclization of 2,3-bisbenzylidene-γ-hydroxybutyric acid cyclic amide ester, it was observed that a γ-butyrolactone ring was formed, which was concurrent with the release of the amine fragment from the amide. The process occurs with high yield giving rise to the formation of β-apopicropodophyllin and its regioisomer. Additional experiments confirmed the photochemical nature of this transformation, and that it is independent of the photocyclization of the benzylidene groups – a typical reactivity for members of the fulgide family. In contrast to the latter UV-driven cyclization, the photochemical cleavage of the amide was proven to proceed under irradiation with visible light. The natural amino acid l-proline was used as a chiral auxiliary in the attempted stereoselective synthesis of dihydronaphthalene lignans [1]. Heller's mechanism of the photocyclization of fulgides involves excitation of the carbonyl group which results in electron deficiency at the benzylic carbon atom. Here we have a rare example of a reaction in which the amide bond is photolytically cleaved with visible light. Our idea was to synthesize a molecule with only one carbonyl group conjugated with the benzylic moiety that would promote a regiospecific cyclization. Therefore, l-proline appeared a good candidate for the chiral auxiliary.

The bisbenzylidenesuccinyl platform as an amine protecting group was demonstrated and this reaction could be useful in the preparation of cyclolignans with two different benzylidenic substituents.

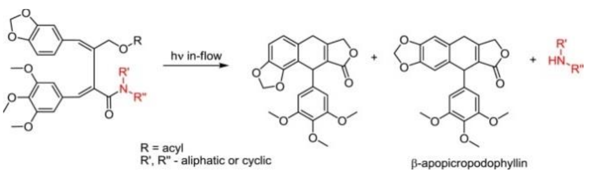


Fig. 1. Summary of the studied topic

As the result of the synthesis shown in Fig. 2 β-apopicropodophyllin **22** and its isomer **23** were obtained in the ratio 2.8/7.2. After separating the isomers on silica gel we did not observe any optical activity of the products. X-ray analysis performed at NCBJ confirmed that they were racemates (Fig. 3).

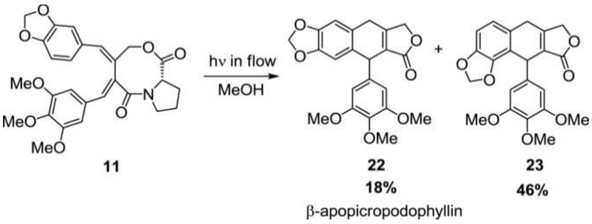
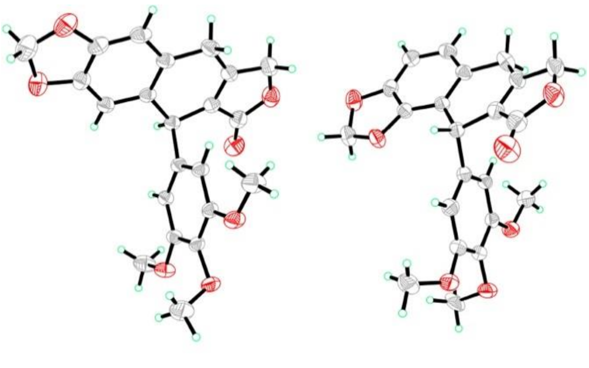


*Fig. 2. Irradiation of **11** in methanol under continuous-flow conditions 0.7 mL/$_{min}$ and λ_{max} = 365 nm.*



22 (A) **23 (B)**

*Fig. 3. ORTEP diagrams of compounds **22** and **23**.* derived from X-ray structural studies

The formation of racemates in our experiment indicates that upon irradiation the amide bond in **11** is cleaved and the lactone is formed before the cyclization occurs. This is a very unexpected observation since in the case of a very similar compound, **23,** the amide bond cleavage was very difficult.

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Mechanism of damage buildup in ion bombarded ZnO

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Defect processes in ZnO single crystals upon 300 keV Ar-ion bombardment were analysed using two complementary techniques: Rutherford Backscattering Spectroscopy in channelling conditions (RBS/c) and High Resolution X-Ray Diffraction (HRXRD), both supported additionally by extended numerical simulations. The RBS/c data were evaluated by means of the McChasy code. This unique code allows to separate determination of depth profiles of randomly displaced atoms and dislocations. A new model of damage accumulation and subsequent transformations in ion bombarded ZnO has been developed. It is based on the fact that simple defect migration and agglomeration results in the formation of two types of dislocation loops: basal loops located at a depth corresponding to the range of the incident Ar ions and pyramidal loops ones located beyond the ion range. As identified by HRXRD the driving force for this process is the lattice stress produced by atomic displacements. Increasing loop concentration produces important growth of the lattice strain resulting in plastic deformation of the implanted layer. The unique complementarity of RBS/c and HRXRD should be pointed out: whereas lattice distortions produced by basal loops extending in the direction perpendicular to the c-axis can be easily detected by HRXRD, RBS/c is completely insensitive to such defects. The opposite situation occurs in the case of pyramidal loops. However, in the latter case only use of the McChasy code for evaluation of RBS/c spectra allows determination of depth distributions of pyramidal loops.

The presented model is in agreement with numerous works of other authors [1-3], especially with some TEM observations, and allows better understanding of their results.

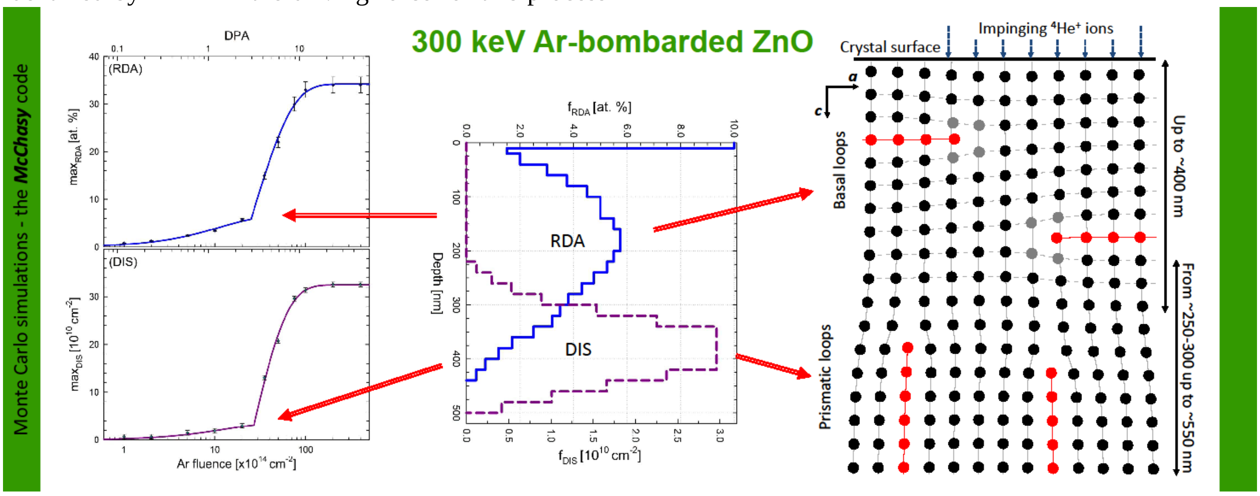

Fig. 1. Illustration of the mechanism of damage buildup in 300keV Ar bombarded ZnO single crystals.

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Structural transformations in heavy ion implanted ZnO

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Summary: Zinc oxide is a wide band gap semiconductor with outstanding optical properties, which can be used in white LEDs instead of the much more expensive GaN. However, utilization of ZnO for such applications requires modification of its optical properties. This can be realized by defect engineering and doping. In this paper we present a detailed study of the structural properties of Yb implanted single ZnO crystals. Hydrothermally grown wurtzite (0001) ZnO crystals were implanted with 150 keV Yb ions to fluencies of $5x10^{14}$, $1x10^{15}$ at/cm^{2}and $2x10^{15}$ at/cm^2. Three types of defect structures were revealed. The surface peak and the damage region located in the region of the ion range exhibit important depletion in oxygen, whereas the damage region at the depth beyond the ion range consists of extended defects, predominantly prismatic dislocations.

Introduction: ZnO is probably the most extensively studied semiconductor over the last decade, primarily due to the fact that it is a promising material for optoelectronic and microelectronic applications [1]. With this respect ZnO is expected to be a cheaper replacement for GaN. Ion implantation has been considered as a promising modification method for ZnO and has been studied by many groups. The principal method used is Rutherford Backscattering/channelling (RBS/c). Analysis of RBS/c spectra for compound single crystals is a demanding task. This is primarily due to the fact that defect accumulation and transformation in ion implanted compound crystals is a complicated multistep process resulting in the formation of a mixture of different types of defects. To cope with these problems we have developed the Monte Carlo simulation code McChasy [2]. The unique feature of this code is its ability to separate contributions from the scattering by different types of defects, i.e. randomly displaced lattice atoms (RDA) and extended defects like loops, dislocations and stacking faults (DIS). This makes it possible to deduce depth distributions of each type of defect separately. The typical evolution of defects in ZnO has been discussed in detail by Turos et al. [3]. By the complementary use of RBS/c and High Resolution X-ray Diffraction (HRXRD) not only the agglomeration curves for RDA and DIS were determined but also the driving force for defect transformation was revealed. The most important issue is a continuous growth of compressive stress with increasing ion fluence leading to nucleation and growth of a dislocation band eventually producing plastic deformation of the implanted region. The critical fluence for plastic deformation in ZnO is about 5 dpa [3]. Here we present follow-on of the previous study, this time focused on the structural transformations in ZnO subjected to heavy ion implantation. The fluences selected for this experiment range from 3 to 11 dpa and encompass the transition region.

Results and discussion: Fig. 1 shows the Zn portion of RBS/c spectra for ZnO implanted to different fluences of Yb ions. They were evaluated by means of the McChasy simulation code. The solid lines in Fig. 1 indicate the quality of the fits.

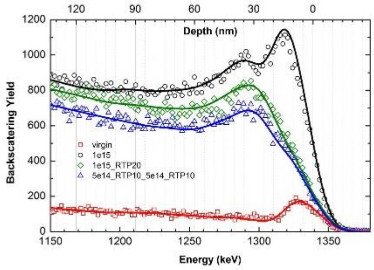

Fig. 1. Aligned RBS/c spectra obtained for ZnO epitaxial layers prior to and after different implantation/annealing cycles for RTA at 800°C. The solid lines show the results of MC simulations.

The results of such an analysis are shown in Fig. 2. Two defect distributions, RDA and DIS, have been determined for each sample. Plotted are f_{RDA} (RDA concentration in at. %) and f_{DIS} (concentration of dislocations in cm^{-2}) for 150 keV Yb-ions. The RDA distribution is bimodal composed of the surface peak and a broad bulk peak extending from 25 nm up to about 150 nm. Surface peaks are separated from the bulk to the depth of 25 nm. The maximum of the bulk defect peak coincides with the maximum of the implanted atom distribution as calculated with the SRIM code [x]. Such a separation between the surface peak and the band of defect clusters was previously observed in ZnO. However, its origin is still under debate. DIS distribution is located at a greater depth and extends to approx. 200 nm. With increasing ion fluence the DIS concentration grows steadily without changing its depth position.

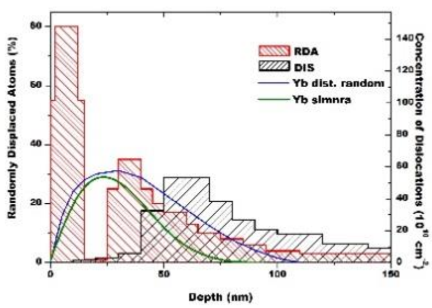

Fig. 2. Depth distributions of defects (results of MC simulations) obtained for ZnO epitaxial layers after implantation with 1E15/cm^2 Yb ions.

The results of complementary HRXRD measurements are shown in Fig. 3. Plotted are X-ray diffraction 2Theta/Omega profiles for three Yb-implanted samples. On the low-angle side of the main Bragg peak due to X-ray scattering by a deep, undamaged part of the crystal a secondary pattern develops that resembles the fringe pattern observed for Ar-ion implanted ZnO [xx]. This is due to the increase of interplanar spacing, i.e. the out-of-plane strain in the bombarded region, which is typical for strained region produced by defect accumulation.

A kind of plateau has developed on the high-angle side indicating formation of a layer with lower lattice spacing than ZnO. The plausible hypothesis is that this lattice shrinkage is due to the oxygen loss.

In fact the lattice constant of Zn is 0.4947 nm, which is by 0.026 nm lower than that of ZnO. By applying the Vegard's law one can estimate the composition of the ZnO_x surface layer with x = 0.8.

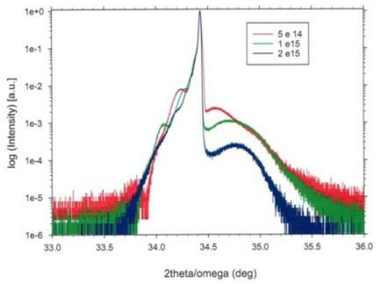

Fig. 3. HRXRD profiles for ZnO single crystals implanted to different fluences of 150 keV Yb-ions.

Depletion in oxygen of ZnO surface layers bombarded with heavy ions was also confirmed by our SIMS measurements [4].

Conclusions: Our analysis revealed a trimodal damage distribution consisting of a surface agglomeration of displaced atoms. The second damage region was located in the region of the ion range. Both exhibit important depletion in oxygen. Another damage region located at a depth beyond the ion range consists of extended defects, predominantly prismatic dislocations. Dopant activation in implanted crystals requires subsequent thermal treatment. Based on our results an appropriate annealing scheme can be devised.

Acknowledgements: This work was supported by the Polish National Centre for Research and Development (NCBiR) through the project PBS2/A5/34/2013.

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Structural and optical studies of Pr implanted ZnO films subjected to a long-time or ultra-fast thermal annealing

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Objectives

ZnO is a very promising material for semiconductor device applications because it can be grown on a large scale by inexpensive methods with industrial capability. The ZnO excitonic light emission is in the violet-blue spectral range, but when doped with Rare Earth (RE) ions is expected to exhibit luminescence over wavelengths ranging from ultraviolet to infrared. This is especially interesting because of potential applications like visible light-emitting phosphors, monochromatic light sources and other optoelectronic devices. In our case ZnO epitaxial layers were doped by ion implantation. The depth distribution of the dopant and its concentration is precisely controlled in the ion implantation technique, but the ballistic nature of this process produces lattice damage. Moreover, in the as-implanted stage most of the dopants are optically inactive. Therefore, annealing leading to lattice recovery and optical activation of dopants is necessary.

Experimental details

High- quality epitaxial ZnO films were grown by Atomic Layer Deposition (ALD) at 300°C on a commercial GaN/Al_2O_3 substrate (Kyma Co.) in PAS, Warsaw, Poland. The samples were implanted in sequential mode at room temperature with Pr ions to a fluence of $1x10^{15}$ /cm^2 at HZDR. After implantation annealing in various ways using RTA for 10 or 20 min at 800^{o}C and FLA with 20 ms pulse length and an energy density deposited on the sample surface of 110 J/cm^2, were performed. Structural properties of implanted and annealed ZnO and the optical response were evaluated by Channelling Rutherford Backscattering Spectrometry (RBS/c), High-resolution X-ray diffraction and Photoluminescence Spectroscopy (PL), respectively.

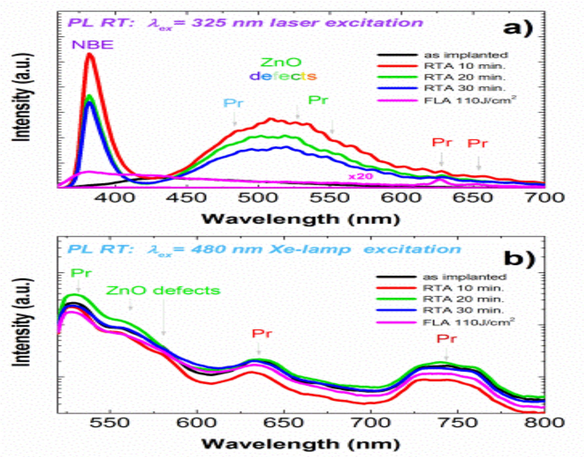

Fig. 1. PL spectra for Pr implanted and annealed ZnO films. For the sample excitation an UV He-Cd laser with 325 nm (a) and Xe-lamp with 480 nm (b) were used.

Results and discussion

The results show, that both annealing techniques lead to recrystallization of the ZnO lattice, damaged during the ion implantation. Upon RTA performed at 800^{o}C a return of Zn atoms from interstitial to their regular site positions is accompanied by rejection of primarily substitutional Pr atoms to the interstitial sites. Consequently, this leads to the out-diffusion and precipitation of Pr atoms on the surface. In contrast to RTA, the diffusion of implanted Pr during a millisecond range FLA treatment is completely suppressed. Despite differences in location of Pr inside the ZnO matrix after FLA and RTA, both annealing techniques lead to the optical activation of Pr3+. Moreover, employment of unique MC simulations to calculate the defect distributions enable usto extend over knowledge of the problem of anomalous post-implantation damage behavior in ZnO. Our results clearly suggest that the IP is present in the oxygen deficient region. PL results show that this region is enriched in Zn_i.

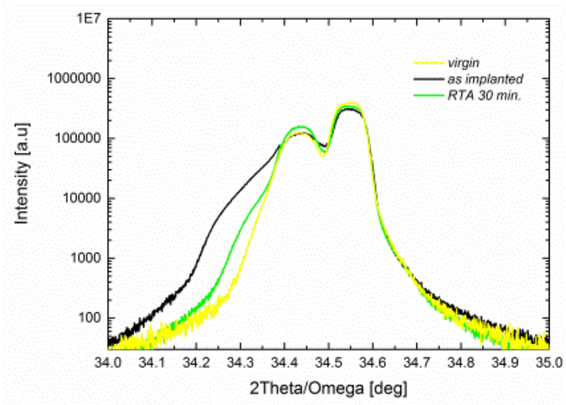

Fig. 2. HRXRD (0002) diffraction profiles for for Pr implanted and annealed ZnO films.

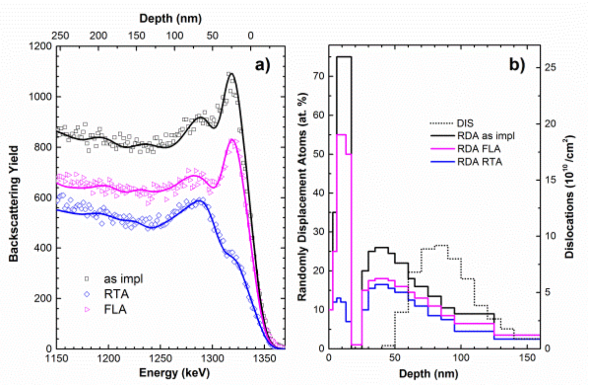

Fig. 3. RBS/c aligned spectra for Pr implanted and annealed ZnO films compared to the results of MC simulations shown by solid lines (a) and corresponding defect depth distributions prior to and after different thermal treatment (b).

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Unfortunately, the weak emission of the Pr3+ indicates that the efficiency of both down converters and light emitting diodes based on ZnO:Pr films will be low. We believe that further optimization of the ion implantation and annealing parameters will allow obtaining crystalline ZnO layer with optically active RE centres to be obtained.

Acknowledgments

This work was supported by the Polish National Centre for Research and Development (NCBiR) through the project PBS2/A5/34/2013. It was also supported by the Polish Ministry of Science and Higher Education from the Science Found for the co-financed international project (Grant No 3418/SPIRIT/2015/0) and for the co-financed project by Helmholtz Zentrum Dresden-Rossendorf (HZDR) in the frame of the program Access to Infrastructure (15100222-ST and 16000696-ST) and by FP7-REGPOT-CT-2013-316014-EAgLE Project and the international project co-financed by Polish Ministry of Science and Higher Education, Grant Agreement 2819/7.PR/2013/2.

Modulation frequency in Pulsed Magnetron Sputtering

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The addition of a modulation frequency (f_{mod}) to the technique of pulsed magnetron sputtering (PMS) has expanded its usability in effectively several different ways. It allows for an increase in the process effectiveness by accelerating the growth rate factor in studied materials (Cu, Al, Ti, Mo) and their nitrides: from small changes in Al and Al-N samples (Δ15%) to extreme increases in the growth rates of Cu/Cu-N and Mo samples (Δ300%) (Fig.1.) [1].

Furthermore, changes in f_{mod} influence the plasma composition during synthesis. Copper sputtered in argon under different values of f_{mod} (Fig.2.) is presented below for illustration. As plasma composition is one of the parameters directly responsible for a materials properties, significant differences in the phase composition of obtained materials can be achieved [2].

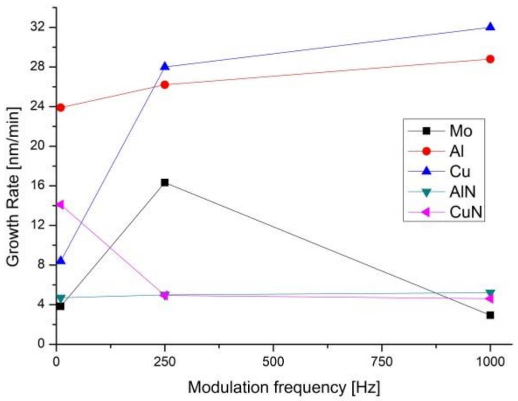

Fig. 1. Growth rate of various materials as a function of modulation frequency.

As the materials properties closely follow its composition, a simple change in modulation can lead to the betterment of our ability to design materials with desirable properties such as transmittance [3], grain size [3] or resistivity[4].

Modulation frequency as a technique-expanding parameter has proven to be very useful in conditions where other parameters cannot, either due to technical or physical restrictions, be changed in the degree necessary to achieve the above described results. Currently, our laboratories are studying this matter and more results are expected to follow.

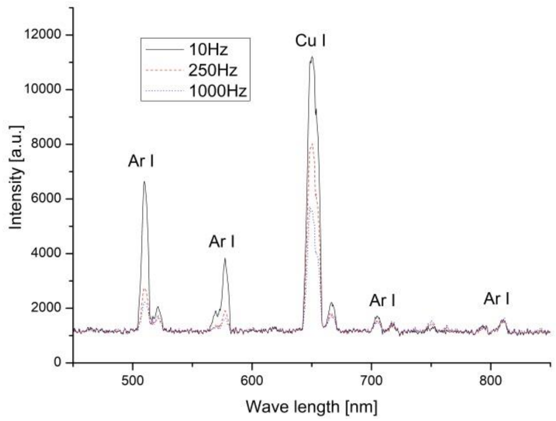

Fig. 2. Emission spectra recorded for copper sputtered in argon for f_{mod} 10Hz, 250Hz and 1000Hz.

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Annealing of Ti implanted GaP - a mparison of thermal and e-pulse annealing

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In the search for a candidate for IBSC (impurity band solar cell) a study was continued on Ti-implanted GaP. The previous study revealed that e-pulse annealed GaP implanted with moderate doses of Ti has identical structural features to that annealed at 800°C in Ar gas [1]. However, there is experimental and theoretical evidence that pulse annealed material should show better impurity solubility and better structural perfectness than that after thermal treatment [2-3]. To clarify the above objections the annealing processes were studied in more detail and under a greater variety of annealing conditions.

Single crystal GaP samples were implanted with 1e15 and 2e15 cm^{-2} of 120 keV Ti ions. The samples were next annealed with e-beam pulses of energy density between 0.38 and 1.29 J/cm^2 (18 different pulse energies) and thermally annealed in Ar gas flow at 400, 500, and 600°C (10 different annealings).

The Ga layer formed on pulse treated samples due to pulse-induced dissociation was etched away in dissolved HCl batch at 100°C. All samples were next studied by RBS and cRBS (Rutherford Backscattering and channelled Rutherford Backscattering) using 1.7 MeV He^+ beam.

Typical results of the experiments are summarized in Fig. 1 which shows the random spectrum of GaP, the aligned spectrum after ion implantation and HCl etching, the spectrum after a subthreshold energy e-beam pulse and after 600°C thermal annealing. The results reveal an interesting observation that a subthreshold pulse may lead to an increase of the implantation damaged region and confirm that thermal annealing is negligible below 800°C.

Work is in progress on further clarification of annealing results in GaP.

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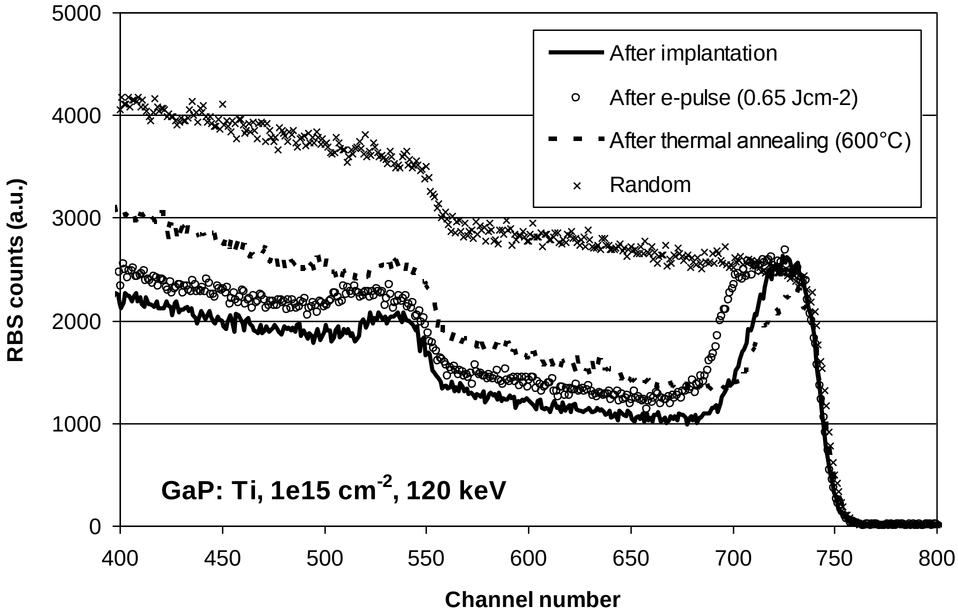

Fig. 1. A comparison of RBS and cRBS spectra of GaP samples after Ti implantation, e-beam pulse annealing and thermal annealing.

Synthesis and characterization of copper nitride layers synthesized by pulsed magnetron sputtering

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The presented work describes a study concerning the synthesis of copper nitride layers by means of the pulsed magnetron sputtering (PMS) method that can work under conditions of various frequencies of modulation. The morphology and phase composition of the layers were determined as a function of the process parameters: the power (P) and frequency of power modulation - the gating frequency (f_{mod}).

The results of the reported study proved the correct selection of the parameters of Cu3N synthesis. In the phase composition of the deposited layers, a polycrystalline copper nitride (Cu3N) was identified, Figure 1. It appeared that the structure of the layers strongly depends on the parameters of the plasma generation (f_{mod} , P). Our investigation showed that modulating the main frequency of the power source by the gating frequency, has a strong impact on the phase state of the condensate. The higher f_{mod} was, the more stoichiometric copper nitride was indicated. Additionally, we observed that the relative intensities of the copper lines in the plasma visible spectrum decrease with increasing of f_{mod}. Figure 1.We suppose that the duration of copper sputtering during each consecutive group of pulses is the origin of this relation. This explains why the conditions of a relatively longer life-time of the plasma at low f_{mod} favours the formation of supersaturated or nonstoichiometric nitride. In this paper, we presented f_{mod} as a significant technological factor, which in fact enables the "tuning" of the phase composition of synthesized layers. The results obtained allow us to assert that during magnetron sputtering not only is power an important parameter of the process, but also the length of the on-time pulse, which can be controlled by the f_{mod} parameter

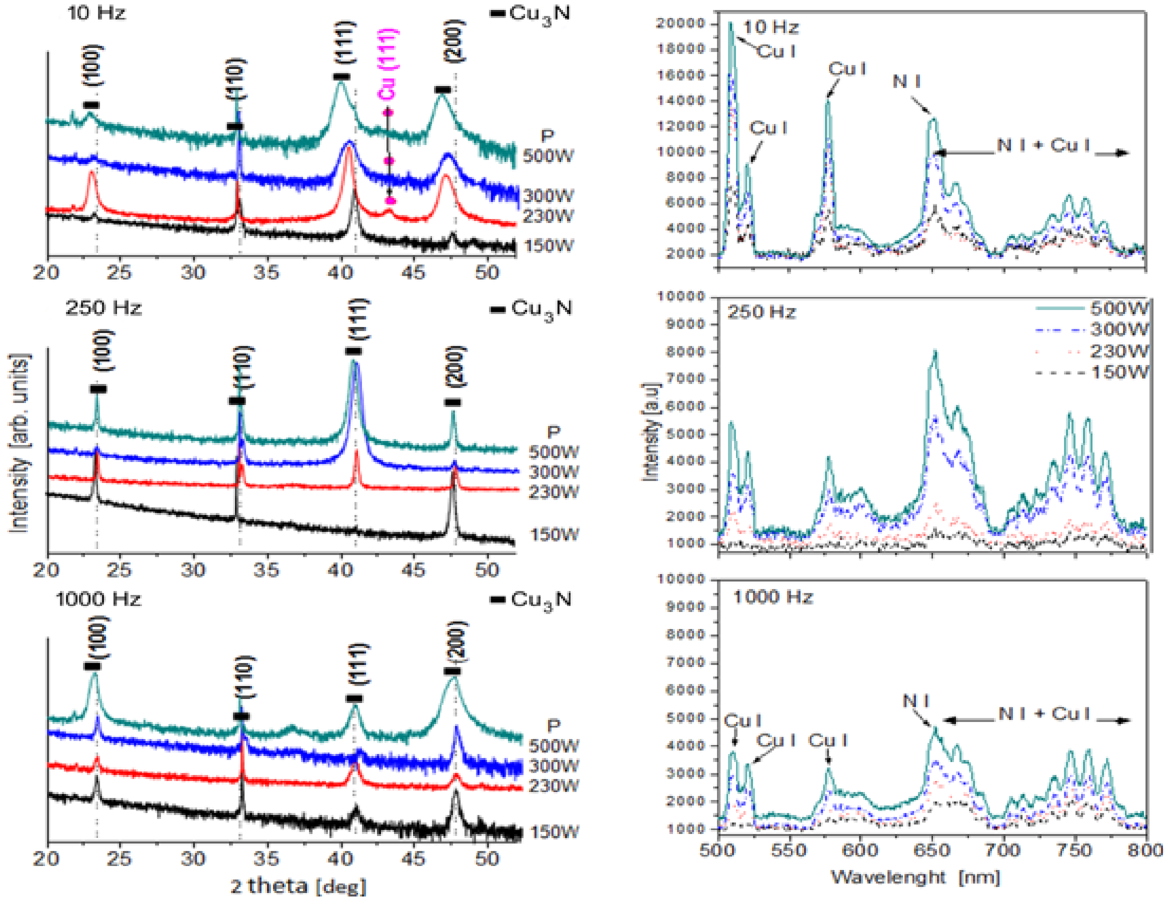

Fig. 1. The X-ray diffraction patterns of the Cu-N layers (left) . Emission spectra, recorded for processes carried out at different f_{mod} and P(right).

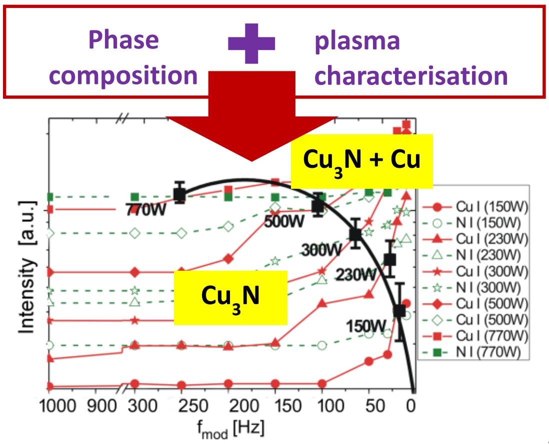

Fig. 2. The relationship of Cu and N line intensity (obtained by OES measurements) depending on P and fmod. The plot determines the characteristics of the synthesis environment during the deposition processes under different conditions of plasma generation.

This work was supported by the Polish National Science Centre within Project 2014/15/B/ST8/01692 CuN–PIP. The most important technical and technological achievements connected with this work include: design, construction and commissioning of a modern facility for synthesis of layers using the GIMS method (Gas Injection Magnetron Sputtering) Figure 3.

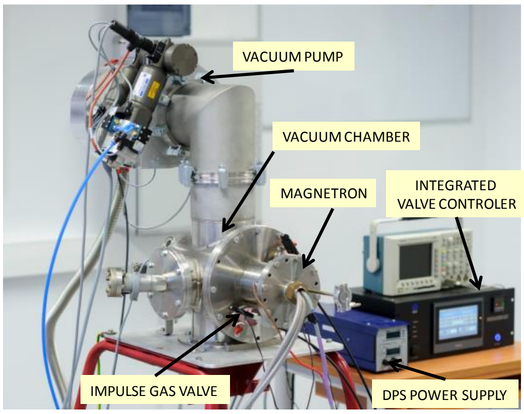

Fig. 3. Modern facility for synthesis of layers using the GIMS method (Gas Injection Magnetron Sputtering).

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Progress in the preparation of lead layer photocathodes for superconducting RF e^- injectors

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Fully superconducting (sc) RF electron guns for sc TESLA-type electron linacs make use of hybrid-type photocathodes consisting of a lead layer deposited on a niobium substrate. Ultra High Vacuum (UHV) arc lead deposition proved superior to other coating methods. It resulted in high quantum efficiency of photocurrent excitation – close to its theoretical value derived on the basis of Spitzers' three-step model [1].

The most serious drawback connected with using UHV coating, however, is the presence of metallic micro-droplets in the coated layer, sized from a fraction of a μm up to nearly 100 μm. They come from erosion of the cathode in the coating device. So far our group has used two approaches aimed at the elimination of microdroplets: 1. Sorting them out from the metallic plasma stream in the coating device using mechanical or magnetic filters. and 2. ex-situ remelting of the deposited Pb layer by treating it with plasma pulses from a multi-rod plasma iniector [2]. The first procedure resulted in excessive slow-down of the deposition proces and the presence of peeling products in the film while the second showed some limitations as to the final flatness of the lead layer. UHV coating with lateral extraction of metallic (lead) ions from the plasma stream proved to be a reasonable compromise method combining film flatness on the one hand with a reasonably high deposition rate on the other. A schematic view of the deposition system is shown in Fig.1. It consists of a direct coating UHV arc system with vertical plasma stream propagation equipped with an additional coated target shifted laterally from the plasma stream, protected by a specially-shaped stainless steel shield and connected to a negative 100 V dc bias voltage. The latter measure is provided to ensure energetic coating and satisfactory film adhesion. The shield is installed to protect the target surface from deposition of droplets or peeling products. The effectiveness of this shielding system depended on the position of the target. The more the target was recessed respective to the shield edge the less Pb surface extrusions were observed in the surface layer. It is clearly visible in the opitical-microscopic images in Figs 2 – 4 which correspond to the target distances from the shield edge of 5, 10 and 20 mm, respectively. The latter shows much reduced droplet size and density. Lead coating of a specially-shaped niobium insert was recently carried aut in our laboratory with optimized deposition parameters. This insert will be installed in a sc RF gun at DESY and tested for Q_o quality factor in an RF field.

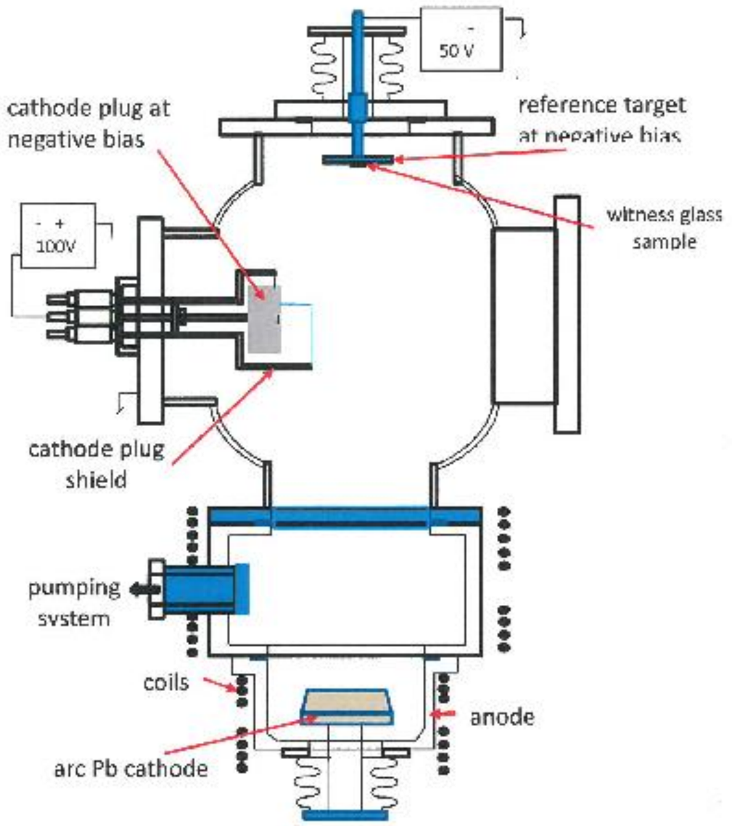

Fig. 1.

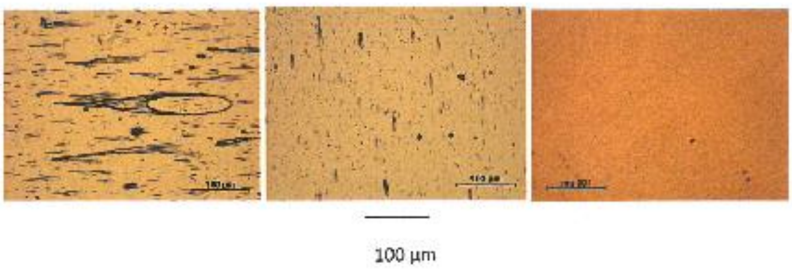

Fig. 2. Fig. 3. Fig. 4.

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Extending tool lifetime

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The furniture industry is a very important part of the economy in e.g. China, Germany, Italy, USA and Poland. For example, there are about 24 000 furniture manufacturing companies in Poland and their products represents about 2% of Polish GNP [1-2].

The high production value results in consumption of large quantities of tools, because during furniture processing tools wear as a result of various interactions with the wood materials in the cutting zone, such as vibrations, friction, chipping, gross fracture, microfracture, abrasion, erosion, elastic and plastic deformations, noise and acoustic emissions, heat generation (the cutting speed of wood-based materials is higher than that of metals, and wood materials are poor heat conductors), chemical and electrochemical reactions (oxidation, corrosion) [3-4]. Additionally, the molten resin, which bounds wood particles and/or wood fibers creates a built up edge on the cutting edge, which changes the machining conditions.

The extension of tool life has an impact on improving the quality of the machined surface, productivity, economy and better environmental protection.

In the literature we can find information on three ways of extending of the lifetime of tools for the machining of wood and wood-based materials:
1) deposition of an additional layer,
2) modification of the surface region,
3) duplex treatment, i.e. modification of the surface region + deposition of an additional layer.

In our investigations, commercially available cemented carbide (WC-Co) tool inserts with dimensions 29.5×12.0×1.5 mm^3, presented in Fig. 1, were used.

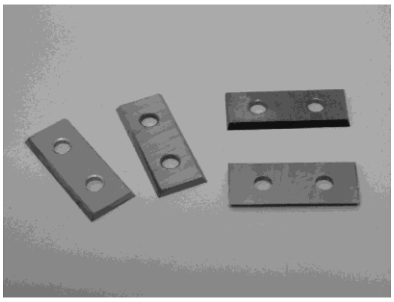

Fig. 1. The cemented carbide tool inserts.

The inserts were modified using either electron or plasma pulses.

In the first case, the tools were irradiated with pulsed electron beams using a “RITM-2M” device, developed and manufactured by the MICROSPLAV OOO company. RITM is a source of low-energy high current electron beam pulses of microsecond duration, which generate a fairly homogeneous wide-aperture electron footprint up to 10 cm in diameter [5].

The main parameters of the process were:
- pulse energy density: about 7 J/cm^2
- pulse duration: about 2 μs
- number of pulses: 1, 5 and 10.

In the second case, the tools were treated using high-intensity plasma pulses generated by the RPI generator - IBIS, developed and operated at the National Centre for Nuclear Research, Świerk.

The main parameters of the process were:
- pulse energy density: about 7 J/cm^2
- pulse duration: about 1 μs
- number of pulses: 1, 5, 10, 20 and 30.

After the modification and supplementary measurements, the inserts were examined with tool wear tests at the CNC working centre Busellato Jet 130, operated at Warsaw University of Life Sciences - SGGW.

The main cutting parameters of the tool life tests were:
- cutting material: particle board
- feed speed: 2.7 m/min.
- feed per tooth: 0.15 mm
- spindle speed: 18 000 rpm
- dullness criterion: 0.2 mm

The results of the tool life tests are presented in Figs 2-3.

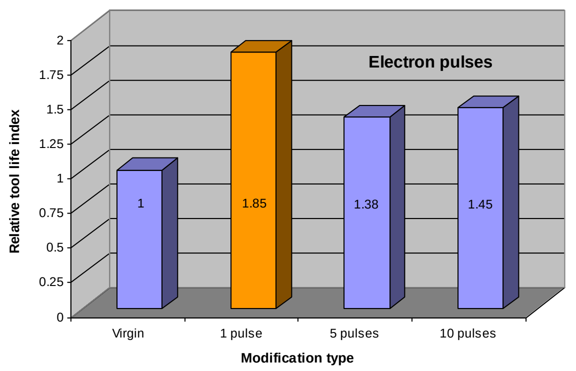

Fig. 2. Relative tool life index for electron pulse treated WC-Co inserts.

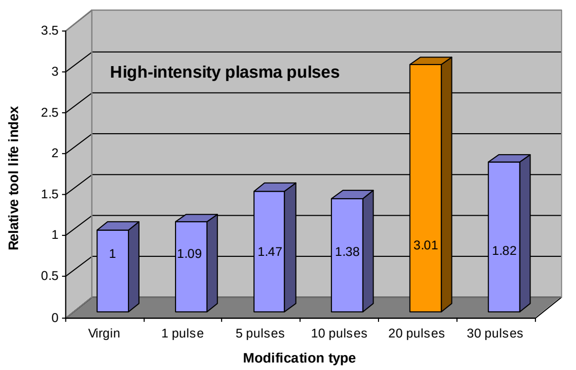

Fig. 3. *Relative tool life index for high-intensity plasma pulse treated WC-Co inserts.*

The results reveal an increased lifetime of the modified tools, up to 1.85 for e-beam and above 3 for plasma pulses. Additionally, we observe better reproducibility of the modified tools during wood machining. The studied methods are promising for industrial applications.

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Diffusion of helium in the uranium dioxide using the "ab initio" method

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In developing this book published and unpublished results of our own work and results of other authors available in the literature were used. The problems of solid-state diffusion and surface absorption have so far been dealt with using completely different theoretical models, diffusion within the classical or quantum model and absorption only within the classical model. Here, for the first time in the literature, both processes are treated uniformly within the quantum model.

Diffusion processes in solids are understood as the spontaneous skipping of the diffusing atoms from some local equilibrium position to another position, also in local equilibrium. The initial and final positions are generally crystallographically equivalent in perfect single crystals, for example octahedral positions in the fcc structure. In actual crystals containing chemical or structural defects, one local minimum energy is separated from the next, not just with a crystal field potential of different height and width. Frequently the potential wells of adjacent positions have different depths. In such situations, according to the law of energy conservation, skipping must be accompanied by absorption or emission of a phonon.

For a great many years this has provided what is believed to be an example of the Arrhenius temperature dependence of the diffusion coefficient. Currently, quantum mechanical descriptions of these phenomena are used. One example is the diffusion of carbon in iron [1] - significant differences are seen between the quantum and classical models and it is found that only a quantum model provides compatibility with the measured results. The key issue here is to calculate the quantal transition rates Γ. From the quantum mechanical point of view, the speed of the jump over the potential barrier is determined by two mechanisms. One jump is above the height of the barrier, which is possible for those atoms which occupy energy levels with energies greater than the height of the barrier. This mechanism is also included in the classical theory. It turns out, however, [2] that the classical methods for determining Γ are not very precise. An additional mechanism must also be considered - penetration through the potential barrier by the remaining atoms of energies less than the barrier height. This is a solely quantum effect. In the latter case, the transparency of the barrier depends not only on its height but also on its shape and in particular on its width. This effect mainly relates to light elements and appears mainly at low temperatures and is dominant at super low temperatures. The above described method for the study of diffusion phenomena refers to both crystalline bulk diffusion and also diffusion in the surface layer and the crystalline fields outside the surface of the crystal. Thus it can be used to study the physical and chemical absorption and adsorption essentially without major adaptation. It is astonishing that in these latter cases, Langmuir's classical theory and its modifications, consisting mainly in taking into account indirect adsorbate-adsorbate interactions on adsorption isotherms, has been used for a hundred years. Considering diffusion in crystalline fields near the surface, the problem we are interested in is the release of the diffusing gas to the atmosphere. If the same gas is also present in the ambient atmosphere, helium atoms from the atmosphere may fill up again the potential wells existing on the surface or just below the surface. The situation is similar to the evaporation of a liquid.

Many problems of low energy physics, chemistry and biology can be explained by the quantum mechanics of electrons and ions using the contemporary numerical methods of advanced quantum theory. One method that is widely applied and generally available is the numerical “ab initio” method which is based on the density functional theory, DFT, developed by Hohenberg and Kohn and Kohn and Sham. “Ab initio" methods allow one to solve many problems, such as e.g. the study of cohesive properties, so for perfect crystals and those containing structural or chemical defects. This allows, among others, the calculation of the local structure parameters and potential, local deformation, local crystalline fields, shapes and sizes of barriers and potentials and the like. We can also study the electronic structure, the spatial distributions of electric charge, the band structure and many others. Most of the information obtained in this way is either very difficult or even impossible to obtain by other means.

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Material description of a unique relief fibula from Poland

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A unique relief fibula dated to the Migration Period [1] (first half of the sixth century) was found in Radziejów, Poland (fig. 1). This stray find changes previous opinions on the lack of settlement in central Poland at that time. As the find is the only one of this type in Poland, a special attention was paid to possible analogies, mainly finds from Scandinavia and Western Europe. The fibula underwent technological analyses in order to reveal its technology of manufacture. For this purpose the chemical and elemental composition of the alloy was studied. Several complementary physico-chemical techniques such as optical microscopy (OM), scanning electron microscopy with energy dispersive X-ray (SEM–EDX) spectroscopy, energy dispersive X-ray fluorescence (ED-XRF) analysis, X-ray diffraction (XRD) analysis and micro-hardness testing (HV0.2) were used to study the technology of the find. The investigations revealed that this artefact was made from brass (4–17 wt% Zn) with an admixture of Sn (2–12 wt%). Two technologies were used: casting for the bow and forming for the part with the axle of the spring. The artefact's surface was tinned by the hot-dipping process. The physical structural analyses demonstrated that the artefact was cast and ornamented by surface stamping at a relatively low temperature (about 500 °C).

Fig. 1. Relief fibula from Radziejów .

A preliminary SEM–EDX study of the fibula shows its surface degradation which was invisible to the naked eye. The results (Fig. 2) demonstrated that it was necessary to work with pure metal alloy whose structure corresponds to the raw material. Irregular cloudy shapes correspond to the corrosion and soil contamination of the structure which is mainly built of light element oxides. The external surface is also rich in iron and copper oxides (up to ca. 50 wt% in total).

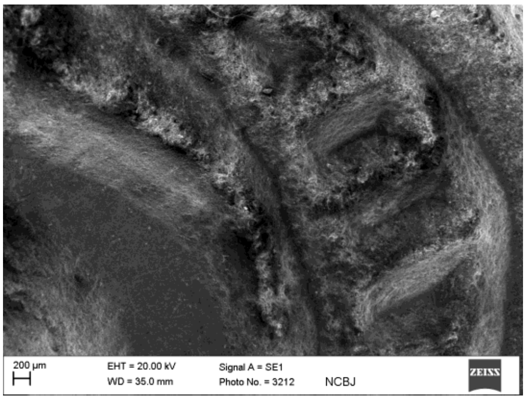

Fig. 2. SEM–SE image of fibula fragment.

The most important conclusion is that the fibula from Radziejów was tinned, as shown by the XRF analysis of the obverse and reverse of the find (fig. 3).

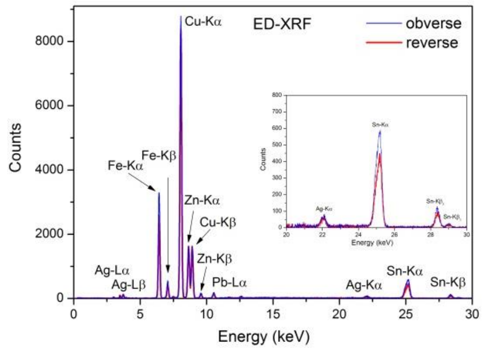

Fig. 3. ED-XRF spectra for the obverse, with the relief ornament (blue) and for the reverse (red),

Usually, fibulae of this type were gilded in the discussed period. The raw alloy was determined as brass with different contents of tin, zinc and trace amounts of lead. The elements were mixed depending on the functional requirements of each part of the artefact. Casting brass was used in the manufacture of the bow. On the other hand, forming brass as a base alloy was applied to the axle of the spring, which was a moving part of the fibula.

Reference

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Compatibility of analysis methods in the estimation of the elemental composition of historical Polish coins

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The X-ray tube developed at the National Centre for Nuclear Research (NCBJ) was used as an X-ray source in a system designed for ED-XRF (energy-dispersive X-ray fluorescence) studies. The system was used to analyze selected Polish historical coins: the 15 *kopek*/1 *złoty* is dated to 1838 and was minted in the period of the Kingdom of Poland being in real union with the Russian Empire. 2 *złote* dated to 1933 was currency in Poland during the interwar period. Both coins are made of Ag-Cu alloy. Fig. 1 presents ED-XRF spectra. As reference, measurements were also performed by wave-dispersive XRF (fig. 2), SEM-EDX (fig.3) and X-ray diffraction.

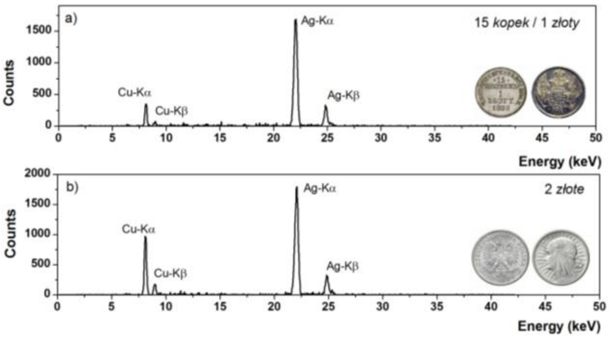

Fig. 1. ED-XRF spectra of 15 kopek/1 złoty and 2 złote.

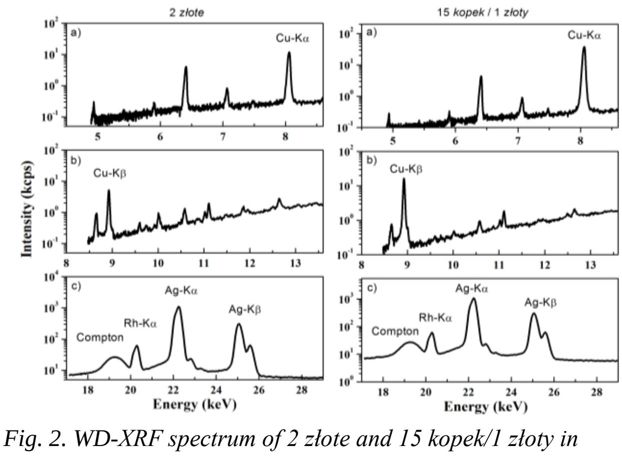

Fig. 2. WD-XRF spectrum of 2 złote and 15 kopek/1 złoty in a distinct energy.

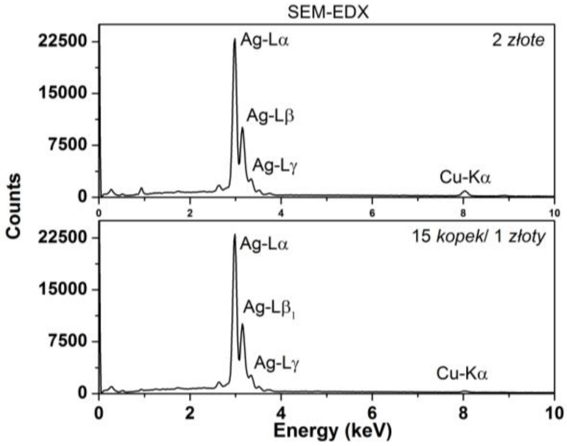

Fig. 3. SEM-EDX spectrum of 2 złote and 15 kopek/1 złoty.

The elemental compositions of the coins were determined and the results compared to those obtained with WD-XRF, SEM-EDX and XRD methods (fig. 4).

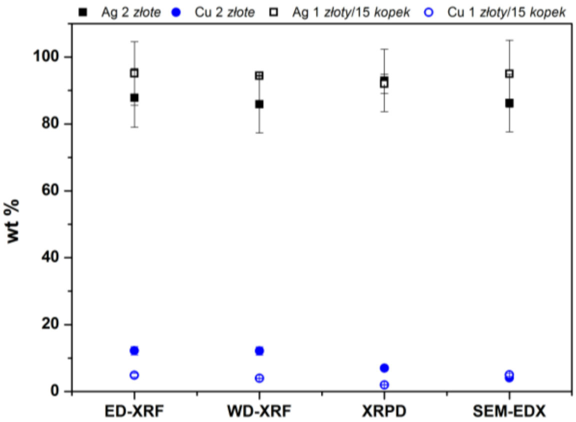

Fig. 4. Comparison of the elemental composition of coins obtained by ED-XRF, WD-XRF, SEM-EDX and XRD.

Generally good agreement between different analytical values were obtained, confirming the accuracy of the new system. Combination of these methods can contibute to the search for sources of precious metals in the Middle Ages.

Reactor Physics, Nuclear Technology in Energy Generation, Modelling and Calculations

Completion of work on work order 11 as part of the cooperation with Argonne National Laboratory on the MARIA core conversion

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The U.S. Department of Energy's (DOE) National Nuclear Security Administration manages the Global Threat Reduction Initiative (GTRI) reactor Conversion Program, a continuation of the Reduced Enrichment for Research and Test Reactors (RERTR) Program that was established by the DOE in 1978. The GTRI-Reactor Conversion Program mission supports the minimization and, as for as possible, elimination of the use of highly-enriched uranium (HEU) in civil nuclear applications by working to convert research reactors and radioisotope production processes to the use of low enriched uranium fuel and targets throughout the world. Argonne National Laboratory has provided technical support for RERTR since its inception.

The MARIA reactor at the National Centre for Nuclear Research (NCNR) in Poland is a high-power research reactor that has used HEU fuel manufactured in Russia since it began operation in 1974. NCNR decided to utilize LEU silicide fuel qualified under the RERTR Program and used successfully in many western research reactors for conversion of the MARIA reactor. Starting in 2008 and up to 2014 the MARIA reactor core underwent successful conversion to LEU fuel utilization.

The Basic Ordering Agreement (BOA) addressed the tasks other than procurement of the LEU fuel that were needed to prepare for and convert the MARIA reactor. ANL provided analytical support to NCNR in the performance of the conversion analysis. Work Order (WO) 1 of this BOA provided an outline of the analyses to be performed. WO-2 provided support for hydraulic testing of the fuel assembly designed by CERCA. WO-3 provided support for performing the analyses required in order to obtain approvals needed to insert the LTAs designed by CERCA. WO-4, WO-7, and WO-9 provided support during start, continuation, and after, respectively, of LTA irradiation testing. WO-5 provided for additional hydraulic testing. WO-6 and WO-10 provided support for replacement of the primary coolant pumps, which was required for conversion of the full core to LEU fuel. WO-8 provided support for the analyses needed in order to obtain the approvals needed to convert the full core to LEU FA designed by CERCA.

The work performed under Work Order 11 was aimed at improving of the neutronic and thermal-hydraulic calculation for the full core conversion. These improvements were forced by the new design of the fuel elements as well as the new cooling circuits but also by the regulatory authority in Poland to issue a new license for reactor operation.

There were 3 tasks in the work order: (1) perform measurements of safety related characteristics, (2) validate neutronic codes (REBUS, MCNP, TRIPOLI4) in the reconstruction of the neutronic characteristics, and (3) develop a RELAP5 model of the cooling loops.

Task 11.1: Perform Measurements of Safety Related Characteristics.
NCNR performed measurements of control rod efficiencies, temperature reactivity coefficients (water, beryllium) for transitory and final stages of conversion. These results were confronted with calculated values. The measurements were performed by means of dedicated data collecting equipment and specially prepared software. The deliverable for this task is a report presenting the results of the measurements and their conformity with the calculations.

Task 11.2: Validate Neutronic Codes (REBUS, MCNP, TRIPOLI4) in Reconstruction Neutronic Parameters. In the frame of this task calculations of the neutron fluxes and spectra, and power distribution among FAs in the course of the conversion process were performed. The results were compared with measured data. A TRIPOLI4 model of the MARIA core was developed. Special emphasis was paid to the peculiar design of the CERCA fuel and its impact (rotational asymmetry) on the excess reactivity. The deliverable for this task is a report presenting the results of the calculations and their comparison with operational and experimental data.

Task 11.3: Develop a RELAP5 Model of the MARIA Cooling Circuits and its Experimental Verification. The currently used thermal-hydraulic code SN will no longer be used as a computational tool for safety analyses of steady and transient states of MARIA fuel. This has also been postulated by the Polish regulatory authority. It has been decided that the RELAP5 system code will be used instead. The correctness of the model was verified by means of operational data but also by dedicated experiments (transients). The deliverable for this task is a report presenting the results of the calculations and their comparison with operational and experimental data.

Cooperation with ANL is currently continuing under Work Order 12.

A research-training stand at the MARIA reactor – 2017 progress report

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A the research-training facility "H2 Channel" at one of the horizontal channels of the MARIA reactor is under construction [1]. It is expected to deliver a neutron beam (with an intensity of 10^9 cm^{-2} s^{-1}) from the reactor core to an irradiation room designed for biomedical and physical research.

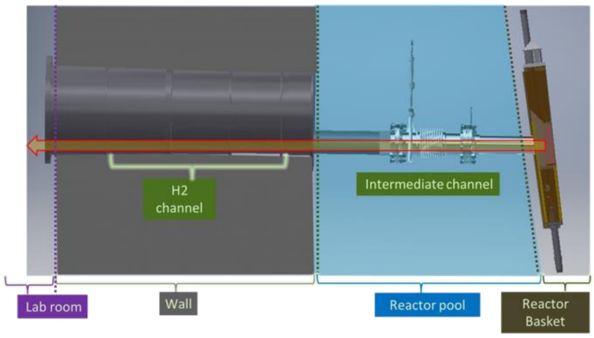

Fig. 1. Cross section of the H2 Channel facility: The converter, the intermediate channel, and the tube of the H2 channel. The arrow shows the beam direction.

The neutron source for the facility is a uranium converter – a subcritical system placed in the reactor vessel [2]. The general objective of the converter is to increase the initial energy of the neutrons so their energy can be fitted to irradiation purposes in further steps. The core of the neutron conversion system is 24 Uranium plates located in two baskets, where fission reaction occurs. The baskets will be placed on a bearer inside the structure based on the original graphite block. The structure consists of cladding, a filter, two side chocks, a curved aluminium block and a bearer mounted on the block and a leg. (See Figure X).

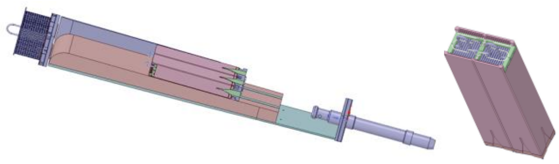

Fig. 2. Left: The converter inner structure design. Right: Isometric view of baskets with plates.

The current efforts of the research team are focused on providing safety of the converter cooling system and improving the radiation conditions in the laboratory room.

A significant amount of heat is generated in a fission reaction thus the cooling conditions are being investigated. The flow inside the uranium converter was modelled with ANSYS tools, a CFD simulation was run with ANSYS Fluent 17.2.

To lead out the beam from the converter an intermediate channel was manufactured. It was designed as a fillable gas container to fit between the H2 channel stub and the converter. Filling the tube with nitrogen will form a gap in the water of the reactor pool and lead the beam out to the irradiation room. The mounting of the intermediate channel is planned for April of 2018.

The requirement for the facility is that it must not interfere with the regular operation of the reactor, (e. g. production of radiopharmaceuticals therefore a beam shutter is needed to provide indispensable protection for the personnel in the room when the reactor is operating at full power.

Since the diameter of the H2 channel is much larger than the diameter of the stub pipe (600 mm and 150 mm respectively), a solution was proposed of a shutter consisting of two parts, fixed and revolving. The revolving part may be set in four positions, one for closing the beam and the other three leading the beam out through dedicated openings. One of the openings will remain empty for water tightness tests, the other two will contain various sets of moderating and filtering materials to shape the beam.

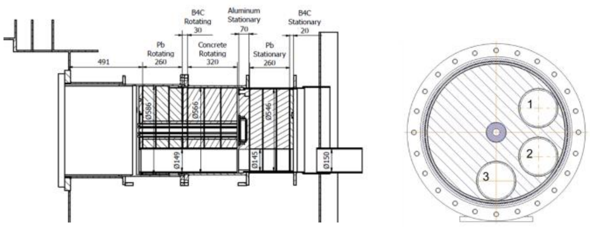

Fig. 3. Left: beam shutter side view. Right: front view of the revolving part with 3 openings.

The materials and thickness of the beam shutter were selected according to Monte Carlo modelling using the MCNP6 code.

The first measurements of the radiation conditions in the irradiation room are planned in May, after mounting the intermediate channel in the reactor pool and the stationary part of the beam shutter in the H2 channel.

References

[1] "BNCT research beam in MARIA reactor (NCBJ, Poland)" .The 9th Young Researchers BNCT Meeting Kyoto, Japan, 2017-11-13

[2] Wyniki analizy cieplno-przepływowej konwertera uranowego. Narodowe centrum Badań Jądrowych, 2017-11-27. Seminarium wewnętrzne

Fission heat generation distribution in fuel plates for the BNCT epithermal neutron converter and analytical steady – state heat transfer evaluation

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The thermal power distribution of the BNCT epithermal neutron converter was determined using the MCNP Monte Carlo code. The BNCT epithermal neutron converter will be a water-cooled facility containing fissile material in which thermal neutrons from the MARIA reactor core will cause fission reactions to produce fast neutrons. The fast neutrons will be directed to the H2 horizontal channel and will be partially moderated to epithermal energies and then used in a BNCT scientific facility outside the reactor pool.

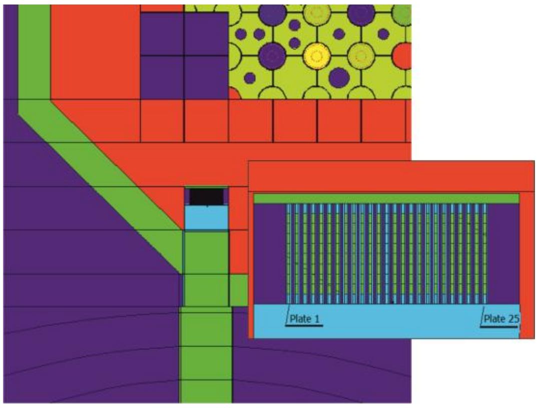

Fig. 1. The BNCT converter located on the periphery of the core – a fragment of the numerical model visualization.

A fissile material produces a large amount of heat during irradiation by thermal neutrons, so the crucial issue in the converter design is the ability to remove heat to fulfill with an appropriate safety margin the non-boiling rule in the core. Although the converter contains fissile material it is deeply undercritical itself ($k_{eff} \approx 0.4$), so it behaves like a neutron absorber and self-shielding effects will prevail over neutron breeding. Considering this fact, the maximum thermal power density will be located on the faces directed to the reactor core.

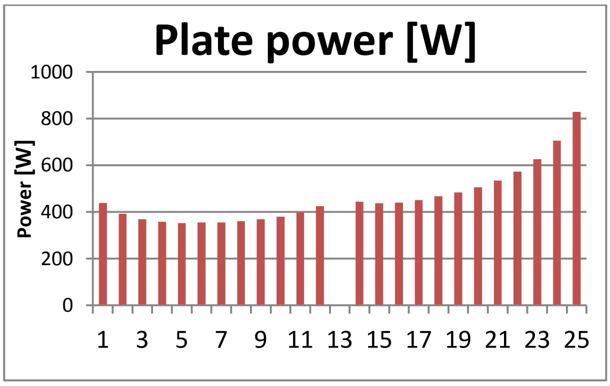

Fig. 2. Thermal power of each plate.

Analytical rough approach to thermal condition evaluation

In the thermal calculations the most crucial issue is to determine the maximum wall temperature and then the onset of the Nucleate Boiling Ratio. These calculations must be made for the hottest spot on the hottest streamline.

85	84	91	99	108	118	135	172
79	76	74	81	88	99	121	161
72	70	71	74	83	94	120	153
71	66	71	74	85	97	115	154
72	69	71	75	83	94	118	155
71	70	70	75	84	99	119	156
71	67	69	77	83	99	117	160
72	70	70	78	86	101	124	160
75	69	73	81	87	100	123	165
77	72	73	81	91	102	123	169
74	73	76	81	89	104	129	169
79	72	76	81	91	109	129	169
80	76	75	81	91	105	131	173
79	76	78	85	92	109	130	173
81	77	81	85	96	107	136	178
85	79	83	87	98	111	139	182
86	81	83	90	97	115	141	186
88	86	88	93	103	120	146	190
97	94	95	101	115	127	154	201
111	111	121	127	138	156	181	222

Fig. 3. The heat flux density of the most powerful plate normalized for the most powerful allowable state of the reactor.

For a flow velocity estimated as 1.5 m/s, the reheat of the hottest streamline is about 8.6 C, which gives a fluid temperature about 486 C. The heat transfer coefficient reaches about 12 000 (Michiejew's formula), giving to about 18.6 C wall-fluid temperature difference and hence about 67.2 C on the wall and T_{ONB} about 127.1 ^{O}C. The ONBR parameter then has a value of about 3.2 , which sets the system far above the minimum value of 1.2. These numbers concern the most demanding set of normal operation, steady – state parameters.

Although the hottest streamline temperature rise is considerable, the overall converter temperature rise do not exceed 0.9 C under normal operating conditions. Considering the fact of the small temperature difference and the irregularity of the temperature field, total thermal power measurements would be challenging.

The presented model was constructed mainly to demonstrate the thermal safety of the BNCT converter under normal operation, steady – state conditions. The assumptions which have been made are harsh. In a real case, the heat conducting fuel and cladding would smear the hot spot and transversal mixing would equalize the temperature of the hottest streamline.

In order to estimate the heat transfer conditions during a power peak, a reactor power level multiplier was introduced and evaluated to reach the ONBR value of 1,2. This condition was fulfilled with a fourfold rise of the reactor power level, so there should be no need to apply non-steady state calculations to examine converter response for a fourfold power peak.

The key role of the MARIA reactor in the European Working Group on reactor dosimetry activities

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The European Working Group on Reactor Dosimetry (EWGRD) is an international association of the European nuclear science and technology institutions directly involved in in-core neutron and gamma-ray measurements. Currently EWGRD has 16 members from 14 European countries.

The EWGRD activities focuses mostly on common neutron activation measurements and nuclear heating calorimetry. However, strong effort is always put into investigation of novel in-core measurement techniques. Every three years the EWGRD together with ASTM (formerly the American Society for Testing and Materials) organises the International Symposium on Reactor Dosimetry. The Symposium is a forum for the interchange of state-of-the-art techniques, data bases and standards for reactor radiation metrology.

The EWGRD also works on standardization of nuclear data bases and measuring techniques. As part of this task an inter-comparison experimental campaign (called a Round Robin) is periodically performed. In the framework of Round Robin the same set of neutron activation (foil) detectors is measured by the participants.

In 2017 a number of activation foils were irradiated in the MARIA reactor. Two separate sets were irradiated: standard neutron activation samples and niobium samples.

The standard neutron activation samples (provided by SCK/CEN, Mol, Belgium) are γ-ray emitters after neutron irradiation. Their activity must be determined by means of high-resolution gamma-ray spectrometry. Knowing the mass of each sample and the activation time, the neutron flux density can be estimated. A number of simultaneously recorded nuclear reactions also allow the estimation of the neutron energy spectrum.

0.1 mm thick foils of the following activation materials were irradiated: Ni (Ø3 mm), Fe (Ø8 mm), Ti (Ø10 mm), Al-Co1% (Ø3mm), Al-Ag1% (Ø3mm). The sets of 5 pieces of each sample were separately irradiated in the hydraulic rabbit system channel No 2 (very centre of the core) in the MARIA reactor separately. The irradiations took from 1.0 to 6.5 hours. The expected nuclear reactions induced both by thermal and fast neutrons were recorded.

The niobium samples (provided by CEA) were devoted to long-lasting fast neutron detection. As a result of nuclear reactions, slowly decaying (12 years half-life) ^{93m}Nb appears. It emits soft (ca. 30 keV) beta particles only. Therefore, the ^{93m}Nb activity measurement is more sophisticated. Usually, Liquid Scintillation counting techniques need to be applied.

In total 60 pieces of niobium foil were irradiated in the hydraulic rabbit system channel No 2. The foils differ both in mass (from 1.0 to 8.6 mg) and tantalum content (from 0.3 to 19.6 ppm). The irradiations took from 36.5 to 140 hours.

All of the samples were sent from Świerk to the Laboratoire National Henri Becquerel (LNHB), CEA Saclay, France. The activity and mass of each sample are measured by LNHB. Then all the samples will be distributed among 16 participants: LNHB France, UJV Rez Czech Rep., LDCI France, IJS Slovenia, ITN Portugal, LARC France, INRNE Bulgaria, NRG Netherlands, BUTE Hungary, NCBJ Poland, SCK/CEN Belgium, SEC-NRC Russia, KI Russia, VTT Finland, VKTA Germany, EPFL Switzerland.

The participants need to determine the sample masses and the activity of the radioactive nuclide included. The results will be compared.

Computation of neutron characteristics of the MARIA reactor graphite reflector

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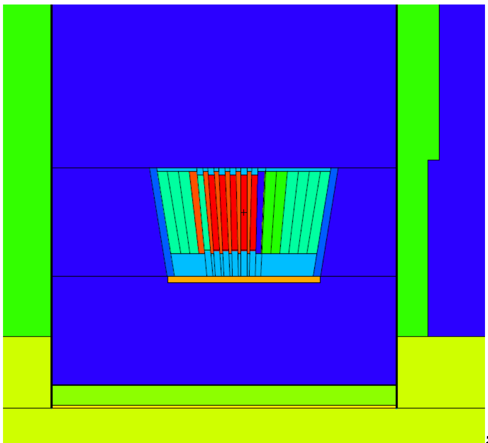
Ageing management of reactor structure components is required to be performed periodically in order to assure safe reactor operation.

The MARIA reactor core consists of an aluminium basket containing nuclear fuel channels between beryllium (moderator) blocks surrounded by graphite (neutron reflector) blocks.

A simplified geometry of the MARIA reactor has been implemented in the MCNP code [1]. The MCNP code, based on the Monte Carlo method, is used for neutron transport calculations and neutron parameter determination [2]. The MARIA reactor numerical model is based on an accurate geometry description [3]. The model is shown in Fig. 1. It has been developed and implemented to estimate fast neutron fluence and radiation degradation parameters (dpa) in each graphite block location (socket).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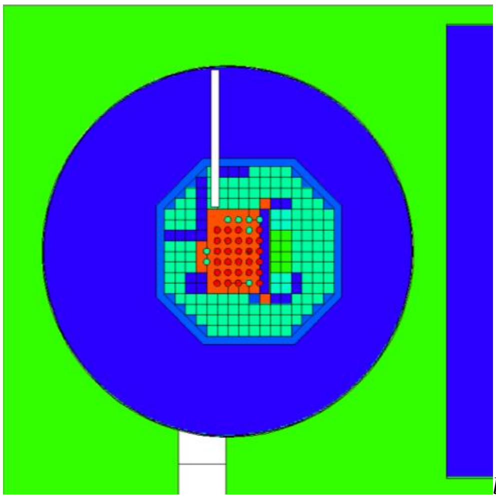
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Fig. 1. Vertical (a) and horizontal (b) views of the MARIA reactor MCNP model.

According to the MARIA Reactor Safety Analysis Report (the main document constituting the operating licence) graphite block operation is limited by fast neutron (En>0.5 MeV) fluence up to $5\cdot10^{21}$ cm^{-2}.

The influence of the interaction of ionizing radiation with matter is usually determined in dpa (displacement per atom) units.

The graphite blocks of the neutron reflector are movable. Many blocks have changed their location during the 40 years of the reactor operation. Some of them have been removed and replaced by newer ones. Therefore, the neutron parameters, i.e. fast neutron flux and dpa rate, have been determined for each of the graphite block locations (sockets). Results of the calculation need to be further implemented for a particular graphite block history.

Two representative configurations of the graphite reflector have been applied in the model: one valid up to November 2002, the other one – later. Calculations of the fast neutron flux and dpa rate have been performed for both configurations.

The MCNP model of the MARIA reactor has been validated based on neutron activation measurements performed between the graphite blocks [4]. Computed nuclear reaction rates have been compared with the measured values. The alculated to experimental ratio appears to be 0.64 ± 0.36 in the case of the ^{59}Co(n,γ) reaction, and 1.17 ± 0.38 in the case of the ^{58}Ni(n,p) reaction. This means that the thermal neutron flux is underestimated in the model (by ca. 36%), however the fast neutron flux is overestimated (by ca. 17%). Therefore, the model is found to be suitable (conservative) for estimation of the fast neutron influence on reactor structure components.

The results of calculations taking into account the history of particular graphite blocks can be used in the reactor ageing management plan.

References

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[2] Initial MCNP6 Release Overview MCNP6 v. 1.0, LANL report LA-UR-13-22934

[3] Geometria rdzenia reaktora MARIA, K. Pytel et at., Raport NCBJ, B-2/2017

[4] Obliczenie DPA w blokach grafitowych za pomocą modelu Kinchuin'a i Pease'a, M. Dorosz, Raport NCBJ B-32/2017

New MR-2 fuel in the MARIA Reactor

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The MARIA research reactor was designed as an MTR with individually cooled fuel channels moderated by water and surrounding beryllium blocks. This design gives it excellent irradiation capabilities in the thermal neutron spectrum with flux up to $3{\cdot}10^{14}$ n/cm^2/s, but fast the neutron flux is limited to $3{\cdot}10^{13}$ n/cm^2/s. To increase its irradiation capabilities with fast flux a new fuel MR-2 design was proposed with place for an irradiation target in the middle of the element - this feature will increase fast flux to $1{\cdot}10^{14}$ n/cm^2/s.

The new MR-2 fuel bears a similarity to the MR-6 fuel that, along with the MC-5 fuel, is currently used in the MARIA reactor in normal operation and can be considered as a modification of it - instead of six fuel tubes it contains only two plus an aluminium flow separator. Removal of the inner fuel tubes gives place for an irradiation container with a diameter δ=34 mm along the whole active length of the fuel, that is 1000 mm, and the total volume of irradiation equals ~90.8 dm^3. Expected maximum fast neutron flux is $1{\cdot}10^{14}$ n/cm^2/s, cadmium shielding was proposed in one of the central container variants as a measure to cut out thermal neutrons from the spectrum. Neutron energy spectra in the irradiation container are presented in Fig. 1.

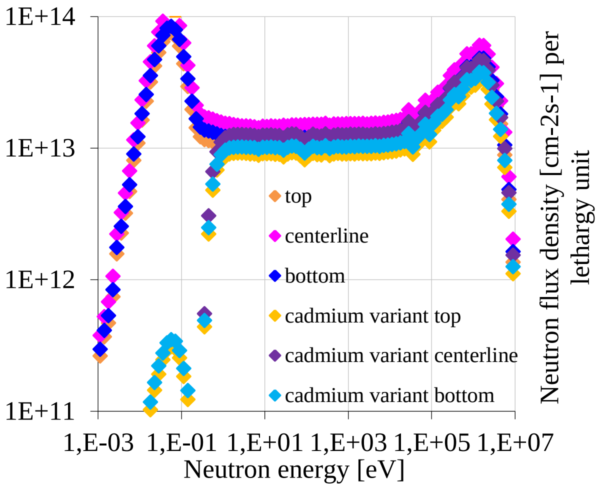

Fig. 1: Neutron energy spectr in the central container.

Steady state and transient calculations with FDM method were performed, in the latter, LOFA incident scenario was assumed. Results for steady state and for hot point in transient are presented in Figures 2 and 3 respectively.

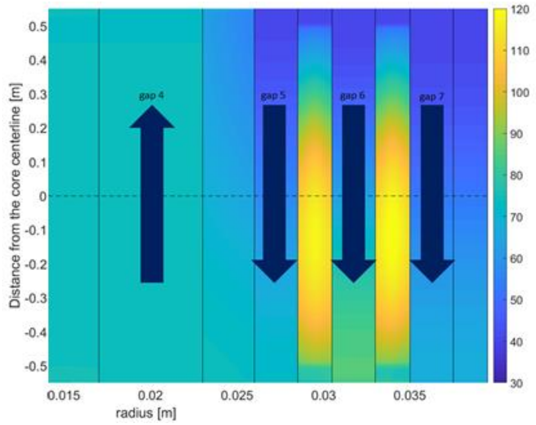

Fig. 2: Temperatures in steady state.

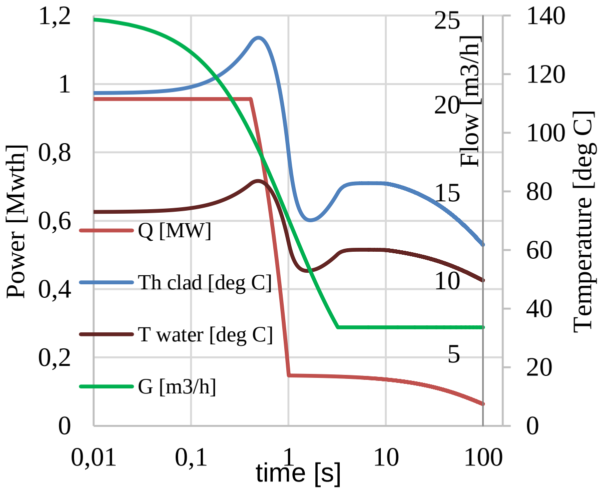

Fig. 3: LOFA transient parameters in a hot point.

The hottest cladding point is located on the outer side of fuel tube nr. 5, 150 mm down from the core centreline.

Calculations have revealed that the new MR-2 fuel can be safely used in MARIA reactor. This opens the possibility of new, especially materials science, research programmes connected to irradiation in the fast neutron spectrum. MR-2 with a 34 mm container provides a large loading volume for irradiation targets with a maximum fast neutron flux of up to $1{\cdot}10^{14}$ n/cm^2/s. Two MR-2 fuel elements are already in the possession of the MARIA reactor. Submission of the necessary documents to the Polish nuclear regulatory body for the license is planned soon, and normal operation is planned to start in 2018.

Neutron measurements between graphite blocks

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The goal of this work was the determination of the neutron flux density between reflector graphite blocks of the Maria Research Reactor. This quantity is crucial to aging management of reactor core elements. After evaluation of the neutron density flux we can calculate the displacement per atom-DPA. This quantity is related to radiation damage caused by neutron radiation in graphite blocks.This work describes the measurement procedure and the results of neutron density flux calculations.

The Maria reactor core consist of fuel elements, beryllium blocks and graphite blocks.

The graphite blocks are in an aluminum cladding. The top dimension of the block (overlay) is 140 mm, and 120 mm at the bottom. The height of the blocks with the pads is 1585 mm. The graphite blocks are truncated pyramids with a square base. Such a conical shape allows the installation of a core of much larger overall dimensions of the reactor components (drives) and experimental equipment. Graphite blocks are covered with aluminum sheet (2 mm). The gap between the cladding and the graphite is filled with nitrogen at a pressure of 0.01 MPa. In order to allow manipulation of the corresponding blocks and place them in the core blocks are arranged at the top and bottom of the aluminum covers. The lower cap has a leg and the upper - a head for the handle. These overlays result in a gap of 1.5 mm over the entire height of the block, which ensures the flow of coolant between the blocks. In the current configuration graphite blocks are not adjacent to the fuel elements.

For neutron measurements following activation detectors were chosen:

- AlCo (0,1%), was chosen for thermal and epithermal neutrons,

-Ni, for fast neutrons region.

The neutron induced reaction for these detectors are:

$$^{59}Co(n,\gamma)\ ^{60}Co$$

$$^{58}Ni(n,p)\ ^{58}Co$$

Neutron activation detectors were in the form of discs (ϕ=3mm) made from thin foil (0.1mm thickness).

Four such detectors were placed in aluminum foil, then placed in a measuring plate, then the tip was bent in a press.

Measuring plate dimensions:

length – 550mm,

width – 20mm,

thickness – 2mm.

In one plate two AlCo and two Ni detectors were inserted.

Twelve measuring plates were prepared and used. The length of the measuring plates was chosen so that the detectors were placed in the middle of the core. Plates with neutron detectors were then placed at selected locations, between graphite blocks (Fig. 1.).

Measurements were carried out between April 29 –May 4 2016. The reactor operated for 118 hours, with thermal power 24MW. Because of the high activity of the measuring plates and detectors they were measured from June 2016 February 2017. Calculations were also performed in this period.

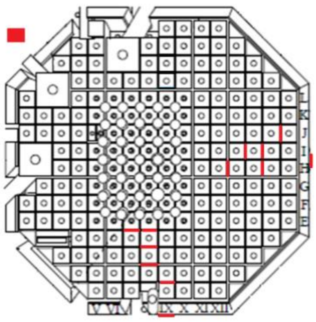

Fig. 1. Location of the experiment in the Maria reactor core.

Calculated neutron fluxes are presented in Fig. 2.a. and Fig 2.b. The figures show the dependence of changes in the neutron flux together with graphite block grid changes. Thermal neutron fluxes are in the range from $2.3\cdot10^{10}$ to $4,5\cdot10^{13}$ and fast neutron fluxes from $1.1\cdot10^{9}$ to $7.4\cdot10^{12}$.

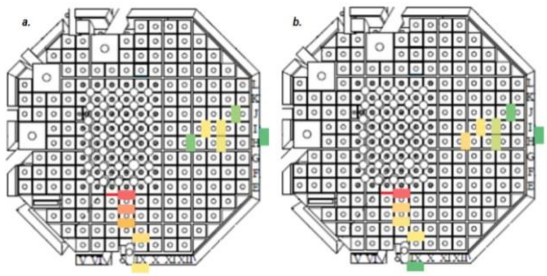

Fig. 2. Thermal neutron (a.) and fast neutron (b.) flux measured in the Maria reactor core, the warmer the colour greater the neutron flux.

Reference

[1] M. Dorosz, Pomiary strumieni neutronów pomiędzy blokami grafitowymi, B – 32 /2017 NCBJ

MARIA reactor operation

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The multipurpose high flux research reactor MARIA is a water and beryllium moderated reactor of pool type with graphite reflector and pressurised channels containing concentric tube assemblies of fuel elements (Fig. 1, 2). It was designed to provide a high degree of flexibility.

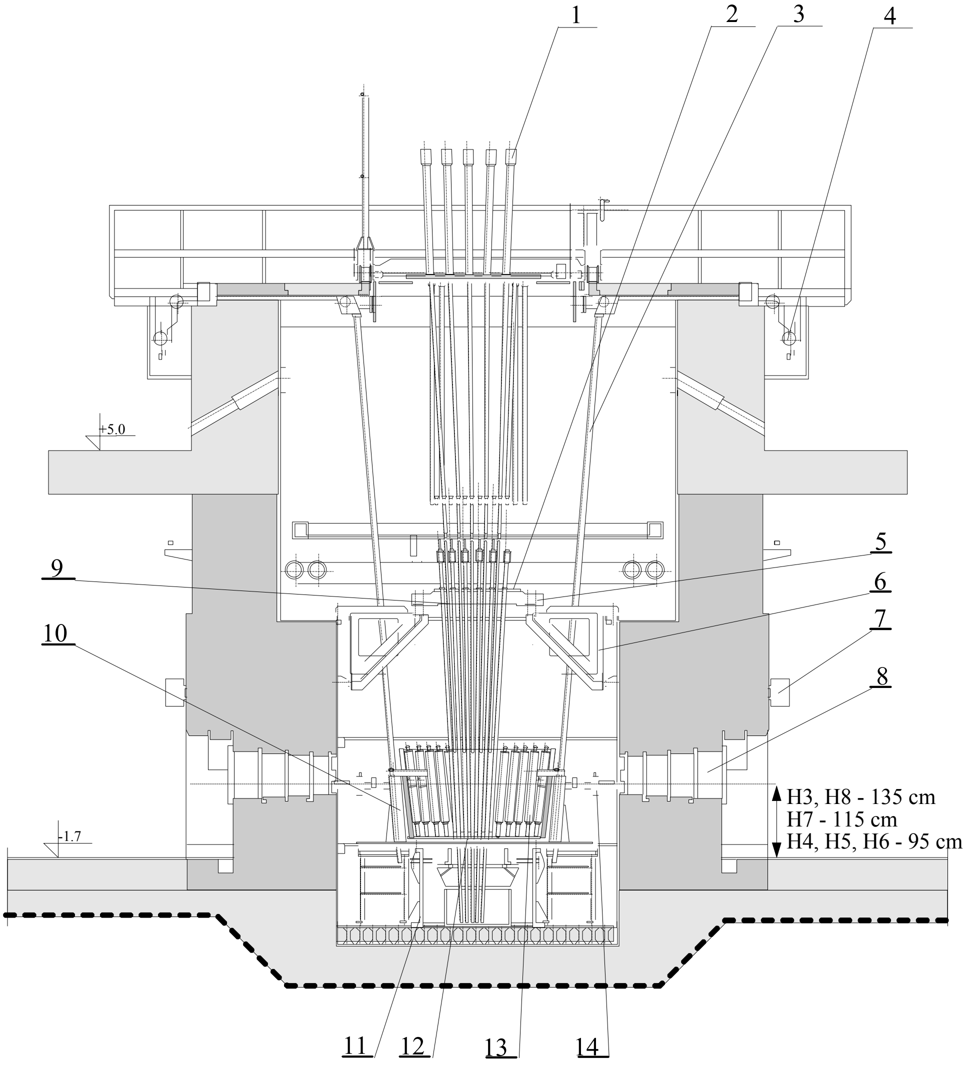

Fig. 1. Vertical section of the MARIA reactor. 1. control rod drive mechanism, 2. mounting plate, 3. ionisation chamber channel, 4. ionisation chamber drive mechanism,5. fuel and loop channels support plate, 6. plate support console, 7. horizontal beam tube shutter drive mechanism, 8. beam tube shutter, 9. fuel channel, 10. ionisation chamber shield, 11. core support structure, 12. core and reflector support plate, 13. reflector blocks, 14. beam tube compensation joint

The fuel channels are situated in a matrix containing beryllium blocks and enclosed by a lateral reflector made of graphite blocks in aluminium cans. The MARIA reactor is equipped with vertical channels for irradiation of target materials, a rabbit system for short irradiations and six horizontal neutron beam channels.

The main characteristics of the MARIA reactor are as follows:

nominal power	30 MW(th)
thermal neutron flux density	2.5·1014 n/cm^{2}s
moderator	H_2O, beryllium
cooling system	channel type
fuel assemblies:	
material	U_3Si_2Al
enrichment	19.75%
cladding	aluminium
shape	five concentric tubes
active length	1000 mm
output thermal neutron flux	
at horizontal channels	3÷5·109 n/cm^{2}s

The MARIA reactor reached its first criticality in December 1974. The reactor was in operation until 1985 when it was shut down for modernization. The modernization encompassed refurbishment and upgrading of technological systems. In particular, the efficiency of the ventilation and cooling systems was improved. In 1993 the MARIA reactor was put into operation again.

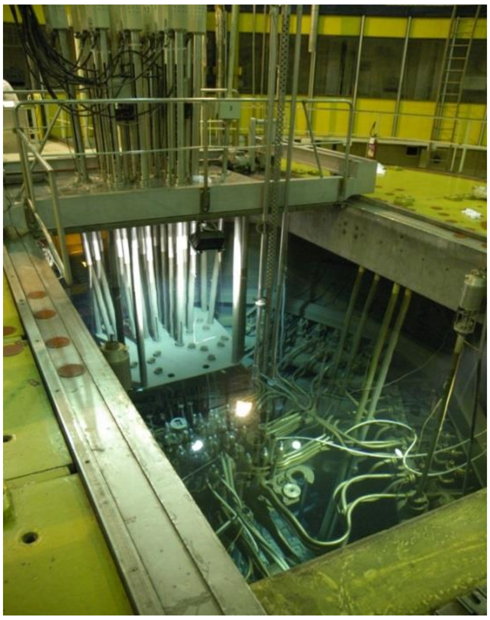

Fig. 2. The view of the reactor pool.

The main areas of reactor applications are as follows:

- irradiation of target materials in the vertical channels and in the rabbit system
- testing of fuel and structural materials for nuclear power engineering
- neutron radiography
- neutron activation analysis
- neutron transmutation doping
- research in neutron and condensed matter physics
- training

In 2017 the reactor completed 36 operation cycles at power levels from 18 MW to 25 MW (Fig. 3). The overall operation time was 4933 h.

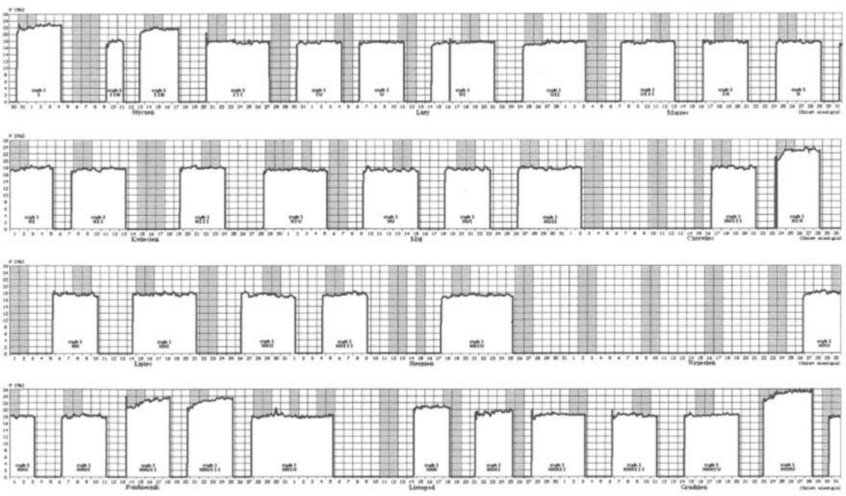

Fig. 3. Schedule of the MARIA reactor operation in 2017.

In 2017, after the cimpletion of the conversion process of reactor Maria core to low-enriched fuel with enrichment 19.75% in ^{235}U only this type of fuel was used.

The core configuration has been changed several times because of fuel and irradiation requirements. The core configuration of December 2017 consisting of 26 fuel assemblies is shown in Fig. 4.

In 2017 the MARIA reactor was operated successfully. The reactor scram was activated 3 times for a very short time and it was not necessary to shorten the operation cycles.

Operational availability factors were as follows:

$$\boldsymbol{A1} = \frac{\boldsymbol{OT}}{\boldsymbol{NH}} \cdot \mathbf{100}\% = \mathbf{99.1}\%$$

$$\boldsymbol{A2} = \frac{\boldsymbol{OT}}{\mathbf{8784}} \cdot \mathbf{100}\% = \mathbf{56.3}\%$$

where OT (operational time) denotes the number of hours on power and NH is the sum of the number of hours on power and the number of unscheduled shutdowns.

In 2017 the total emissions of radioactive materials to the environment were:

- inert gases (mainly ^{41}Ar): $1.0 \cdot 10^{13}$ Bq, i.e. 1,0% of the limit determined by the NAEA
- iodine: $4.0 \cdot 10^{7}$Bq, i.e. 0.8% of the limit determined by the NAEA.

The yearly emissions of the noble gases and iodines are presented in Figs. 5 and 6.

In 2017 ninety eight workers received measurable whole body doses from 0,1 to 2.55 mSv and 8 workers received skin doses from 1.01 to 2.08 mSv.

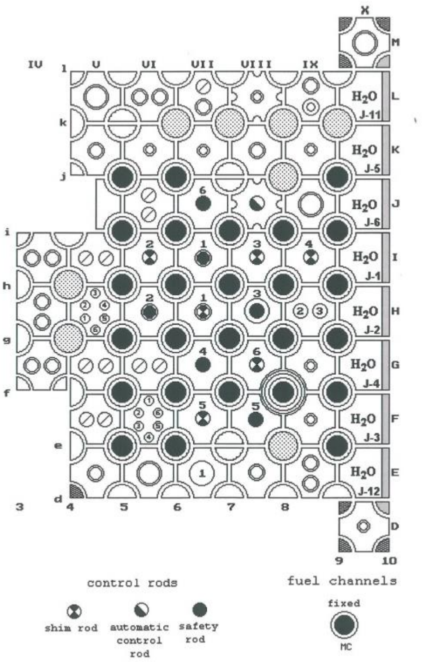

Fig. 4. Core configuration of December 2017.

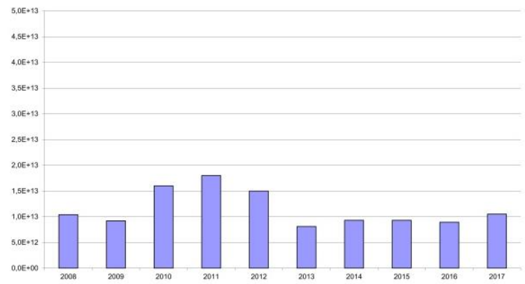

Fig. 5. Yearly emissions of noble gases in the last ten years.

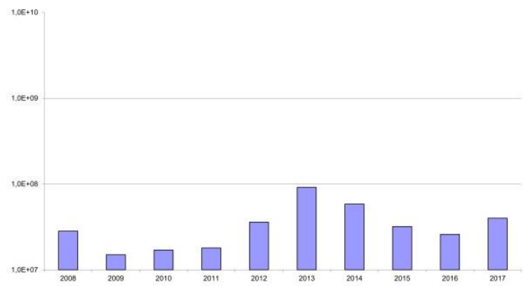

Fig. 6. Yearly iodines total emissions in the last ten years

Neutron irradiation services

MARIA is one of the largest research reactors in the Europe. The neutron irradiation services provided at the MARIA research reactor include a wide range of radioisotope production, neutron activation analyses and biomedical technology.

Nuclear reactors remain a key component in the production of useful isotopes for nuclear medicine. Available services cover the activation of a large variety of target materials for the production of isotopes, which can be processed at the discretion of the customer. Irradiation services are performed in various facilities constructed at the MARIA reactor, depending on the required neutron flux levels, irradiation times, targets mass and geometry. The standard vertical in-core isotope channels as well as special ones equipped with hydraulic transport systems are in operation.

For domestic customers the targets of KCl, $LuCl_3$, S, Yb_2O_3, Sm_2O_3 and Cu, Ho, In, Cr, NiO, Re, Cr, W, MoO_3 were irradiated (Fig. 7). Most of them were irradiated for the *Radioisotope Centre POLATOM of the National Centre for Nuclear Research* for radioisotope production. Total annual isotope production reached 1415 TBq in 2017. Production of ^{99}Mo as a fission product of the irradiation uranium targets was equal 2 337 TBq.

Irradiation of uranium targets for ^{99}Mo production plays a particular role in the utilization of the Maria reactor. This activity supports the global chain of research reactors producing ^{99}Mo. Among them are: HFR (Netherlands), BR2 (Belgium) and LVR15 (Czech Republic).

A key medical isotope is ^{99m}Tc, which is a decay product of ^{99}Mo. One of the possible sources of ^{99}Mo can be achieved in the course of the ^{235}U fission reaction. The main objective of ^{235}U irradiation is to obtain the ^{99m}Tc isotope, which is widely used in the domain of medical diagnostics. The ^{99m}Tc from a source of decaying ^{99}Mo can be easily transported to hospitals, where it is extracted and used for a variety of nuclear medicine diagnostics procedures.

The commercial irradiation of uranium plates for ^{99}Mo production has been carried out at the MARIA reactor since 2010. In 2017 five reactor operation cycles were dedicated to ^{99}Mo production. The targets were irradiated according to order on the two or three positions inside the irradiation rigs. This means that one reactor operation cycle includes irradiation of 16 or 24 uranium targets per cycle. Following the shortage of the key medical radioisotope ^{99}Mo and its ^{99m}Tc related to long-term reliability the MARIA reactor has declared its readiness to irradiate new desig LEU targets. One of the main producers of ^{99}Mo, who collaborates with MARIA, *Mallinckrodt Pharmaceuticals* (actual *CURIUM*), decided to start a programme of certification of the new LEU targets (*Low-Enriched Uranium*). The programme has been successfully completed and irradiation of LEU targets has been performed since December 2017. The good perspective of using ^{99}Mo in medicine allows us to start a second programme dedicated to ^{99}Mo production. This programme, started in 2017, is realized in collaboration with the company *NorthWest Medical Isotopes (NWMI)* from the USA. The programme is focused on the full technology of production of the ^{99}Mo radioisotope, starting from irradiation of the new type of targets in the MARIA reactor to extraction of ^{99}Mo radioisotope as a product of radiochemical processing. The advantage of the new technology is based on the new construction of the uranium targets and the limited quantity of waste. The targets are constructed using a special kind of microspheres including a UO_2 core. The target prepared for the hot test is a result of a collaboration between the MARIA reactor team and specialists from MURR (*Missouri University Research Reactor*). The *Safety Analysis Report* has been submitted for approval by the NAEA (Regulatory Body). The special irradiation facility constructed and manufactured by the MARIA reactor team is already prepared.

The first tests were performed in August 2017. The targets irradiated in the special irradiation facility at the reactor MARIA were transported to a laboratory located in the Radioactive Waste Management Plant (ZUOP). The radiochemistry procedure was using adapted to the hot cell

Based on the feasibility study and experience in irradiation of ^{235}U targets in the MARIA reactor, the “Molybdenum Świerk Project” for production of ^{99}Mo was continued during 2017. The project for production facility foresees the adaptation of the existing infrastructure in the MARIA reactor and infrastructure of POLATOM for ^{99}Mo/^{99m}Tc generator assembly.

Based on cooperation with the Dutch company *QUIREM Medical BV Division* technology of irradiation of the Ho-PLLA microspheres was completed. The microspheres containing holmium are used in radioembolization procedures as an innovative form of radiotherapy for the treatment of liver cancer.

Neutron irradiation services utilizing the MARIA reactor also include the colouring of topaz minerals. The irradiation of minerals in special channels located outside the reactor core changes the clear natural state to shades of blue, thereby increasing the commercial value of the product. Blue topaz is released to the market as non-radioactive material, conforming to strict international criteria.

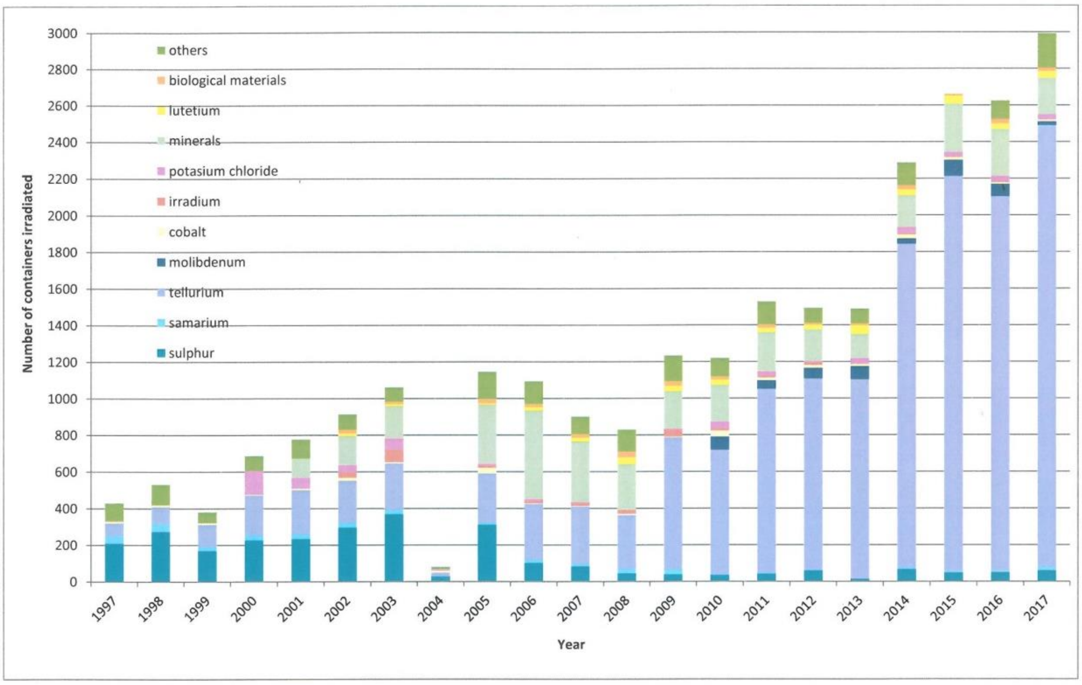

Fig. 7. Distribution of target materials irradiated

Neutronics calculations of Li-6, H-3 and He-3 buildup in beryllium moderator: application to the MARIA reactor

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Introduciton

The MARIA reactor operates using beryllium and water as moderators. Due to interactions with neutron, so-called poisons in beryllium are produced. This study was carried in order to improve modelling of the generation of these isotopes and their spatial distribution.

Methodology and results

The calculations were made using two continuous energy Monte Carlo neutron transport codes: SERPENT2 [2] and TRIPOLI-4®.10 [10], as well as the APOLLO2.8.3 deterministic transport code (MOC/CEA2005, SHEM281 -group [11]) These codes were used in combination with the neutron data library derived from the same JEFF-3.1.1 nuclear data file.

SERPENT2 provides the depletion calculations without the need externally to define the decay chain of the depleted materials [4]. The reactions are available defined in the code. The TRIPOLI-4® Monte Carlo however, requires the definition of the depletion chains for each type of depleted material. The daughter and mother isotopes are connected with each other by reaction type. The same has to be done in the APOLLO2 code.

An additional two chains were added to the earlier developed depletion chain in order to correct the results of the APOLLO2 calculations for the isotopic transmutations in beryllium. They are presented in fig. 1.

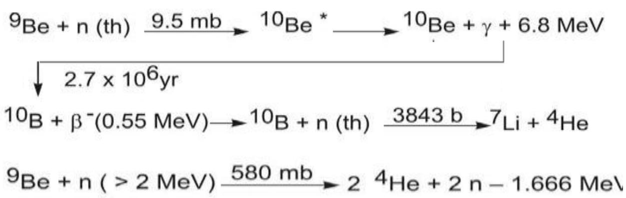

Fig. 1. (n,γ) and (n,2n) triggered reactions.

After including more reactions in the calculation scheme the results of the multiplication factor for multiple cycles burnup calculations was compared with the previous results. The results are presented in fig. 2.

The concentrations of the poisons were compared and the results for Li^6, H^3 and He^3 are presented in Figs. 3 to 5.

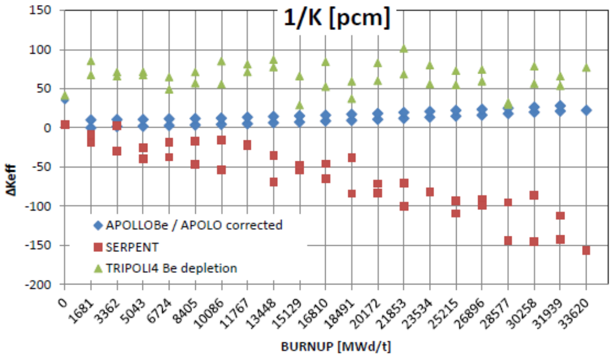

Fig. 2. Discrepancies of multiplication factor.

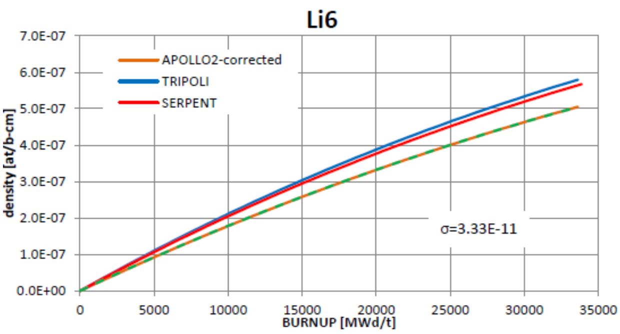

Fig. 3. Li^6 Concentration buildup

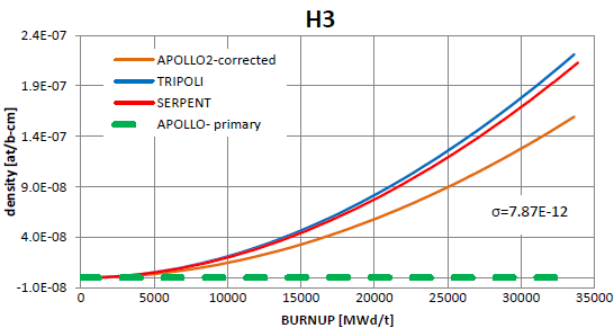

Fig. 4. H^3 Concentration buildup

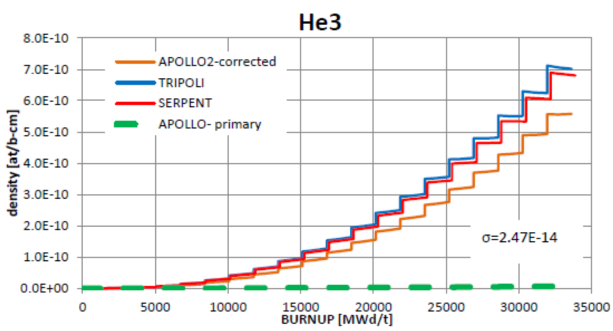

Fig. 5. He^3 Concentration buildup

Conclusions

The conducted studies represent an improvement in the correct prediction of Li6, He3 and H3 build-up in irradiated beryllium. It was shown that detailed modelling of all elements impacts the information obtained from the simulation and the possibility of correct future measurement results, as part of the evaluation of this calculation scheme is an experimental campaign.

Further analysis assumes performing an experiment firstly with fresh and then with poisoned beryllium. The calculations and studies carried out so far, have shown the relevance of performing direct measurements.

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Validation of the sub-channel level CFD approach for bare rod bundle

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At the end of 2016 NCBJ and the Nuclear Research and Consultancy Group (NRG, Netherlands) signed an agreement regarding scientific and research cooperation. In the framework of this research programme a high quality Direct Numerical Simulation (DNS) database for a closely-spaced, bare rod bundle configuration will be generated. This database will serve as a reference for validation purposes for the models of lower order accuracy.

Detailed knowledge of mass and heat transfer with strong 3D effects in a fuel assembly of a reactor core has always been an important factor in the design of nuclear systems. However, these local phenomena, which in turn are quite essential, cannot be simulated by traditionally adopted subchannel analysis codes. To overcome this knowledge gap, computational fluid dynamics (CFD) has recently become a valuable research tool to analyze complex fuel assembly thermal hydraulics (flow field presented in Fig. 1).

Nevertheless, a proper prediction of the flow and heat behaviour inside a rod bundle is a challenge for the commonly used unsteady Reynolds-Averaged Navier-Stokes (URANS) turbulence models because they need to be validated and improved for certain conditions and specific geometries. Although the measurement techniques are constantly improved CFD-grade experiments on the subchannel scale are quite costly or even impossible to perform. In addition, lack of experimental databases makes it impossible to validate properly and/or calibrate these models. In this context, DNS can serve as a reference for model development and validation. However, despite the advancement in the super computing, performing a DNS for a realistic rod bundle at a high Reynolds number is not foreseeable in the near future. Thus, it is important properly to design a numerical experiment, which will be used in order to generate a DNS reference database.

Design of the numerical experiment is an iterative process, which requires a series of long pre cursor calculations. In order properly to calibrate the computational domain which will be used to carry out a high fidelity thermal-flow analysis the following steps have beencarried out:

1. Scaling of the Reynolds number
2. Optimization of the computational domain
3. Introduction of the thermal fields

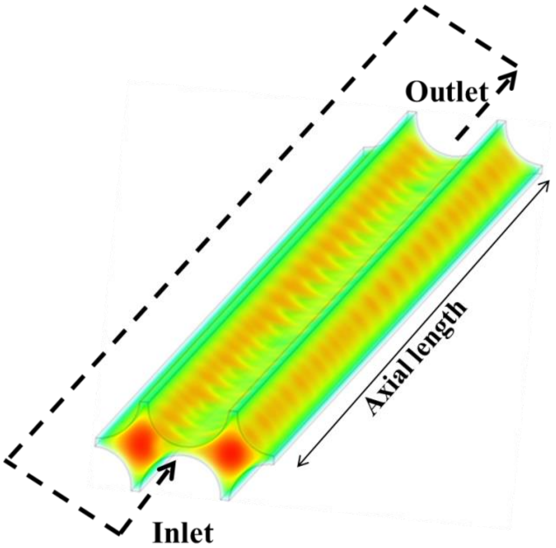

Fig 1. Computation domain. Characteristic pulsation in the subchannel region.

The fulfillment of the above steps allowed us to:

- scale-down the Reynolds number by preserving the overall features of the expected flow field – the size of the turbulence length scales has been increased

- optimize the axial length of the computational domain in order to make it feasible for the available computational resources

- take into account the heat transfer analysis for four different passive scalars representing four different fluids. The heat transfer of these fluids was studied in combination with two different boundary conditions at the walls, i.e. a constant temperature and a constant heat flux

Finally, the obtained RANS results allowed us to compute the Kolmogorov and Batchelor length scales which are crucial in estimating the overall meshing requirements for targeted DNS computations, which are feasible for the available computational resources.

Application of the fault tree analysis in the safety classification of structures, systems and components of the Maria research reactor

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National Centre for Nuclear Research, Otwock-Świerk,Poland

The MARIA research reactor, operated by the National Centre for Nuclear Research (NCBJ), is a multi-purpose high flux reactor of the pool type, moderated with water and beryllium with a graphite reflector and pressurized channels consisting of concentric tube assemblies of fuel elements. The channels are situated in a matrix containing beryllium blocks and enclosed in a lateral reflector made of graphite blocks in aluminum cans. Currently, the main area of reactor application is radioisotopes production.

Maria comes under international requirements and national law on safety classification (SSC). However, while the guidelines on SSC for nuclear power reactors are well established on both the national and international level, neither Polish Atomic Law nor the guidelines of the National Atomic Energy Agency consider any specific standards or requirements for research reactors. This makes the process more problematic, since the technical solutions applied to the Maria reactor are unique and thus difficult to be addressed within the general framework of the classification process developed for power reactors.

One of the most important issues considered during the classification process and required by Polish Atomic Law is the probability that a classified system, component or construction element will be necessary to fulfill the safety functions. In order to assess the probability, one needs to calculate the initiating events frequency and the probability that particular safety functions will not be performed in response to the event occurrence. This requires the following items to be developed first:

1. a list of initiating events with specification of reactor states caused by the events;
2. a list of components, whose failures may lead to the postulated initiating events;
3. a list of engineered safety functions triggered by the postulated initiating events;
4. a list of systems, components and elements, dedicated to fulfilling the safety functions;
5. reliability data (failure probability) for the considered components/elements.

Based on these data a fault tree analysis has been performed to assess the frequency of the selected initiating events: loss of coolant flow through the reactor fuel channels (Fig. 1), loss of coolant flow in the reactor pool, loss of external power supply, and decrease in cooling capacity within the secondary cooling loop. In order to assess how often the safety functions will be triggered by the initiating events and what is the probability that they will not be performed, the fault tees for each safety system will be developed as a continuation of this work.

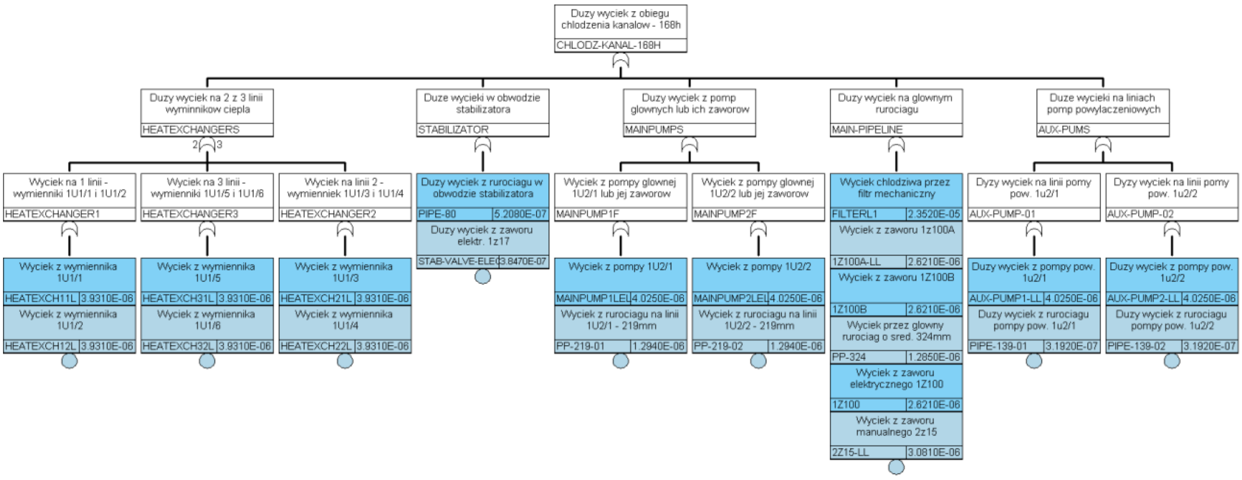

Fig. 1. The fault tree structure developed in SAPHIRE code modelling loss of coolant flow through the reactor fuel channels.

Neutronic characteristics of the EPR core with accident tolerant fuel cladding material

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The rapid increase of interest in accident tolerant fuel is due to the 2011 Tsunami disaster in Fukushima. One of the factors that can contribute to improving fuel failure resistance is the use of fuel cladding with greater oxidation resistance than zirconium. Multiple materials are considered as cladding for accident tolerant fuel. The main candidate materials as replacement for Zr alloys are ceramics and molybdenum alloys [1, 2, 3]. New materials could potentially replace Zr alloys or be used as one of the cladding layers. For this analysis, molybdenum and SiC were used as cladding materials. Ceramics are characterized by high temperature resistance, good thermal conductivity and high creep resistance. Although silicon carbide's (SiC) hardness is 9.5 on the Mohs scale, at the same time is a very brittle material. Therefore, SiC / SiC composites, consisting of a SiC matrix and reinforced by SiC fibres are proposed as cladding materials. Molybdenum has a higher absorption cross section for thermal neutrons than others materials. The influence of using M5, SiC and Mo cladding on an LWR core is based on the European Pressurized Reactor (EPR) core model[4-8]. M5 is dedicated as cladding for the EPR and the results are referenced. Results of the multiplication factor are shown in Table 1.

Table 1. Multiplication factor k_{eff} for the EPR core with 1600ppm of boron in water.

CZP		
fuel cladding	k_{eff}	stand. dev.
M5	0.98448	0.00031
Mo	0.8563	0.00030
SiC	0.98802	0.00032
HFP		
fuel cladding	k_{eff}	stand. dev.
M5	0.98079	0.00030
Mo	0.83135	0.00027
SiC	0.98668	0.00032

Core reactivity with molybdenum fuel cladding is the lowest because of the thermal neutron absorption cross section. The difference between Mo cladding and M5 cladding for HFP equals 18% and for CZP equals 15%. The difference between M5 and SiC is below 1%. This means that M5 material cannot be replaced by molybdenum of the same thickness. Comparing the two investigated materials, SiC is more promising than Mo from the neutronic point of view. Neutronic calculations were performed using the MCNPX code version 2.7.0 developed by Los Alamos and using ENDF/B-VII.0 nuclear data library[9].

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ALLEGRO core neutron physics studies

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The gas cooled fast reactor demonstrator ALLEGRO was originally proposed and developed by the CEA, France. Subsequently development activity has been transferred to V4G4 countries – the Czech Republic, Slovakia, Hungary and Poland. In the framework of VINCO EU project two neutronic benchmarks oriented on burnup of 2D numerical models of the ALLEGRO fuel subassembly at infinite lattice were defined.

The goal of the calculation exercise was to verify the reactor physics codes, namely to get information about modelling uncertainties. The deviations obtained between the participants characterize user effects, the modelling uncertainties and the influence of the nuclear data differences altogether, without the possibility of their separation because of the complexity of the benchmark problem.

To enable identification of the reasons for the deviations a simpler problem – an infinite regular lattice problem with burnup and with leakage represented by fixed buckling was defined as the first part of the neutronic benchmark in the VINCO project.

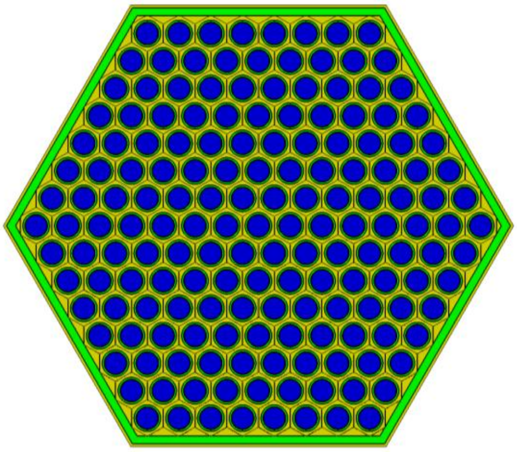

Fig. 1. Model of an ALLEGRO fuel assembly defined in the benchmark using the NEWT/SCALE6.2.2 code

The second part of the VINCO neutronic benchmark was oriented on burnup of 2D numerical models of an ALLEGRO fuel assembly (Fig. 1) at infinite lattice without fixed buckling and without a critical spectrum, with MOX and UOX fuel. The more complex definition (assemblies) is much closer to the usual utilization of the tested codes – preparation of libraries for macrocodes. Exclusion of critical spectrum calculations (both for burnup and for reactivity effects) enables a more detailed comparison of deterministic and stochastic calculations. Pin geometry, materials and some other data were taken from the first part of the benchmark. The main differences are as follows: model of the whole assembly, approximation of realistic temperature distribution, no buckling fixation - results based on an infinite multiplication factor, a wider set of results including kinetic parameters and transport cross ssections. Utilization of experience from the solution of the first part was supposed.

The physical effects of the modelling to be verified by solving the benchmark were as follows:

1. Nuclear data uncertainties,
2. Satisfactorily detailed energy discretization,
3. Resonance self-shielding in the energy region of the resolved resonances,
4. Resonance self-shielding in the unresolved region using a statistical approach
5. Representing anisotropy of the scattering in the leakage calculation,
6. Representing anisotropy of the flux in the leakage calculation.

The detailed specification contained:

- Pin geometry and material composition at nominal conditions, including MOX and UOX fuels,

- Fuel subassembly geometry and material composition at nominal conditions,

- Core nominal parameters,

- Detailed description of branches including thermal linear expansion parameters,

- Set of requested results.

The participants in the benchmarks are listed in Table 1. One of the teams was the representative of theNational Centre for Nuclear Research – Małgorzata Klisińska and Łukasz Koszuk.

Table. 1. Participants in the ALLEGRO neutronic benchmarks

Company/Institute /University	Group members	Code	Library
ÚJV Řež, a.s.	Milan Gren	ECCO-ERANOS2.2	JEF3.1
VUJE, a.s.	Petr Dařílek	HELIOS 2.1.1	ENDF/B-VII.0
VUJE, a.s.	Radoslav Zajac, Tomáš Chrebet	SERPENT 2.1.25	ENDF/B-VII
Narodowe Centrum Badań Jądrowych	Łukasz Koszuk, Małgorzata Klisińska	SCALE 6.2.2	ENDF/B-VII.1
Magyar Tudományos Akadémia Energiatudományi Kutatóközpont	Emese Temesvári	ECCO module of ERANOS2.2	JEF3.1
CEA	Gerald Rimpault	ERANOS	JEF3.1.1

The results of the benchmarks with detailed discussion were presented in reports from the VINCO project [1, 2] and during the "International Conference on Fast Reactors and Related Fuel Cycles: Next Generation Nuclear Systems for Sustainable Development" [3]. The final paper [3], in preparation, will be published in 2018.

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9th International School on Nuclear Power

A. Strupczewski[1], Ł. Koszuk[1], E. Szlichcińska[1], A. Korczyc[2], A. Korgul[3]

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[2]Division of Radioactive Waste Disposal, Otwock-Świerk, Poland

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The ninth edition of the International School on Nuclear Power took place in Warsaw, Świerk and Różan (Fig. 1) from of 14th-17th November 2017.

A team of 24 eminent experts from 14 countries, each highly regarded in his field of expertise, presented lectures on subjects of most interest for the further development of nuclear power, and 200 participants come from various regions and organizations in Poland. The School was organized jointly by the National Centre for Nuclear Research and the Department of Nuclear Energy in the Ministry of Energy, in cooperation with the Faculty of Physics of Warsaw University and the Enterprise for Radioactive Waste Management.

Fig. 1. The opening session of the 9th International School on Nuclear Power

The 9th International School on Nuclear Power was addressed to teachers and students of technical universities, to workers in administrations and local authorities involved in nuclear power licensing, siting and operational issues, to nuclear power plant investors, industrial organizations and technical support organization employees and all interested in nuclear power issues.

During the four days of the School there were two days of the lectures provided cost-free to all participants in the School and two days of workshops organized in two groups each day, with visits to the National Centre for Nuclear Research - the MARIA research reactor, the research laboratories of the Institute and in the Enterprise for Radioactive Waste Management - while another group visited the National Repository for Radioactive Waste at Różan.

During the two lecture days the participants listened to 20 lectures, provided by the best experts from 14 countries, who had come from most distant places - from the USA to Japan – on three continents to share their knowledge with theSchool participants. This generous offer of the School was possible owing to the support provided by organizations related to nuclear power development.

The workshops listed above were supported by the partners of the National Centre for Nuclear Research, namely the five organizations building nuclear power plants:

China General Nuclear Power, which currently has 14 reactors under construction, that is a quarter of all new power reactors in the world,

Electricite de France, which leads the operation of the largest fleet of nuclear power plants and offers new nuclear units with EPR reactors for the UK,

General Electric Hitachi, which with ABWR reactors started the implementation of III generation reactors and is currently developing Economic Simplified Boiling Water Reactor with passive safety features,

Korea Hydro and Nuclear Power, developing III generation reactors APR 1400 with new improvements in the field of reactor safety after severe accidents with core melt,

SNC-Lavalin, developing and building heavy water reactors of the CANDU type.

In addition, support for the National Centre for Nuclear research was provided by the following organizations:

URENCO – the market leader in nuclear fuel enrichment services and the main player in the nuclear fuel supply chain,

PSE S.A. – the Polish Electric Network Company,

IRTech – a Polish company producing radiation detectors.

Media patronage was provided by two agencies: Biznes Alert and CIRE.

The School lasted for four days.On the first and fourth days (14th and 17th November) there were workshops (Fig. 2) in the Centre at Świerk and in Różan. They covered the following points: the MARIA high flux research reactor, the State Enterprise for Radioactive Waste Management, the Department of Education and Training, the Laboratory of Dosimetric Measurements, and a Workshop prepared by IRtech. Two days – 15th and 16th November – were filled with lectures in the lecture hall provided for the School by the Department of Physics of Warsaw University (Fig. 3).

Programme of the School (15th-16th November):

1. Polish nuclear energy program
Status of the Polish Nuclear Energy Programme, dr. J. Sobolewski, Director, Nuclear Energy Department, Ministry of Energy, Poland

Programme of the first nuclear power plant construction in Poland, K. Sadłowski, President, PGE EJ 1, Poland

How to integrate a nuclear power plant into the Polish power system, Mr. Z. Uszyński, PSE S.A., Poland

Fig. 2. Workshop at the Maria research reactor.

2. Atoms for the future
Nuclear power is needed for sustainable development, dr. H-Holger Rogner, International Institute for Applied Systems Analysis, Austria

Financing of nuclear projects in Europe, Mr. A. Goicea, FORATOM, Belgium

HTR reactors within the Polish strategy of nuclear energy development, prof. dr. G. Wrochna, National Centre for Nuclear Research, Poland, dr. T. Shibata, Japan Atomic Energy Agency, Japan

3. Fuel cycle
An update of the nuclear fuel supply industry, dr. M. Mori, Manager Marketing & Sales, URENCO, UK/Germany/Netherland

Recycling of nuclear fuel – reasons and perspectives, prof. dr. A. Strupczewski, National Centre for Nuclear Research, Poland

4. 150th anniversary of Maria Skłodowska-Curie's birth
The great scientist - Maria Skłodowska-Curie, prof. dr. A. K. Wróblewski, Faculty of Physics, University of Warsaw, Poland

5. Radiation protection
Was it necessary to evacuate the population around Chernobyl and Fukushima? What changes are needed in radiation protection regulations? dr. M. Doss, Scientists for Accurate Radiation Information S.A.R.I., USA.

Safety of the population around the radioactive waste repository, Ms. A. Korczyc, Division of Radioactive Waste Disposal, Poland.

6. Safety of nuclear power plants
Secondary passive residual heat removal system R&D and engineering applications, Mr. L. Ren, China General Nuclear Power Corporation, China.

Negative power reactivity coefficient in EPR – influence on primary system break (LOCA) and steam line break (SLB) accidents, Mr. A. Panichi & Mr. J. Galarin, EDF, France.

Experiences from the UK safety case assessment of the ABWR and relevance for Poland, D. Hinds & K. Okumura, GE Hitachi, USA/Japan.

How is the safety of APR-1400 in the case of core melt accidents assured in NPPs being built in Korea and the United Arab Emirates, Mr. D.H. Hwang, Korea Hydro & Nuclear Power, South Korea.

CANDU safety basis: limiting & compensating for positive reactivity insertion, dr. A. Lee, Manager, Physics, Licensing and Safety, SNC-Lavalin, Canada.

7. Fukushima impacts

The effects of the Fukushima accident, prof. L. Dobrzyński, National Centre for Nuclear Research, Poland

8. Competitiveness of nuclear power

Are offshore wind farms competitive to nuclear? prof. dr. A. Strupczewski, National Centre for Nuclear Research, Poland

9. Destination: Mars

Nuclear reactors for space, Ms. Z. Hodgson, National Nuclear Laboratory, UK

Space radiation protection, dr. U. H. Straube, M.D., Medical Operations & Space Medicine, European Astronaut Centre Department, European Space Agency

Fig. 3. The participants of the 9th International School on Nuclear Power

The 9th International School on Nuclear Power in Warsaw presented the best world specialists and most authoritative and objective data in chosen fields of nuclear power. It was a successful event, with large attendance and high interest from the participants. The presentations delivered during the School are available on the Internet at the address www.szkola-ej.pl.

The measurements of the high energy evaporated neutrons by means of ^{89}Y threshold reaction activation method

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[2]Joint Institute for Nuclear Research, 141980 Dubna, Russia

This work was carried out within a project to investigate radioactive waste utilization problems using the Quinta assembly simulating ADS (Accelerator Driving Systems). The deeply subcritical Quinta set-up has about 500 kg of natural uranium and lead shielding (Fig. 1). The assembly was irradiated by proton and deuteron beams with energies from 0.66 to 6 GeV from accelerators located at the JINR laboratories, Dubna. The (n,xn) threshold reaction method based on yttrium activation detectors enables us to evaluate the average neutron flux spectrum for energies higher than that of fission neutrons and near the maximum evaporation energy (about 40 MeV). The neutron flux density measured in three different neutron energy ranges: 11.5–20.8 MeV, 20.8-32.7MeV and 32.7–100 MeV will be presented as well as their comparison.

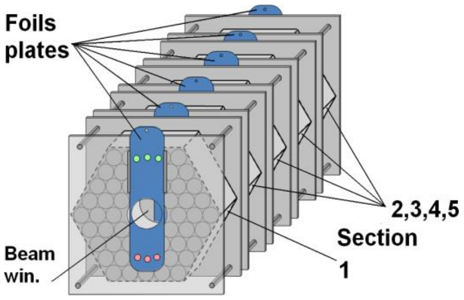

Fig. 1. The Quinta assembly.

High energy neutrons are an ideal tool to induce fission in most transuranium isotopes, giving us the possibility to transmute radioactive waste (RAW).

Theoretical analysis of the neutron flux inside the Quinta assembly irradiated by a deuteron beam (Fig. 2 a, b), shows an interesting aspect [1]. In the calculations for a deuteron beam of 1 GeV (Fig. 2 a) the neutron flux in the energy range from 20 MeV to 100 MeV starts to increase and then decreases with energy again, while for the higher deuteron beam energy of 4 GeV (Fig. 2 b) the neutron flux in the considered energy range decreases all the time.

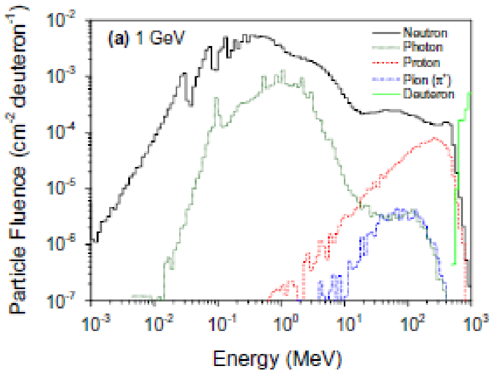

Fig. 2 (a). Neutron spectrum as a function of energy (solid black line) for a deuteron beam with an energy of 1 GeV [1].

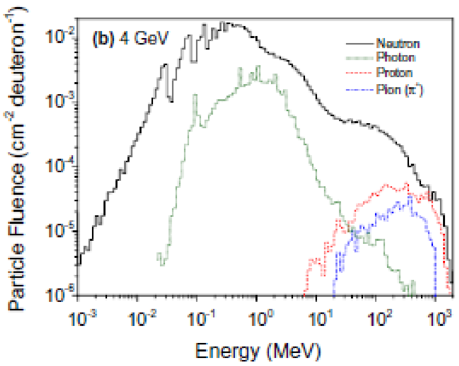

Fig. 2 (b). Neutron spectrum as a function of energy (solid black line) for a deuteron beam with an energy of 4 GeV [1].

This motivates us to consider our measurements of average neutron flux density versus three different energy ranges: 1- (11.5-20.8 MeV), 2- (20.8-32 MeV), 3- (32-100MeV) and five planes of the Quinta assembly.

We have concentrated on measuring the neutron flux distribution (radial and axial) for neutron energies above 10 MeV applying deuteron beams of energies from 1 GeV to 8 GeV and a proton beam of 0.66 GeV.

In the case of the 0.66 GeV experiment, the neutron flux density for the energy range 20.8-32.7 MeV was higher than for the range 11.5-20.8 MeV. This seems to be an unexpected feature of the measurement (Fig. 3).

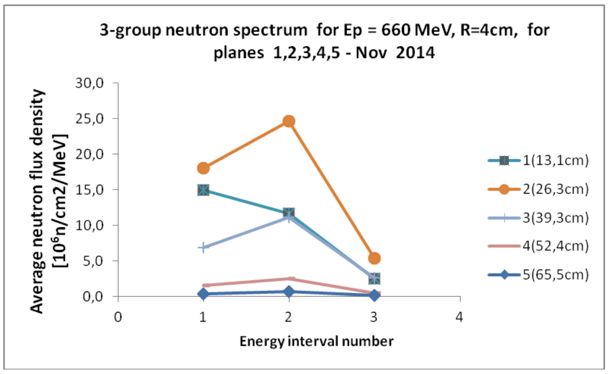

Fig. 3. Average neutron flux density versus three different energy ranges: 1-(11.5-20.8 MeV), 2-(20.8-32 MeV), 3-(32-100MeV) on five planes (legend on the right-hand side of the Figure); R=4 cm, proton beam energy 0.66 GeV, experiment: Nov 2014 [2 – 5].

The same effect was found for a deuteron beam energy of 2 GeV. In the case of the experiments with a higher beam energy (4 and 6 GeV), the average neutron flux density for the energy range 11.5-20.8 MeV is higher than for the range 20.8-32 MeV, as expected (Fig. 4).

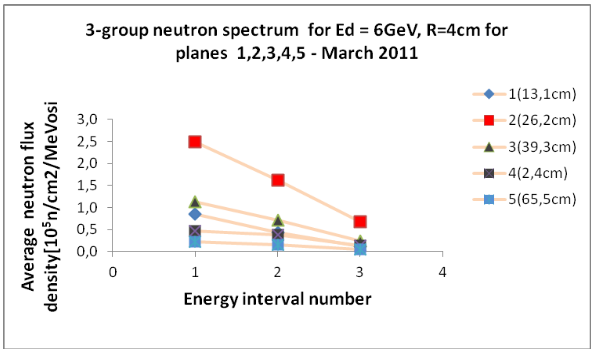

Fig. 4. Average neutron flux density versus three different energy ranges: 1- (11.5-20.8 MeV), 2- (20.8-32 MeV), 3- (32-100MeV) on five planes (legend on the right-hand side of the Figure); R=4 cm, deuteron beam energy 6 GeV, experiment: March 2011 [2 – 5].

Concluding, we can say that the experimental results presented above support the theoretical Monte Carlo calculations [1].

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Non-electric applications of generation IV nuclear reactors

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The concepts of High Temperature Gas Cooled and Very High Temperature Reactors (HTGR, VHTR) or Dual Fluid Reactors (DFR) are examples of attempts to build industrial applications based on Generation IV nuclear technologies. These applications concern not only generation of electricity but the production of process heat, hydrogen or hydrazine, which is of great importance for the chemical industry. However, the licensing process of the newly designed reactors, comprising safety and reliability issues of the whole processing installations of the chemical plant, needs special attention and an appropriate research programme to solve a number of foresight problems, not considered so far or not treated deeply enough in previous studies. The paper [1] summarizes the current state of the development and identifies needs for further research.

The most important technical problems that must be solved because of licensing, have already been identified in the NC2I-R project [2], and they are related to safety. They concern the following:

- evaluation of the fission product transfer coefficients in the fuel coatings and graphite matrix;

- finding a means for evaluating the fuel temperature in standard and accidental operation;

- the achievement of a suitable radiative emissivity of the core barrel;

- in service inspection of the primary structures including graphite structures, fuel elements (blocks) and steam generator tubes;

- the evaluation of dust behaviour, distribution in the primary pipes and components (potential for accumulation, plate-out, etc.), resuspension and dust bound fission products phenomena and, in general, the development of a complete chain of computer codes for the modelling of source terms in the case of depressurisation scenarios.

Most research needed for the implementation of HTR for industrial purposes concerns rather the choice of optimal solutions for specific technical problems than basic barriers. The other reason for the need of further research is related to solving licensing issues. The basic directions of research should be the following:

- deterministic safety analysis for HTR, i.e. neutronics and thermo-hydraulics calculations, in particular:

- integrated models for thermo-hydraulics and neutronics analyses;

- development of high fidelity models for HTR;

- validation of the numerical tools used for HTR design, concerning neutronics and thermo-hydraulics (distribution of power, neutron flux, temperature).

- probabilistic safety assessment of HTR integrated with chemical installation – integrated risk analysis chemical-nuclear installations, including analysis of interfaces, mutual reactions and interdependencies;

- materials science issues: mechanical and thermal characteristics, corrosion effects in specific radiological conditions to determine reactor safety limits;

- determining basic characteristics of HTR like reactivity, distribution of core temperature, changes of pressure gradient;

- development and testing instrumentation of HTR;

- studies for new concepts of fuel and core structure.

In particular, the results of research should answer the following questions:

- Which types of interactions between nuclear and non-nuclear systems have to be considered, concerning safety aspects during normal and accidental situations?

- What is the impact of a non-nuclear incident (fire, explosion, toxic release) for the nuclear part of the installation?

- Is there a need for a higher safety standard for a nuclear reactor operating as part of a chemical installation?

- Is there a need to modify the strategy of defence in depth?

- What kind of approach (deterministic, probabilistic, hybrid) is suitable during the design and licensing phase for cogeneration systems?

- Which containment characteristics play a deciding role for safe operation of a nuclear reactor in a cogeneration system?

Is there a need for special regulations concerning emergency planning and response for such a processing system?

It seems that licensing procedures are the most burning issues as new regulations and procedures have to be developed by the regulator in order to reflect all the features of HTRs. This, however concerns not only the nuclear part but also the chemical one. Therefore, it seems that there is a need to develop a new framework for an integrated approach to the safety of combined nuclear-chemical installations. This is important both from the technical point of view as well as for the legislative process. Building such a framework could accelerate successful, practical realization of cogeneration applications.

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Nuclear Technology in Health and Environmental Protection, Management of Hazards

Irradiation of Ho-PLLA microspheres in the MARIA reactor

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Radioembolization is an innovative form of radiotherapy for the treatment of liver cancer. It is a very promising and valuable treatment method. In radioembolization, small particles, known as microspheres are administered in the liver artery. The microspheres lodge in the tumour microvasculature and deposit a targeted dose of radioactivity.

For many year, there were only two commercially available radioembolization products, both based on the ^{90}Y isotope. This radionuclide has a half-life of 64 h and emits β-particles of energy up to 2.28 MeV. Since ^{90}Y emits only β -particle, it is difficult to track and verify the distribution of the particle after administration.

As an answer to the above-mentioned limitations, a next generation radioembolization method has been developed, based on ^{166}Ho (27 h half-life). ^{166}Ho emits β -particles of energy up to 1.86 MeV, but it emits also primary photons of 80.58 keV. This allows single-photon-emission computed tomography (SPECT)to be used to determine the microsphere distribution and applied dose. Holmium is paramagnetic so it allows also nuclear magnetic resonance (NMR) imaging to be used to determine the microsphere distribution [1].

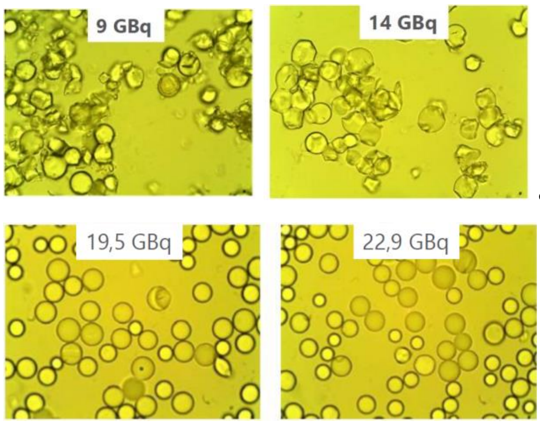
The microspheres containing holmium are made of biodegradable poly(L-lactic acid) – PLLA. They are ca. 30 μm in diameter. The microspheres are CE-marked and available under the brand name QuiremSpheres® (Quirem Medical BV, The Netherlands).

Recently, Quirem Medical BV asked NCBJ to prepare the technology of Ho-PLLA microsphere irradiation in the MARIA reactor. The irradiation process must ensure a precise ^{166}Ho activity (depending on the microsphere mass, patient dose, transport time etc.), while maintaining the physical integrity (size, spherical, homogeneity, etc.).

Degradation of PLLA microspheres starts above a temperature of ca. 60°C. Therefore, the crucial issue is to avoid overheating the microspheres during irradiation. The temperature of the irradiation target depends on the (nuclear) heat generation in the target, heat conduction and cooling water temperature. Only the latter value is known accurately. Therefore, the standard irradiation conditions led to unsatisfactory results (cf. Fig.1a).

In order to reduce nuclear heating in irradiated Ho-PLLA microspheres the peripheral irradiation channel of hydraulic rabbit system No 4 was selected to perform the irradiations. Improved water cooling was applied to the hydraulic rabbit system channels. A purpose-designed irradiation vial for Ho-PLLA microspheres and filling the irradiation container with helium allows for more efficient heat removal from the microspheres during irradiation.

Adjacent to the irradiation channel of the hydraulic rabbit system No 4 a set of nuclear radiation detectors has been installed in order to monitor irradiation conditions on-line. Two self-powered neutron detectors (equipped with silver and rhodium emitters) were used to determine the thermal neutron flux density. They were absolutely calibrated by means of activation (cobalt) foils. Both the KAROLINA [2] nuclear calorimeter and gamma-thermometer were used to determine the nuclear heat value. A purpose pressure sensor installed in the rabbit system allows the irradiation time to be determine with an accuracy of over 0.5 sec.



a

b

Fig. 1. Examples of irradiated Ho-PLLA microspheres: a – standard, b – improved irradiation conditions.

A series of experimental irradiations allowed the irradiation technology to be improved (cf. Fig. 1b). That led in July 2017 to successful validation of the MARIA reactor as a supplier of irradiated QuiremSpheres®.

Since then Ho-PLLA microspheres irradiated in the MARIA reactor have been supplied by Quirem Medical BV to a number of medical centres in Europe for cancer patient treatment.

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Overview of the activities of the research Department of Radioisotope Centre Polatom

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The R&D Department of the Radioisotope Centre POLATOM carries out research programme related to the application of radioactive preparations and radiolabelled compounds in various fields of medicine, research and industry.

The results of our investigations are directly implemented in the technologies development at POLATOM. The R&D Department contributes to the pharmaceutical documentation required in the process of Marketing Authorization for novel radiopharmaceuticals, in accordance with the current regulations.

The most important achievements in 2017 were:

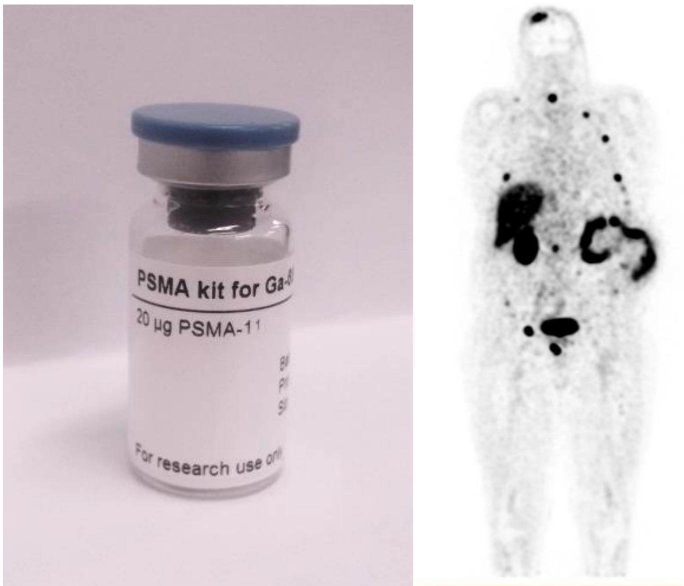
1) Validation of a radiopharmaceutical kit (PMA-01) for preparation of ^{68}Ga-PSMA – a radiopharmaceutical for PET diagnostics of prostate cancer and preparation of the marketing authorization dossier.

2) Development and synthesis of a new PSMA molecule for radiolabelling with technetium-99m for SPECT scintigraphy of prostate cancer

3) Under the INNOMED project we developed the technology of DOTATATE peptide synthesis using an automatic peptide synthesizer.

4) The PET-SCAND project resulted in the first production in Poland of scandium-44 in a cyclotron and the preparation of a pharmaceutical form enabling preparation of radiolabelled clinically important substances like: DOTATATE, EDTMP i DOTA-Substance-P.

5) BIOTECHNET – a new stationary ^{99}Mo/^{99m}Tc generator based on MPCM highly selective resin has been developed.



The PMA-01 kit developed by RC POLATOM (left); PET/CT image of disseminated metastases of prostate cancer cells to the skeleton visualized by ^{68}Ga-PSMA-11 prepared from the kit (right)

Currently, the R&D Department is involved in projects financed by the following Polish institutions: the National Centre for Research and Development and the National Science Centre. The active projects are:

1. NCBiR, No. ERA-NET TRANSCAN/01/2013 in the framework of the international project "Phase I clinical trial using a novel CCK-2/gastrin receptor-localizing radiolabelled peptide probe for personalized diagnosis and therapy of patients with progressive or metastatic medullary thyroid carcinoma" (2013 - 2016).

2. NCBiR Project No. PBS3/A9/28/2015 "Preparation of radiopharmaceuticals based on scandium radionuclides for positron emission tomography PET-SKAND" (2015- 2017).

3. STRATEGMED2/269080/8/NCBR/2015 "Innovative ^{99}Mo/^{99m}Tc technetium generator with microporous sorbent, chitosan based, using ^{99}Mo molybdenum, designed for use in isotope diagnostics" with the acronym "BIOTECHNET" (2015-2018).

4. The Operational Programme Smart Growth 2014-2020, Measure 1.2, Sectoral Programmes, Innomed Programme; Multivariate formulations of DOTATATE peptide as a precursor for the preparation of radiopharmaceuticals (MultiSom) (2016-2018).

5. Innovative methods of ^{47}Sc and ^{67}Cu production in a nuclear reactor and cyclotron. International Co-Financed Project - MNiSW No. 3639/FAO/IAEA/16/2017/0 (SCAND-I-CO) (2017-2018).

In receny year the R&D Department has participated in and is currently active in the IAEA coordinated projects:

1. IAEA No. 20496 "Therapeutic Radiopharmaceuticals Labelled with New Emerging Radionuclides (^{67}Cu, ^{186}Re, ^{47}Sc) (F22053)" (2016-2019).

2. IAEA No. 18475/RO "Nanosized delivery systems based radiopharmaceuticals in Poland" (2014-2017).

3. IAEA No. No 20496 - Therapeutic Radiopharmaceutucals Labelled with New Emerging Radionuclides (Cu-67, Re-186, Sc-47)

In 2017 we contributed to COST (European Cooperation Program of Scientific and Technical Cooperation):

1. COST CM1207 – GLISTEN: GPCR-Ligand interactions, structures, and transmembrane signaling: a European Research Network.

2. COST BM1403 - Native Mass Spectrometry and Related Methods for Structural Biology (2014-2018).

A kit for the preparation of ^{68}Ga-PSMA-11. The critical parameters during labelling and storage of the kit

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^{68}Ga-PSMA-11 (^{68}Ga-HBED-CC-PSMA, Fig. 1) is a relatively new radiotracer of high importance in post-surgery diagnosis and staging of patients with prostate cancer [1,2]. Recently at POLATOM we have developed a kit for ^{68}Ga labeling of PSMA-11**.** The kit composition allows labelling with ^{68}Ga eluates of various HCl concentrations, e.g. Eckert&Ziegler (0.1M HCl) or ITG (0.05M HCl), in volumes ranging from 1 to 5 ml. We present the results of our experimental approach towards the determination of the influence of potential metallic impurities on the ^{68}Ga-PSMA-11 radiolabelling yield, as well as results on kit stability and optimal storage conditions.

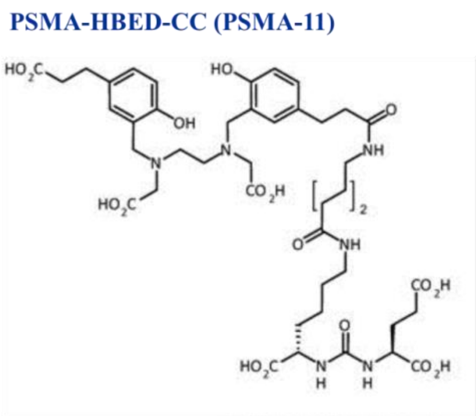

Fig. 1. Structure of PSMA-11 (POLATOM).

The influence of potential metallic impurities such as Fe, Cu, Zn, Ni and Pb on the efficiency of Ga labelling was determined by the synthesis of the "cold" metal-PSMA-11 complexes. Briefly, to 60 mg of sodium acetate dissolved in 0.5 mL of 1M HCl, 30 µg of PSMA-11 solution in water and 15% molar excess of "cold" metal ion (ICP standard) were added, followed by incubation at 95 ^{o}C for 10 minutes. The formation of complexes was confirmed by LC-MS. We also investigated the possible contaminating metal exchange in the PSMA-11 complex for Ga by addition of an equimolar quantity of "cold" Ga(III) followed by LC-MS determination.

For analysis of "cold" metal-PSMA-11 complexes LC-MS was used: LCMS-IT-TOF (Shimadzu) with Phenomenex Kinetex C18, 75x2.1mm, 2.6 µm column; gradient method - A: H_2O, 0.1% HCOOH, B: AcN, 0.1% HCOOH; 0-5 min 5-50% B, 5-7.5 min 50-5% B; 0.4 mL/min, injection volume 10 µl.

For testing the radiochemical purity (RCP) of ^{68}Ga-PSMA-11 the RP-Radio HPLC was used as described previously and the TLC method (ITLC SG; 10% Ammonium acetate/MeOH 50/50 v/v). Freeze-dried kits of PSMA-11 were stored at 2-8ºC, at 25ºC and at 40ºC / 70% RH according to *ICH Topic Q 1 A (R2) Stability Testing of new Drug Substances and Products (CPMP/ICH/2736/99).* Stability of the kits was assessed by testing the radiochemical purity (HPLC and TLC) and pH after ^{68}Ga labelling.

Table 1. Summary of metal ion reactivity with PSMA-11.

Metal	Complex with PSMA-11	Metal exchange with Ga
Fe	+	-
Cu	+	+
Ni	+	+
Zn	-	N.A.
Pb	-	N.A.

PSMA-11 complexes with Fe, Cu, Zn, Ni and Pb were prepared in standardized conditions. However, only the complex with Fe ions was strong, non-exchangeable for the Ga ion. Very weak metal ion-PSMA-11 complexes were obtained for Cu and Ni ions, since these ions were easily exchanged from PSMA-11 complex for Ga ion [Tab. 1]. No complex formation was found for Zn and Pb.

The PSMA kits for ^{68}Ga labelling were stable both at lowered temperatures (2-8^{o}C) and at elevated temperatures ranging up to 40 ºC [Fig. 2]. Based on the results obtained at 40 ºC the stability of the kits can be extrapolated to 1 year at 25ºC.

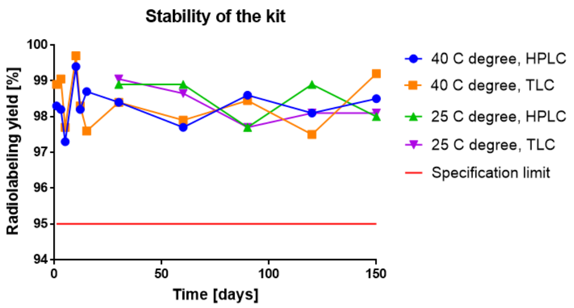

Fig. 2. Kit stability at various storage conditions (batch 01/16). reactivity with PSMA-11.

This study was presented as a poster at ISRS 2017 in Dresden

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Correlated ionization clusters in two-volumes – a novel experiment with the Jet Counter

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The track structure of ionizing particles is frequently considered to play an important role in the whole balance of radiation damage. To date, few devices have been developed that are capable of measuring track structure characteristics on the nanometric scale. They are known as the Track Ion Counter,[1] the Jet Counter[2-3], the Ion Counter[4] and the Startrack Counter.[5] All these constructions are able to measure the number of ions created by a heavy charged particle in a single nano-site. Ions created in such a nano-volume form an ionization cluster and the number of ions in a cluster is called the cluster-size. An estimation of the ionization cluster-size probability distribution, ICSD, is the main result of nanodosimetric experiments.

To provide a more in-depth view into particle track structure an experiment with two neighbouring sensitive volumes has been proposed.[6] Simultaneous measurements of ions created by a single projectile in two adjacent volumes provides an opportunity to the study correlation between cluster-sizes. The correlation is the reflection of the ionisation phenomenon in which both ion and secondary electron are produced. This secondary electron can produce another ion in the same or in the neighbouring volume. The strength of the correlation is an excellent test for theoretical models used in Monte Carlo simulations.

The Jet Counter radial measurements set-up[7] was used as a starting point for this new kind of experiment. However, a constant separation voltage on grid G1 cannot be used in this case, as it will prevent ions created in volume V1 reaching the ion detector and no polarisation will lead to mixing of ions created in both volumes due to diffusion (see fig. 1). To separate groups of ions and not lose those created in volume V1 the polarisation is on white waiting for an ionisation particle and is turned off several microseconds after projectile arrival. This way two well separated groups of ions can be distinguished on the drift time spectrum (see Fig. 2).

A direct result of the two-volume nanodosimetric experiment isa two-dimensional ionisation cluster-size probability distribution (2D-ICSD), as probability is estimated for each pair of cluster-sizes. A series of experiments with 3.8 MeV alpha projectile has been carried out to measure the 2D-ICSD for different scales. An example of the results is presented in figure 3. As one can see, the most probable cluster-size μ the V2, which is distantfrom the track core, is 0, so most of the DNA damage is caused very close to the track core (high probability of cluster-sizes $\nu \geq 2$). However, as V2 cuts only a small solid angle (~0.21π) around the particle path the overall probability of creating additional ionisation in the track penumbra is much higher than is apparent from fig. 3. Thus, secondary electrons may play an important role in creating complex DNA damage. Further investigation is needed properly to asses stheir impact and a possible synergetic effect of such extensive damage.

This measurement technique can provide an answer to the question about the importance of secondary electrons to the overall efficiency of creating complex DNA damage by heavy charged particles. Further studies in other geometries and for other projectiles are planned.

Acknowledgements The authors thank Mrs E. Jaworska and Mr A. Dudziński for their technical assistance during the experiments.

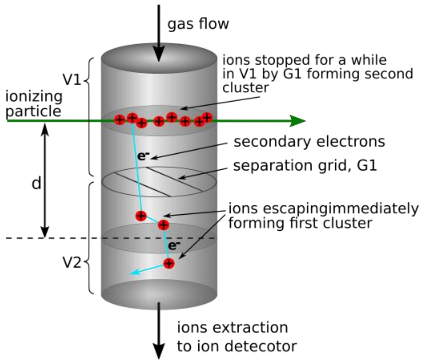

Fig. 1. Schematic view of the interaction chamber of the Jet Counter used in the correlation experiments.

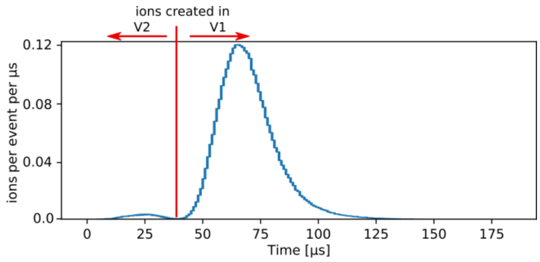

Fig. 2. Drift time spectrum of ions created in the interaction chamber. The red line shows the minimum separating two groups of ions.

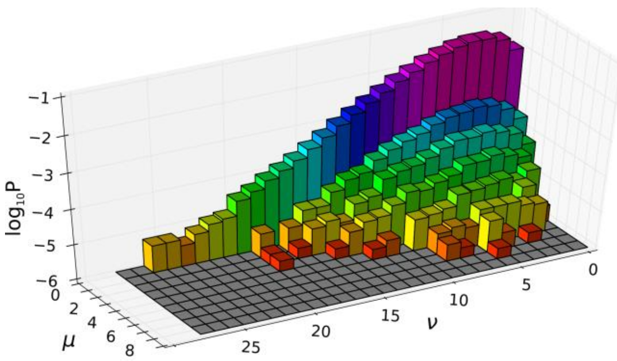

Fig. 3. 2D-ICSD for 3.8 MeV alpha particles measured for two adjacent volumes each of size 3.2 nm in diameter and 3.2 nm height. ν, µ – cluster-sizes in V1 and V2 respectively. Normalization is over all measured cluster-size pairs.

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The Laboratory of Radioactivity Standards of Radioisotope Centre POLATOM – Overview of activity

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The Laboratory of Radioactivity Standards (LRS) in the Radioisotope Centre POLATOM, National Centre for Nuclear Research, in Otwock, is the only laboratory in Poland performing radioactivity measurements of α-, β- and γ-emitters by absolute methods and performing calibration of standard solutions and radioactive sources.

The President of the Central Office of Measures in Poland (GUM) established the National Standard of Radionuclides Activity in Poland in 1999. The standard is stored and used at LRS. LRS has implemented and maintained a quality management system compliant with the international standard ISO/IEC 17025:2005. The accreditation certificate awarded by the Polish Centre for Accreditation (accreditation no. AP 120) is the confirmation of our technical competence as a calibration laboratory.

The Laboratory of Radioactivity Standards is the only Polish manufacturer of radioactive standard sources for customers in the country and abroad. The LRS is also the only calibration laboratory in Poland that fulfills the requirements of the Regulations of the Health Ministry from 18th February 2011 on the conditions of safe application of ionizing radiation in all kinds of medical exposure (consolidated text, Journal of Laws 2017, Item 884) in the field of specialized technical tests for dose calibrators used by nuclear medicine departments.

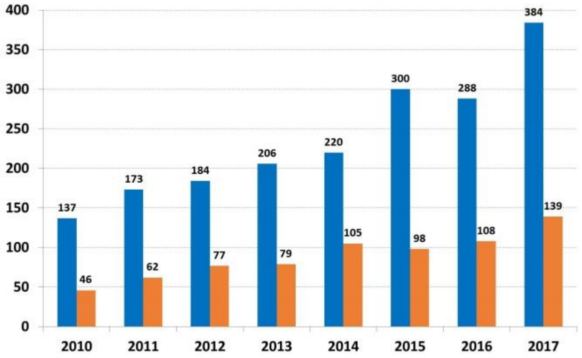

Fig. 1. Trend in customer requests for calibration of dose calibrators and standard sources in 2010-2017.

During 2017 maintenance and development of the National Standard was partially financed as a grant-in-aid by the Polish Ministry of Energy. Connected activities were divided into 4 tasks:

- Technical service the National Standard systems.
- Transferring of the activity unit to users in Poland and abroad.
- Comparisons of radionuclide activity measurements.
- Maintaining the management system according to the ISO/IEC 17025:2015 standard.

One of the main tasks performed by the LRS is the continuous improvement and expansion of our measurement capabilities in the field of radionuclide metrology. Our primary goal is to ensure traceability with National Standard for activity measurements of radioisotopes used in nuclear medicine.This is done by development of primary methods and calibration of secondary and working standards.

LRS also participates in international comparisons of radioactivity measurements, enabling linking to the global system of national standards. These comparisons are organized by the International Bureau of Weights and Measures (BIPM) and the European Association of National Metrology Institutes EURAMET. The laboratory also participates in comparisons within the framework of the International Reference System (SIR).

In order to provide a means for laboratories to substantiate calibration and measurement capability (CMC) claims for 68Ge, a Key Comparison was proposed, agreed, and carried out, designated CCRI(II)-K2.Ge-68. Samples were distributed to 18 participants. Results were received from 17 participants. A Comparison Reference Value (CRV) of 621.7(11) kBq g−1 were proposed, based on 14 values. Two results were identified as outliers. One result was not from primary methods. Degrees of equivalence with the proposed CRV were reported and the showed that NCBJ RC POLATOM value was in very good agreement with the results from other laboratories (see Fig. 2).

A bilateral comparison between ENEA-INMRI (Italy) and NCBJ RC POLATOM of 131I solution activity measurements was also organized and piloted by POLATOM, which provided the sources for the comparison. The 131I master solution was standardized independently at both institutes using Liquid Scintillation Counting (using primary activity measurement techniques, based on 4π(LS)-γ coincidence and anti-coincidence counting, the triple-to-double coincidence ratio (TDCR) method and the CIEMAT/NIST efficiency tracing method, with 3H as a tracer) and ionization chamber techniques. The solution was then sent by POLATOM to the BIPM International Reference System (SIR). The comparison was registered as EURAMET.RI(II)-K2.I-131 key comparison allowing the ENEA-INMRI result to enter in the SIR database.

All results obtained by both laboratories are in excellent agreement (see Fig. 3), confirmed by the fact that all absolute values of the En parameter of any pair of results are significantly lower than 1. The laboratories selected their most robust results, obtained using the 4π(LS)-γ coincidence (DCC) method (ENEA-INMRI) and the 4π(LS)-γ coincidence and anti-coincidence method (POLATOM) as the outcome of this bilateral comparison. They are in excellent agreement with the KCRV value, within uncertainties.

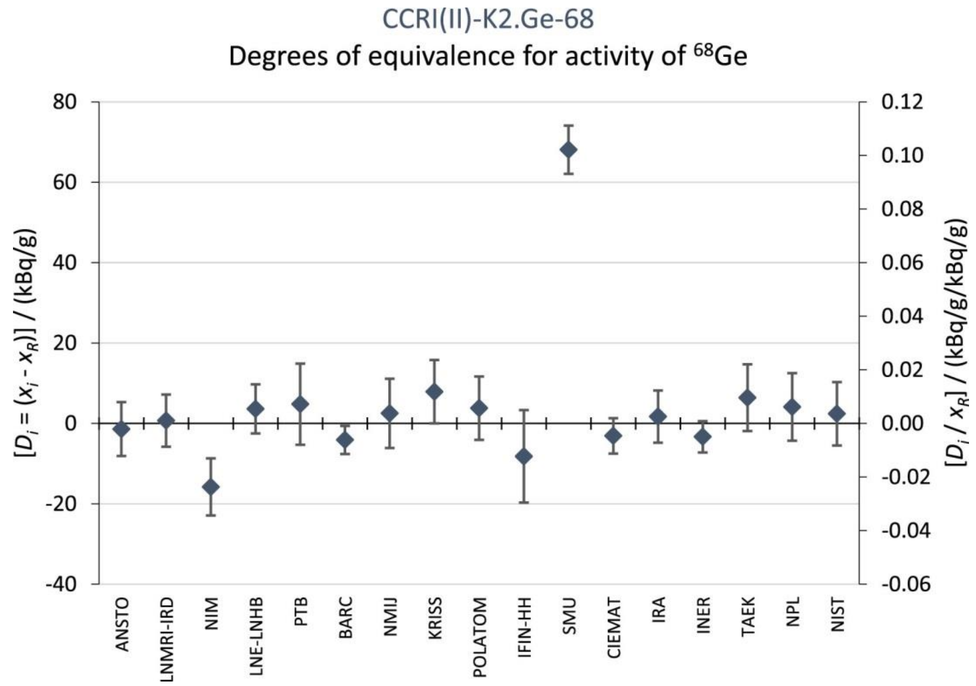

Fig. 2. Degrees of Equivalence, D_i, for participants in the CCRI Key Comparison CCRI(II)-K2.Ge-68. The value of D_i is computed as x_i - x_R, where x_i is the laboratory reported result and x_R is the proposed Comparison Reference Value. The uncertainty bars correspond to the expanded uncertainty (k = 2).

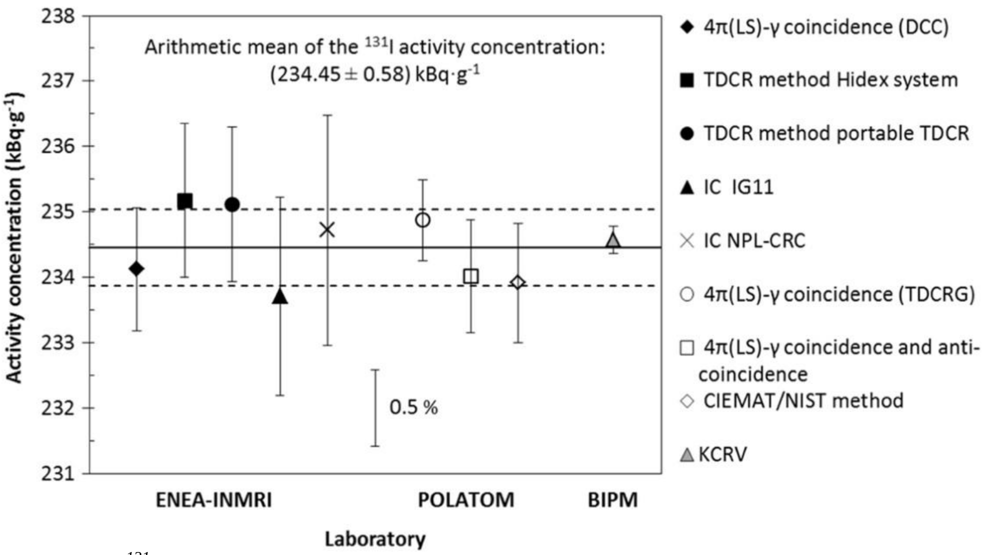

Fig. 3. Final results of the ^{131}I bilateral comparison of activity concentration measurements with their combined standard uncertainties. The arithmetic mean value is shown (solid line) with its standard uncertainty (dotted lines).

Identification of atmospheric contamination sources in an urban area

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Releases of dangerous substances are the most serious in urbanized areas, where the number of potentially exposed people is very high. Although accurate modelling of atmospheric contaminant transportation in a dense urban area is not trivial, in principle, given a gas source and a wind field, with an appropriate atmospheric dispersion model it is possible to calculate the expected gas concentration for any downwind location. On the other hand, even with a vast network of appropriately spaced sensors transmitting registered concentrations, the arrangement of buildings, wind field, and other atmospheric air parameters, identifying the release source is complicated. This task can be understood as presenting the dispersion model reproducing the contamination. This, in turn, requires defining the set of model parameters. Such an inverse problem has no unique analytical solution, but it might instead be analyzed with probabilistic frameworks, such as the Bayesian approach, where all quantities are modelled as random variables. This randomness can be interpreted as a lack of complete knowledge of parameter values and is reflected in the uncertainty around the target values. The bayesian approach transforms the aforementioned inverse problem into the search for a posterior distribution based on sampling of an ensemble of simulations using a priori knowledge and observed data.

We propose to apply the Approximate Bayesian Computation (ABC) algorithm to reconstruction in the urban environment problem. This approach has proven itself to be useful in solving atmospheric mobile contamination source identification problems [1]. This method is especially effective in dynamic complex problems in which the likelihood function is costly to compute. The proposed algorithm updates knowledge of the source parameters along with new substance concentrations transmitted by multiple sensors. We extended our study presented in [2] by increasing the number of searched parameters and significantly modified the algorithm by: updating the scheme of the threshold schedule, the adapting transition kernel, a strongly motivated selection of a priori distribution (see Fig. 1). The reconstructed parameter set includes (x,y,z) source position, mass of release (q), release start time (s) and its duration.

To validate the proposed methodology we used data from the central London DAPPLE experiment performed in June 2007. To model the contaminant dispersion in the city, we used the Quick Urban Industrial Complex (QUIC) Dispersion Modelling System.

To compute mean flow fields around buildings we applied the fast running QUIC-URB model, while the QUIC-PLUME model was used to predict the concentrations at the sensor locations. QUIC-PLUME is a Lagrangian particle model which describes gas dispersion by simulating the release of particles and moving them with an instantaneous wind composed of mean and turbulent components.

The present study has proved that the event reconstruction problem can be solved for an urban area without using a time-consuming Computational Fluid Dynamics model.

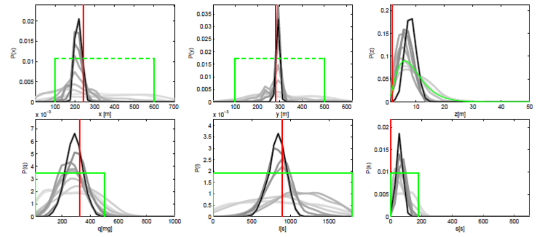

Fig. 1. Prior and marginal posterior probability densities for the joint inference of six parameters; green line - prior probability density 2; grey and black lines - marginal posteriori probability density for subsequent time steps (the darker the colour the later the time step); red line - target value of parameter.

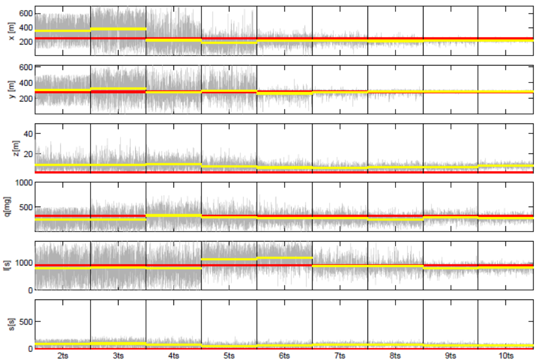

Fig. 2. The trace plots for all searched parameters $\boldsymbol{\theta} = (\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{z}, \boldsymbol{q}, \boldsymbol{l}, \boldsymbol{s})$ in all time steps. The red line marks the target value of the parameters,at the yellow line is the mean value inside a particular time step, the grey colour represents a simple trace plot of all samples.

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"RAT-if Risk" Assessment Toolbox at hazardous industrial facilities posing a threat outside their area

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RAT-if is an advanced IT tool operating on the basis of the so-called "computing cloud" using models that have practical application in planning spatial management in the context of preserving the so-called "safe distances" of industrial facilities in relation to the surrounding objects and areas. The RAT-if system is a deliverable of the national project EVARIS.

Within this project we are developing a system capable of analyzing particular industrial facility to recognize all types of risk it can produce. The risk quantification procedure develops through the evaluation, for all risk sources, of the accident occurrence frequency and the magnitude of the casualties caused by such events. The system takes into account the local, individual, social and environmental risks [1].

In the framework of the RAT-if system the procedure for area risk analysis, which is created by the industrial plant in question, is carried out through the following steps:

1) detailed mapping of the area of the plant and the area around the plan;

2) specification of the possible emergency scenarios;

3) selection of the computing model appropriate to model the output of the specified type of failure;

4) based on the outcome of the failure, calculating the risk in the area covered by the threat;

5) calculation of the total risk resulting from all accidents considered;

6) estimation of a safe distance from the plant under consideration.

The developed system utilizes the Topographic Data Database, BDOT10k provided by the Central Center for Geodetic and Cartographic Documentation (CODGiK) to map the terrain. The database of topographic objects BDOT10k covers the following parts, each of which is stored in several layers: water network, communication network, utility network, land cover, buildings, structures and devices, land use complexes, protected areas, territorial division units, and other objects.

A list of considered scenarios is prepared for each industrial facility individually utilizing the prepared database of generic scenarios. The RAT-if system is capable of generating automatically the list of scenarios that should be considered. This is done with the use of the Methodology for the Identification of Major Accident Hazards (MIMAH), which is carried out bythe development of generic fault and event trees based on a typology of equipment and substances [2]. On the basis of the equipment considered and the properties of the chemicals handled, MIMAH is able to predict which major accidents are likely to occur.

The RAT-if system will be a valuable tool allowing for the identification of hazards which arise from the use of dangerous substances in industrial facilities, early identification, and assessment of the risks "in situ"

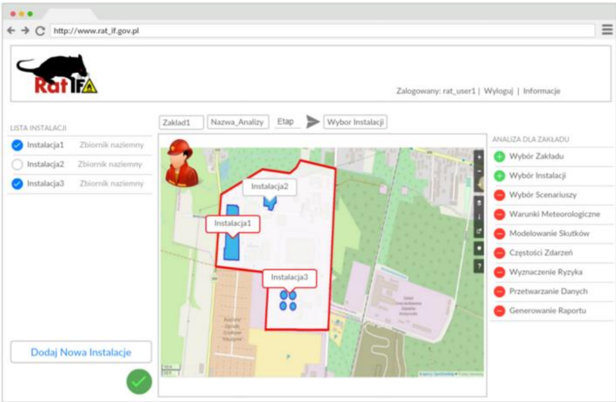

Fig.1. The project of RAT-if system interface project presenting the stage of specifying the characteristics of the installations in the facility.

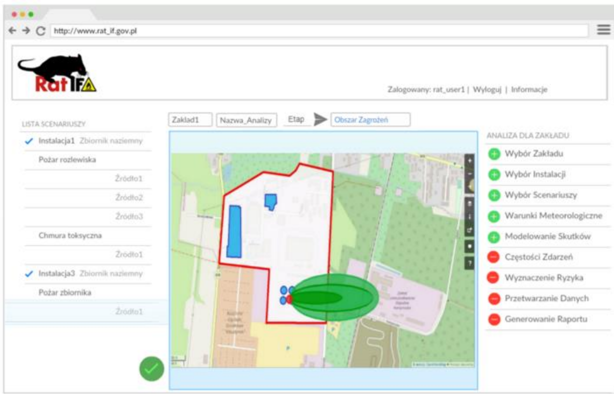

Fig. 2. The project of RAT-if system interface project presenting stage of modelling the output of the considered threat in the facility.

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WRF and QUIC modelling capabilities in the UDINEE exercise IOP4

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The release of chemical or radiological substances in an urban environment can lead to significant consequences and could have a huge impact on social, economic and health aspects.

The presented study and analyses were realized within the Urban Dispersion International Evaluation Exercise (UDINEE) project, led by the EC-Joint Research Centre (DG-JRC) [1]. The main goal of the project was to evaluate various urban atmospheric dispersion models that can be used in emergency preparedness and response. Each of the models has its own pros and cons a the comparison is essential to understand their behaviour. To validate the models used by different research teams the organizers provided data from the Joint Urban 2003 (JU2003) field experiment that was held in Oklahoma city USA [2]. During JU2003, National Oceanic and Atmospheric Administration workers from the Air Resources Laboratory Field Research Division conducted multiple instantaneous puff releases of sulphur hexafluoride (SF_6) gas in Oklahoma Down Town Area. Each release was held at a different time of day time and happened under various weather conditions.

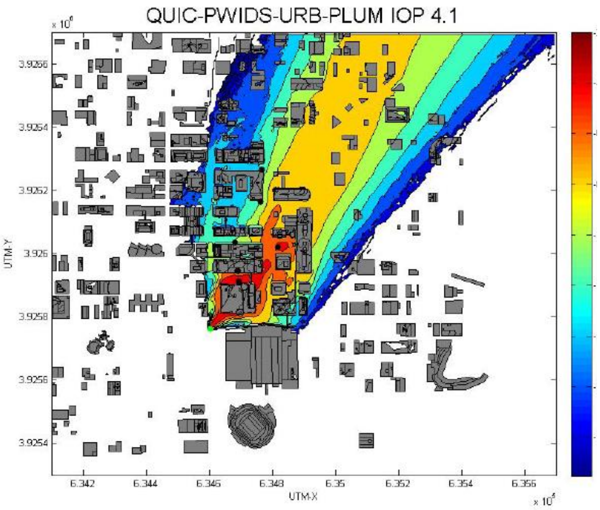

Fig.1. Near-surface airborne mean dosage from IOP4

The aim of the present study is to describe the results of dispersion simulations performed with the help of the Quick Urban& Industrial Complex (QUIC) program for the UDINEE project. The QUIC software tool was developed by Los Alamos National Laboratory to perform quick computation of gas transport, dispersion and particle release in the areas near buildings The QUIC model - theory and user guides can be found in [3]. In order to validate QUIC program's calculation capabilities different setups combining QUIC-URB, QUIC-PLUME or QUIC-CFD models with meteorological data from measurement stations and the WRF mesoscale numerical weather prediction model were used. Each proposed setting contains various components of the wind and the gas transport model. In addition, various meteorological input data were used.

The results of the simulations were verified against measured concentrations in the locations of sensors. Figure 1 shows the time average simulated dosage of SF_6 gas (on log scale) for URB-PLUME model setup obtained during IOP4. The results for sensor L01 show that except for the WRF-PLUM model the rest models produced very good results (as seen on Fig.re 2).

This study has shown that various settings of the QUIC system have led to somewhat different results for the same cases, however there is no clear advantage of one or the other setup. Comprehensive research results will be presented in a special edition of the Boundary Layer Meteorology journal [4].

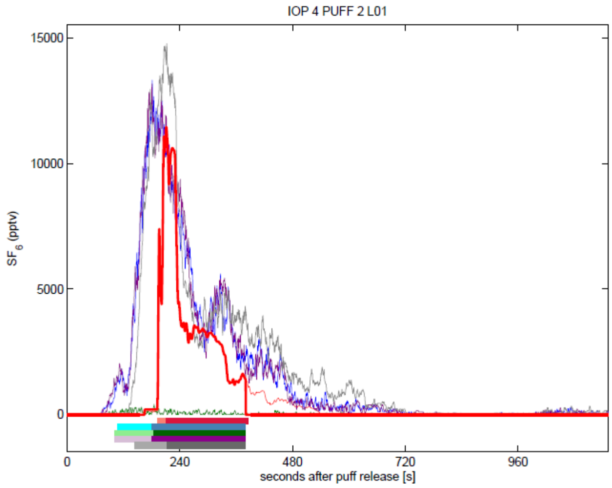

Fig. 2. Observed and modelled SF_6 concentration [pptv] time series from L01 during IOP4. Red colour SF_6 observed concentration, other colours simulated values of SF_6.

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Measurement system for monitoring radioactive contamination and components of natural cosmic radiation in the station system: Otwock (Świder) - Hornsund (North Pole) - Kasprowy Wierch (~ 2000 m a. s. l.)

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To determine the concentration of radionuclides in the atmosphere high volume air samplers are used, where aerosol collection takes place on a special filter fabric (Petrianov filter tissue FPP-15-1.5). In 2002 the high volume air sampler AZA-1000 was installed at the Polish Polar Observatory of the Polish Academy of Sciences in Hornsund, Spitsbergen, designed to operate in all-weather conditions of the cold polar region. Since 1991 (with short breaks) the ASS-500 air sampler has been in operation located in Świder at the Kalinowski Geophysical Observatory of the Geophysics Institute of the Polish Academy of Sciences. The following results for radionuclides concentrations are obtained from both stations: ^{7}Be, ^{137}Cs, ^{134}Cs, ^{210}Pb, ^{40}K. These data are compared with each other.

In 2016, as a result of scientific cooperation between the National Centre for Nuclear Research (NCBJ) and the Institute of Meteorology and Water Management – National Research Institute, Branch in Krakow (IMGW-PIB), a new project was started to create another research station on the roof of the High-Altitude Mountain Observatory at Kasprowy Wierch (IMGW-PIB). In addition, apart from radionuclide analysis, the monitoring network included detection of high-energy ionizing radiation coming from space (GLE – Ground Level Events and SPE – Solar Particle Events).

Results

In September 2017 several-day pilot measurement campaign was carried out at the Kasprowy Observatory. The following set of detectors was used in the measurement campaign:

Recombination chambers REM-2 and GW2

The first campaign carried out at the Kasprowy Observatory was an experiment to check the measuring capabilities of recombination chambers in outdoor conditions. The collected data do not exclude the use of these detectors in mountain conditions, but indicate the steps to be taken to improve their ability to estimate exposure in low-background fields. The following measurement campaign should include:

- using as short cables as possible,
- chamber calibration for ambient temperature,
- designing a recombination chamber with a higher sensitivity dedicated to low-background, outdoor measurements.

Ionization chamber Reuter-Stokes type RSS-131

Measurements using the ionization chamber were carried out continuously from 23:00 on 18-09-2017 to 15:00 on 20-09-2017. The average value of H*(10) was 121,7 nSv/h. During the measurements two distinct peaks were recorded. At the current stage – preliminary data analysis – it is not possible to determine if its origin was related to the radiation pulse registration or if they were based on possible interference from the observatory's broadcasting antennas. In the final part of the measurements, there was a tendency to increase the value of H*(10). This increase could be related to meteorological conditions, in particular cloud cover and precipitation.

Berthold LB 6411 Neutron Probe

The neutron probe measurements were carried out on two different floors inside the building. The results obtained indicate that the location of the device had a significant influence on the neutron component measurement result – the neutron ambient dose equivalent H*(10). Analysis of these data should be the subject of further research, but the fact that the building is made from granite blocks that provide good protection for neutrons will have a significant impact.

Conclusion

It appears from the above analyses that further measurement campaigns are required using various high-energy radiation detection systems. In the future the construction of a third high volume air sampler is also planned, located at the Kasprowy Observatory. Finally, data on air radiology and high energy cosmic radiation will be collected from three measurement points: Otwock (Świder) – Hornsund (North Pole) – Kasprowy Wierch (~ 2000 m a. s. l.).

Application of the NCBJ Mobile Air Monitoring Laboratory to the determination of air quality

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The capabilities of the NCBJ Mobile Air Monitoring Laboratory (in short: mobile laboratory) have been extended with the inclusion of concentration measurements of nitrogen oxides in ambient air. The mobile container has been equipped with $NO/NO_2/NO_x$ model T200 Teledyne API analyzer, calibrator type CMK5and zero air supply type NGA19S of MCZ Umwelttechnik and a calibration gas mixture in a gas cylinder. The modified mobile laboratory was used for determination of air quality in the NCBJ area. The mobile container was localized at the north-east periphery (Fig. 1).

Fig. 1. Location of the mobile laboratory at the north-east periphery of the NCBJ area.

The main sources of air pollutants in this region are:

- the national road No 17 with a traffic volume of 19 500 cars per twenty-four hours,
- the village Wólka Mlądzka with many one-family houses. In most of them coal-burning stoves are utilized for heat generation,
- two car-parks localized at the gateway to NCBJ as well as the NCBJ coaches which bring the employees to/from work.

The two-week continuous measurements of the mass concentrations of PM_{10}, $PM_{2,5}$ and $NO/NO_2/NO_x$ in ambient air were performed in August 2017. Low concentrations were recorded [1].

The air quality index is an index reporting daily air quality. It informs how polluted the air is and what associated health effects might be a concern. This index is determined for six major air pollutants: SO_2, NO_2, CO, PM_{10}, $PM_{2,5}$ and O_3. It is based on the concentration levels of these pollutants measured in monitoring stations. For each pollutant there are six quality index categories, namely: excellent, good, moderate, sufficient, poor and very poor. Each category corresponds to a specific level of pollutant concentration and the appropriate public health advisory is assigned a specific color.

Fig. 2 presents the Polish index of air quality for three pollutants: NO_2, PM_{10} and $PM_{2,5}$.

Polish index of air quality	NO_2 [μg/m³]	PM10 [μg/m³]	PM2,5 [μg/m³]
Excellent	0-40	0-20	0-12
Good	41-100	21-60	13-36
Moderate	101-150	61-100	37-60
Sufficient	151-200	101-140	61-84
Poor	201-400	141-200	85-120
Very poor	>400	>200	>120

Fig. 2. Polish index of air quality for three pollutants.

Fig. 3 presents the 24-hour PM_{10} mass concentrations recorded in the measurements. The results fall into two quality categories (excellent–dark green colour and good–light green color), thus there is good air quality at the NCBJ site regarding PM_{10} mass concentrations.

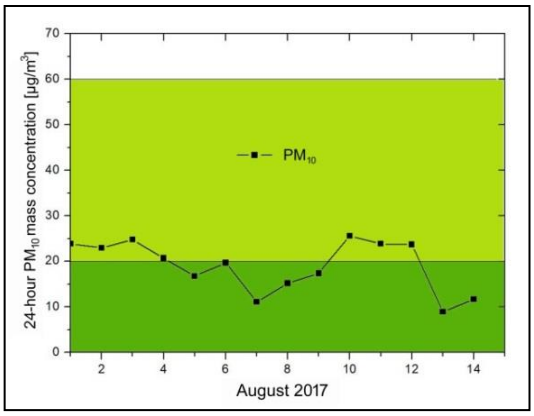

Fig. 3. Index of air quality at the NCBJ site regarding PM_{10}.

Fig. 4 presents the recorded 24-hour $PM_{2,5}$ mass concentrations during the tests.

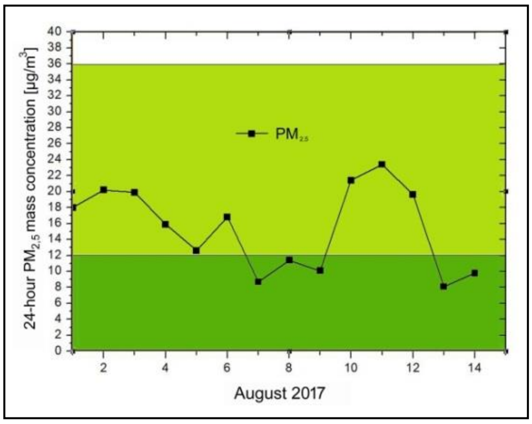

Fig. 4. Index of air quality at the NCBJ site regarding $PM_{2,5}$.

The air quality at the NCBJ site is also good regarding PM $_{2,5}$ mass concentrations. The obtained results of 24-hour NO_2 mass concentrations fall within the excellent air quality index. The good index of air quality was determined at the NCBJ site, so it is good air quality for outdoor activities.

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   E. Strano, ... , **N. Keeley**, ... et al.
   Acta Phys. Pol. B Vol. 48 (2017) 615

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    W. Wiślicki
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14. Introduction of Total Variation Regularization into Filtered Backprojection Algorithm
    L. Raczyński, ... , **W. Wiślicki**, **K. Klimaszewski**, **W. Krzemień**, **P. Kowalski**, **R.Y. Shopa**, ... et al.

Acta Phys. Pol. B Vol. 48 No 10 (2017) 1611

15. J-PET: A New Technology for the Whole-body PET Imaging
S. Niedźwiecki, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **R.Y. Shopa**, **W. Wiślicki**, ... et al.
Acta Phys. Pol. B Vol. 48 No 10 (2017) 1567

16. Low-energy Antikaon–Nucleon/Nuclei Interaction Studies by AMADEUS
K. Piscicchia, ... , **S. Wycech**, ... et al.
Acta Phys. Pol. B Vol. 48 No 10 (2017) 1875

17. On Gamov states of Sigma+ Hyperons
S. Wycech, K. Pisciccia
Acta Phys. Pol. B Vol. 48 (2017) 1861

18. On Gamov States of Σ^+ Hyperons
S. Wycech, K. Piscicchia
Acta Phys. Pol. B Vol. 48 No 10 (2017) 1869

19. Production of light nuclei in the thermal and coalescence models
St. Mrówczyński
Acta Phys. Pol. B Vol. 48 (2017) 707

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U. Wiącek, ... , **M. Gierlik**, **R. Kwiatkowski**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**, **I. Zychor**, ... et al.
Acta Phys. Pol. B Vol. 48 No 3 (2017) 687

21. Three-dimensional Image Reconstruction in J-PET Using Filtered Back-projection Method
R.Y. Shopa, ... , **K. Klimaszewski**, **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
Acta Phys. Pol. B Vol. 48 No 10 (2017) 1757

22. Underwater detection of dangerous substances: Status of the SABAT project
M. Silarski, **P. Sibczyński**, Sz. Niedzwiecki, S. Sharma, J. Raj, P. Moskal
Acta Phys. Pol. B Vol. 10 (2017) 1675

23. Wilczynski plots forever?
W. Gawlikowicz, **J. Błocki**
Acta Phys. Pol. B Vol. 10 (2017) 81

24. Critical phenomena in the non-extensive nambu–jona-lasinio model
J. Rożynek
Acta Phys. Pol. B Proc. Suppl. Vol. 10 (2017) 1001

25. Singularities and cyclic universes
M.P. Dąbrowski
Acta Phys. Pol. B Proc. Suppl. Vol. 10 (2017) 415-418

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O. Hrycyna
Acta Phys. Pol. B Proc. Suppl. Vol. 10 (2017) 425

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R. Boussarie, B. Pire, **L. Szymanowski**, S. Wallon
AIP Conf Proc Vol. 1819 (2017) 060008

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R. Boussarie, A.V. Grabovsky, **L. Szymanowski**, S. Wallon
AIP Conf Proc Vol. 1819 (2017) 030009

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A. Gherghel-Lascu, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
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J. Kunikowska, **D. Pawlak**, M.I. Bąk, B. Kos-Kudła, **R. Mikołajczak**, L. Królicki
ANN NUCL MED Vol. 31 (2017) 347

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A. Balcerzak, **M.P. Dąbrowski**, V. Salzano
Annalen Phys. Vol. 16 (2017) 000409

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Z. Marcinkowska, **K. Pytel**, **A. Frydrysiak**
Annals Nucl. Energy Vol. 99 (2017) 366-371

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M. Barlak, J. Wilkowski, P. Boruszewski, **Z. Werner**, B. Pałubicki
Annals of Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology Vol. 97 (2017) 133-139

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J. Wilkowski, P. Kołodziejczak, **M. Barlak**, P. Czarniak, **Z. Werner**, **B. Staszkiewicz**
Annals of Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology Vol. 98 (2017) 148-152

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M. Barlak, J. Wilkowski, P. Boruszewski, **J. Zagórski**, **Z. Werner**
Annals of Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology Vol. 98 (2017) 16-19

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P. Kołodziejczak, J. Wilkowski, **M. Barlak**, P. Czarniak, **Z. Werner**, **J. Zagórski**
Annals of Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology Vol. 98 (2017) 48-52

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R. LeTellier, **E. Skrzypek**, L. Saas
Appl Therm Eng Vol. 120 (2017) 314-326

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Appl. Radiat. Isot. Vol. 124 (2017) 124-131

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D. Błachut, J. Szawkało, P. Pomarański, P. Roszkowski, **J.K. Maurin**, Z. Czarnocki
Arkivoc Vol. 2017 (2017) 369-389

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K. Małek, ... , **A. Pollo**, ... et al.
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A. Solarz, ... , **M. Bilicki**, **A. Pollo**, **A. Durkalec**, ... et al.
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J.T.A. DeJong, ... , **M. Bilicki**, ... et al.
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M. Moresco, ... , **K. Małek**, **A. Pollo**, ... et al.
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C.P. Haines, ... , **K. Małek**, **A. Pollo**, ... et al.
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S. DelaTorre, ... , **K. Małek**, **A. Pollo**, ... et al.
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A. Marchetti, ... , **K. Małek**, **A. Pollo**, ... et al.
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M. Siudek, ... , **K. Małek**, **A. Pollo**, ... et al.
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J. Krywult, ... , **K. Małek**, ... et al.
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O. Cucciati, ... , **K. Małek**, **A. Pollo**, ... et al.
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L.A.M. Tasca, ... , **A. Durkalec**, ... et al.
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Astropart. Phys. Vol. 95 (2017) 25

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P. Kankiewicz, M. Rybczyński, Z. Włodarczyk, **G. Wilk**
Astroph.J. Vol. 839 (2017) 31

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K. Abe, ... , **P. Mijakowski**, **K. Frankiewicz**, ... et al.
Astroph.J. Vol. 850 No 2 (2017) 166

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A. Królak, ... , **A. Kutynia**, **A. Zadrożny**, ... et al.
Astroph.J. Vol. 841 (2017) 89

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VincenzoSalzano, **M.P. Dąbrowski**
Astroph.J. Vol. 851 (2017) 97

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Astroph.J. Vol. 847 (2017) 47

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A. Cuoco, **M. Bilicki**, J.-Q. Xia, E. Branchini
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S. Ahmad, L. Shukla, J. Szawkało, P. Roszkowski, **J.K. Maurin**, Z. Czarnocki
Catal Commun Vol. 89 (2017) 44-47

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M. Gawęda, E. Długoń, M. Leśniak, **Ł. Kurpaska**, W. Simka, M. Sowa, M. Sitarz
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A. Królak, ... , **A. Kutynia**, **A. Zadrożny**, ... et al.
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Contributions of the Astronomical Observatory Skalnate Pleso Vol. 47 No 1 (2017) 19-28

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P. Stano, D. Weziak-Bialowolska
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G. Wilk, Z. Włodarczyk
Entropy Vol. 19 (2017) 670

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S.M.J. Mortazavi, ... , **L. Dobrzyński**, ... et al.
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M. Rybczyński, **G. Wilk**, Z. Włodarczyk
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J.N. Capdevielle, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**
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G. Wilk, Z. Włodarczyk
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T. Ablyazimov, ... , **M. Adamczyk**, **J. Rożynek**, ... et al.
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A. Pakou, ... , **N. Keeley**, ... et al.
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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 294

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J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 678

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J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 569

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Eur. Phys. J. C Vol. 77 (2017) 209

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A. Aduszkiewicz, ... , **K. Kowalik**, **E. Rondio**, **J. Stepaniak**, ... et al.
Eur. Phys. J. C Vol. 77 No 9 (2017) 626

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Eur. Phys. J. C Vol. 77 (2017) 245

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S. Acharya, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
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S. Acharya, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 658

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.

Eur. Phys. J. C Vol. 77 (2017) 459

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 269

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 467

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 161

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 92

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 354

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 746

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 172

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 236

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 751

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 15

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A. Anduszkiewicz, ... , **K. Kowalik**, **E. Rondio**, **J. Stepaniak**, ... et al.
Eur. Phys. J. C Vol. 77 No 10 (2017) 626

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K. Kowalska, **E. Sessolo**
Eur. Phys. J. C Vol. C77 (2017) 79

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Eur. Phys. J. C Vol. 77 No 4 (2017) 238

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Eur. Phys. J. C Vol. 77 No 2 (2017) 72

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S. Acharya, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 339

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D. Adamova, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 389

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A. Airapetian, ... , **W. Augustyniak**, **B. Mariański**, **A. Trzciński**, **P. Żuprański**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 378

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 845

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 636

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Eur. Phys. J. C Vol. 77 No 4 (2017) 224

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 635

115. Search for new phenomena with the M_{T2} variable in the all-hadronic final state produced in proton-proton collisions at $\sqrt{s}$= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 710

116. Search for physics beyond the standard model in events with two leptons of same sign, missing transverse momentum, and jets in proton–proton collisions at $\sqrt{s}$= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 578

117. Searches for pair production of third-generation squarks in $\sqrt{s}$= 13 TeV pp collisions
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 327

118. Study of charmonium production in b-hadron decays and first evidence for the decay B0s→ϕϕϕ
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Eur. Phys. J. C Vol. 77 No 9 (2017) 609

119. Suppression and azimuthal anisotropy of prompt and nonprompt J/ψ production in PbPb collisions at $\sqrt{s_{NN}}$= 2.76 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 77 (2017) 252

120. Two-particle correlations in azimuthal angle and pseudorapidity in inelastic p + p interactions at the CERN Super Proton Synchrotron
A. Aduszkiewicz, ... , **K. Kowalik**, **E. Rondio**, **J. Stepaniak**, ... et al.
Eur. Phys. J. C Vol. 77 No 2 (2017) 59

121. Single soliton solution to the extended KdV equation over uneven depth
G. Rowlands, P. Rozmej, **E. Infeld**, A. Karczewska
Eur. Phys. J. E Vol. 40 (2017) 100

122. Determination of the event collision time with the ALICEdetector at the LHC
J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. Plus Vol. 132 (2017) 99

123. Baryon-to-meson transition distribution amplitudes: formalism and models
B. Pire, K. Semenov-Tian-Shansky, **L. Szymanowski**
Few Body Syst. Vol. 58 No 2 (2017) 74

124. $CeBr_3$ –based detector for Gamma-ray Spectrometer Upgrade at JET
R. Kwiatkowski, ... , **G. Bołtruczyk**, **A. Brosławski**, **M. Gosk**, **S. Korolczuk**, **S. Mianowski**, **A. Szydłowski**, **A. Urban**, **I. Zychor**, ... et al.
Fusion Eng. Des. Vol. 123 (2017) 986-989

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G. Bołtruczyk, ... , **A. Brosławski**, **M. Gosk**, **S. Korolczuk**, **R. Kwiatkowski**, **A. Urban**, **I. Zychor**, ... et al.
Fusion Eng. Des. Vol. 123 (2017) 940-944

126. Long-lived radionuclide activity formed in ITER construction steels in ^{6}Li-D converter neutron field
W. Pohorecki, P. Jodłowski, **K. Pytel**, **R. Prokopowicz**
Fusion Eng. Des. Vol. 124 (2017) 1042-1045

127. Upgrade of the tangential gamma-ray spectrometer beam-line for JETDT experiments
M. Curuia, ... , **S. Mianowski**, **I. Zychor**, ... et al.
Fusion Eng. Des. Vol. 123 (2017) 749

128. Classical dynamics of the Bianchi IX model with timelike singularity
S.L. Parnovsky, **W. Piechocki**
Gen. Relat. Gravit. Vol. 49 No 7 (2017) 1

129. In-flight energy calibration of the space-borne Compton polarimeter POLAR
H. Xiao, ... , **T. Batsch**, **D. Rybka**, **J. Szabelski**, **A. Zwolińska**, ... et al.
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A. Stoch, **J.K. Maurin**, J. Kulawik, **P. Stoch**
J Eur Ceram Soc Vol. 37 (2017) 1467

131. The complete molecular geometry and electric dipole moment of salicyl aldehyde from rotational spectroscopy
O. Dorosh, E. Bialkowska-Jaworska, M.T. Krygowski, H. Mader, M. Kanska, L. Pszczolkowski
J Mol Spectrosc Vol. 335 (2017) 3-12

132. DIRAC universal pilots
F. Stagni, ... , **W. Krzemień**, ... et al.
J Phys Conf Ser Vol. 898 No 9 (2017) 092024

133. Experimental studies of the kaon-nucleus interaction at low energy with x-ray
H. Shi, ... , **S. Wycech**, ... et al.
J Phys Conf Ser Vol. 800 No 1 (2017) 012007

134. Internal clocks in timeless universe
P. Małkiewicz
J PHYS CONF SER Vol. 880 No 1 (2017) 012046

135. Laboratory simulations of astrophysical jets: results from experiments at the PF-3, PF-1000U, and KPF-4 facilities
V.I. Krauz, ... , **E. Składnik-Sadowska**, **M.J. Sadowski**, **R. Kwiatkowski**, ... et al.
J Phys Conf Ser Vol. 907 (2017) 012026

136. Probing kaon-originated neutrinos with the muons produced outside of T2K Near Detector
J. Łagoda
J Phys Conf Ser Vol. 888 (2017) 012217

137. Reconstruction of low momentum protons with fine-grained detector of the T2K experiment
J. Zalipska
J Phys Conf Ser Vol. 888 (2017) 012172

138. Meta-analysis of thirt-two case-control and two ecological radon studies of lung cancer
L. Dobrzyński, K.W. Fornalski, **J. Reszczyńska**,
J Radiat Res Vol. 061 (2017) 1-15

139. The effect of He^+ irradiation on hardness and elastic modulus of Fe-Cr–40wt.% TiB2 composite rod designed for neutron absorbing
P. Litwa, **Ł. Kurpaska**, R.A. Varin, K. Perkowski, **J. Jagielski**, S. Jozwiak, T. Czujko
J. Alloys Comp. Vol. 711 (2017) 111-120

140. Comparison of the structural properties of Zn-face and O-face single crystal homoepitaxial ZnO epilayers grown by RF-magnetron sputtering
R. Schifano, ... , **R. Ratajczak**, ... et al.
J. Appl. Phys. Vol. 121 (2017) 015304

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R. Ratajczak, ... , **C. Mieszczyński**, **A. Turos**, ... et al.
J. Appl. Phys. Vol. 121 (2017) 075101

142. Towards understanding thermal history of the Universe through direct and indirect detection of dark matter
L. Roszkowski, **S. Trojanowski**, K. Turzyński
J. Cosm. Astroparticle Phys. Vol. 10 (2017) 5

143. Optical and scintillation characteristics of Gd2YAl2Ga3O12:Ce and Lu2YAl2Ga3O12:Ce single crystals
W. Chewpraditkul, ... , **T. Szczęśniak**, **Ł. Świderski**, **M. Moszyński**, ... et al.
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144. Charged-particle nuclear modification factors in PbPb and pPb collisions at $\sqrt{s_{NN}}$= 5.02 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 04 (2017) 039

145. Exclusive photoproduction of a gamma rho pair with a large invariant mass
R. Boussarie, B. Pire, **L. Szymanowski**, S. Wallon
J. High Energy Phys. Vol. 1702 (2017) 054

146. Expectations for the muon g-2 in simplified models with dark matter
K. Kowalska, **E. Sessolo**
J. High Energy Phys. Vol. 1709 (2017) 112

147. Intrinsic limits on resolutions in muon- and electron-neutrino charged-current events in the KM3NeT/ORCA detector
S. Adrián-Martínez, ... , **P. Mijakowski**, ... et al.
J. High Energy Phys. Vol. 1705 (2017) 008

148. Measurement and QCD analysis of double-differential inclusive jet cross sections in pp collisions at $\sqrt{s}$= 8 TeV and cross section ratios to 2.76 and 7 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 03 (2017) 156

149. Measurement of CP observables in $B^{\pm}\to DK^{*\pm}$ decays using two- and four-body D final states
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **D. Melnychuk**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 1711 (2017) 156

150. Measurement of electrons from beauty-hadron decays in p-Pb collisions at $\sqrt{s_{NN}}$=5.02 TeV and Pb-Pb collisions at √sNN=2.76 TeV
J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
J. High Energy Phys. Vol. 07 (2017) 052

151. Measurement of electroweak-induced production of Wγ with two jets in pp collisions at $\sqrt{s}$= 8 TeV and constraints on anomalous quartic gauge couplings
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 06 (2017) 106

152. Measurement of the inclusive energy spectrum in the very forward direction in proton-proton collisions at $\sqrt{s}$= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 08 (2017) 046

153. Measurement of the J/ψ pair production cross-section in pp collisions at s√=13TeV
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 06 (2017) 047

154. Measurement of the ratio of branching fractions and difference in CP asymmetries of the decays $B+\to J/\psi\pi+$ and $B+\to J/\psi K+$
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.

J. High Energy Phys. Vol. 1703 (2017) 036

155. Measurement of the semileptonic ttbar + γ production cross section in pp collisions at √s= 8 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 10 (2017) 006

156. Measurement of the transverse momentum spectra of weak vector bosons produced in proton-proton collisions at √s= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Traczyk**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 02 (2017) 096

157. Measurement of the transverse momentum spectrum of the Higgs boson produced in pp collisions at √s= 8 TeV using H → WW decays
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 03 (2017) 032

158. Measurement of the ttbar production cross section using events with one lepton and at least one jet in pp collisions at √s= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 09 (2017) 051

159. Measurements of differential production cross sections for a Z boson in association with jets in pp collisions at √s= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 04 (2017) 022

160. Measurements of jet charge with dijet events in pp collisions at √s= 8 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 10 (2017) 131

161. Measurements of properties of the Higgs boson decaying into the four-lepton final state in pp collisions at √s= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 11 (2017) 047

162. Measurements of the pp →Wγγ and pp →Zγγ cross sections and limits on anomalous quartic gauge couplings at √s= 8 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 10 (2017) 072

163. Muon g-2 and related phenomenology in constrained vector-like extensions of the MSSM
A. Choudhury, **L. Darme**, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**
J. High Energy Phys. Vol. 05 (2017) 72

164. Observation of the decay B0s→ηcϕ and evidence for B0s→ηcπ+π−
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 1707 (2017) 021

165. Observation of the decay Λ0b→pK−μ+μ− and a search for CP violation
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 1706 (2017) 108

166. Observation of the suppressed decay Λ0b→pπ−μ+μ−
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 1704 (2017) 029

167. Observation of Y(1S) pair production in proton-proton collisions at √s= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 05 (2017) 013

168. Resonances and CP violation in B0s and B¯0s→J/ψK+K− decays in the mass region above the ϕ(1020)
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 1708 (2017) 037

169. Search for a heavy resonance decaying to a top quark and a vector-like top quark at √s= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 09 (2017) 053

170. Search for a light pseudoscalar Higgs boson produced in association with bottom quarks in pp collisions at √s= 8 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 11 (2017) 010

171. Search for anomalous Wtb couplings and flavour-changing neutral currents in t-channel single top quark production in pp collisions at √s= 7 and 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 02 (2017) 028

172. Search for associated production of a Z boson with a single top quark and for tZ flavour-changing interactions in pp collisions at √s= 8 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 07 (2017) 003

173. Search for associated production of dark matter with a Higgs boson decaying to bbbar or γγ at √s= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 10 (2017) 180

174. Search for CP violation in ttbar production and decay in proton-proton collisions at √s= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 03 (2017) 101

175. Search for dark matter and unparticles in events with a Z boson and missing transverse momentum in proton-proton collisions at √s= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 03 (2017) 61

176. Search for dark matter produced with an energetic jet or a hadronically decaying W or Z boson at $\sqrt{s}$= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 07 (2017) 014

177. Search for decays of neutral beauty mesons into four muons
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 1703 (2017) 001

178. Search for direct production of supersymmetric partners of the top quark in the all-jets final state in proton-proton collisions at $\sqrt{s}$= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 10 (2017) 005

179. Search for electroweak production of a vector-like quark decaying to a top quark and a Higgs boson using boosted topologies in fully hadronic final states
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 04 (2017) 136

180. Search for electroweak production of charginos and neutralinos in WH events in proton-proton collisions at $\sqrt{s}$= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 11 (2017) 029

181. Search for electroweak production of charginos in final states with two τ leptons in pp collisions at $\sqrt{s}$= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 04 (2017) 018

182. Search for heavy neutrinos or third-generation leptoquarks in final states with two hadronically decaying τ leptons and two jets in proton-proton collisions at $\sqrt{s}$= 13 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 03 (2017) 077

183. Search for heavy resonances decaying to tau lepton pairs in proton-proton collisions at $\sqrt{s}$= 13 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 02 (2017) 048

184. Search for high-mass $Z\gamma$ resonances in $e^+e^-\gamma$ and $\mu^+\mu^-\gamma$ final states in proton-proton collisions at $\sqrt{s}$= 8 and 13 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 01 (2017) 076

185. Search for light bosons in decays of the 125 GeV Higgs boson in proton-proton collisions at $\sqrt{s}$= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 10 (2017) 076

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 03 (2017) 162

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 10 (2017) 073

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 07 (2017) 013

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 11 (2017) 085

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 05 (2017) 029

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 05 (2017) 158

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 07 (2017) 121

193. Search for top quark decays via Higgs-boson-mediated flavor-changing neutral currents in pp collisions at √s= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 02 (2017) 079

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 08 (2017) 073

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 10 (2017) 019

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 07 (2017) 001

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 02 (2017) 135

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S. Acharya, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
J. High Energy Phys. Vol. 09 (2017) 032

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 08 (2017) 029

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 11 (2017) 030

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
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J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
J. High Energy Phys. Vol. 02 (2017) 077

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M. Rabiński, ... , **L. Jakubowski**, **K. Malinowski**, **M.J. Sadowski**, **J. Żebrowski**, **M.J. Jakubowski**, **R. Mirowski**, ... et al.
J. Instrum. Vol. 12 (2017) C10014

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A. Picciotto, ... , **A. Szydłowski**, **A. Malinowska**, ... et al.
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M. Szczekowski, ... , **A. Ukleja**, ... et al.
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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. Instrum. Vol. 12 (2017) P04023

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M. Antonello, ... , **J. Łagoda**, **D. Stefan**, **R. Sulej**, ... et al.
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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. Instrum. Vol. 12 (2017) P10003

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V. Weinzettl, ... , **J. Żebrowski**, **M.J. Jakubowski**, **M. Rabiński**, **K. Malinowski**, ... et al.
J. Instrum. Vol. 12 (2017) C12015

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
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D. Rigamonti, ... , **A. Brosławski**, **S. Korolczuk**, **I. Zychor**, ... et al.
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M. Pałka, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
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P. Ziń, **M. Pylak**
J. Phys. B: At. Mol. Opt. Phys. Vol. 50 (2017) 085301

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G. Wilk, Z. Włodarczyk
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R. Lica, ... , **Z. Patyk**, **V. Charviakova**, ... et al.
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M. Skrzypek, **E. Skrzypek**, L. Saas, R. LeTellier
J. Power Technol. Vol. 97 No 02 (2017) 110-116

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T. Kwiatkowski, **P. Prusiński**, **D. Zgorzelski**, **S. Kozioł**
J. Power Technol. Vol. 97 No 3 (2017) 252-258

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T. Ziemek, ... , **R. Broda**, **T. Dziel**, **A. Jęczmieniowski**, **E. Lech**, **A. Listkowska**, **Z. Tymiński**, ... et al.
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K. Rzemek, A. Czerwiński, **J. Ośko**, **K. Tymińska**, **M. Dymecka**, **T. Pliszczyński**
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P. Sobkowicz
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B. Mariański
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Chr. Rangger, ... , **D. Pawlak**, **R. Mikołajczak**, ... et al.
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J. Harnois-Deraps, ... , **M. Bilicki**, ... et al.
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J. Madej, A. Różańska, **A. Majczyna**, M. Należyty
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N. Malavasi, ... , **K. Małek**, ... et al.
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A. Królak, ... , **A. Kutynia**, **A. Zadrożny**, ... et al.
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B.-B. Zhang, ... , **A. Ćwiek**, **A. Zadrożny**, ... et al.
Nature Astronomy Vol. (2017)

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P. Rozmej, A. Karczewska, **E. Infeld**
Nonlinear Dynam Vol. 1 (2017) 9

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X. Wu, T. Mui, G. Hu, H. Meidani, **T. Kozłowski**
Nuc. Eng. Design Vol. 319 (2017) 185

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J. Pijarowska-Kruszyna, ... , **U. Karczmarczyk**, **A. Jaroń**, **E. Laszuk**, **M. Radzik**, **P. Garnuszek**, **R. Mikołajczak**, ... et al.
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M. Nocente, ... , **M. Moszyński**, **J. Rzadkiewicz**, **I. Zychor**, ... et al.
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R.C. Wolf, ... , **M. Barlak**, **J. Jagielski**, **R. Kozioł**, **P. Kraszewski**, ... et al.
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X. Litaudon, ... , **A. Brosławski**, **M. Gosk**, **R. Kwiatkowski**, **S. Mianowski**, **J. Rzadkiewicz**, **Ł. Świderski**, **I. Zychor**, ... et al.
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G. Gawlik, P. Ciepielewski, **J. Jagielski**, J. Baranowski
Nucl. Instr. and Meth. B Vol. 408 (2017) 228

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G. Gawlik, P. Ciepielewski, **J. Jagielski**, J. Baranowski
Nucl. Instr. and Meth. B Vol. 406 (2017) 683

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Ł. Kurpaska
Nucl. Instr. and Meth. B Vol. 409 (2017) 171-174

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Ł. Kurpaska, **M. Frelek-Kozak**, **K. Nowakowska-Langier**, M. Lesniak, J. Jasinski, **J. Jagielski**
Nucl. Instr. and Meth. B Vol. 409 (2017) 81-85

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K. Nowakowska-Langier, ... , **Ł. Kurpaska**, **G. Strzelecki**, ... et al.
Nucl. Instr. and Meth. B Vol. 409 (2017) 167-170

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M. Grodzicka-Kobyłka, **T. Szczęśniak**, **M. Moszyński**, **S. Korolczuk**, J. Baszak, **M. Kapusta**
Nucl. Instr. Meth. A Vol. 869 No 11 (2017) 153-162

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M. Grodzicka-Kobyłka, **T. Szczęśniak**, **M. Moszyński**
Nucl. Instr. Meth. A Vol. 856 No 1 (2017) 53-64

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G. Abdellaoui, ... , **T. Batsch**, **J. Karczmarczyk**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Nucl. Instr. Meth. A Vol. 866 (2017) 150-163

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N. Produit, ... , **T. Batsch**, **D. Rybka**, **J. Szabelski**, **A. Zwolińska**, ... et al.
Nucl. Instr. Meth. A Vol. 877 (2017) 259-268

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M. Kole, ... , **T. Tymieniecka**, **A. Zwolińska**, **J. Szabelski**, **D. Rybka**, ... et al.
Nucl. Instr. Meth. A Vol. 872 (2017) 28-40

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N. Yawai, ... , **T. Szczęśniak**, **Ł. Świderski**, **M. Moszyński**, ... et al.
Nucl. Instr. Meth. A Vol. 844 (2017) 116

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J. Smyrski, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
Nucl. Instr. Meth. A Vol. 851 (2017) 39-42

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M. Grodzicka-Kobyłka, **T. Szczęśniak**, **M. Moszyński**, **Ł. Świderski**, **M. Szawłowski**
Nucl. Instr. Meth. A Vol. 874 No 1 (2017) 137-148

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A.I. Wawrzyniak, ... , **R. Nietubyć**, ... et al.
Nucl. Instr. Meth. A Vol. 411 (2017) 4

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C. Fuglesang, ... , **T. Batsch**, **J. Karczmarczyk**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
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O. Vázquez~Doce, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
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R.T.J. Bustamante, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 576-579

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R.A. Bertens, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 385-388

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M. Saleh, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 468-471

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M. Tarhini, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 588-591

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A. Barbano, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 612-615

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M. Germain, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 696-699

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D. Stocco, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 309-312

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F. Krizek, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 321-324

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D. Caffarri, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 528-531

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A. Timmins, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 43-50

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N. Zardoshti, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 560-563

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K. Gajdošová, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 437-440

270. Jet-hadron correlations relative to the event plane at the LHC with ALICE
J. Mazer, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 500-503

271. Measurement of J/ψ production as a function of event multiplicity in pp collisions at $\sqrt{s}$ = 13 TeVwith ALICE
S.G. Weber, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 333-336

272. Measurements of the nuclear modification factor and elliptic flow of leptons from heavy-flavour hadron decays in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV with ALICE
D. Moreira~de~Godoy, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 688-691

273. Multiplicity dependence of identified particle production in proton-proton collisions with ALICE
V. Vislavicius, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 337-340

274. Multiplicity dependence of jet-like two-particle correlations in pp collisions at $\sqrt{s}$ = 7 and 13 TeV with ALICE
I. Lakomov, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 329-332

275. Net-baryon fluctuations measured with ALICE at the CERN LHC
A. Rustamov, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 453-456

276. Neutral meson production and correlation with charged hadrons in pp and Pb-Pb collisions with the ALICE experiment at the LHC
A. Vauthier, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 688-691

277. Photoproduction of heavy vector mesons in ultra-peripheral Pb–Pb collisions
E.L. Kryshen, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 273-276

278. Probing non-linearity of higher order anisotropic flow in Pb–Pb collisions
Y. Zhou, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 377-380

279. Production of $\Sigma(1385)^{\pm}$ and $\Xi(1530)^{0}$ measured by ALICE in pp, p–Pb and Pb–Pb collisions at the LHC
J. Song, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 920-923

280. Search for η-mesic ^{4}He in the $dd\rightarrow{}^{3}Hen\pi^{0}$ and $dd\rightarrow{}^{3}Hep\pi^{-}$ reactions with the WASA-at-COSY facility
P. Adlarson, ... , **W. Augustyniak**, **M. Berłowski**, **W. Krzemień**, **A. Kupść**, **B. Mariański**, **H.P. Morsch**, **D. Pszczel**, **J. Stepaniak**, **A. Trzciński**, **J. Zabierowski**, **P. Żuprański**, ... et al.
Nucl. Phys. A Vol. 959 (2017) 102-115

281. System-size dependence of the charged-particle pseudorapidity density at $\sqrt{s_{NN}}$=5.02 TeV with ALICE
C.H. Christensen, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 301-304

282. The new Inner Tracking System of the ALICE experiment
P. Martinengo, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 900-903

283. ϕ meson production in Pb-Pb collisions at $\sqrt{s_{NN}}$=5.02 TeV with ALICE at the LHC
E.A.R. Casula, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 967 (2017) 425-428

284. Exclusive ω meson muoproduction on transversely polarised protons
C. Adolph, ... , **W. Augustyniak**, **K. Klimaszewski**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Nucl. Phys. B Vol. 915 (2017) 454

285. Muon density mesurements for the light and heavy mass groups of cosmic rays at the KASCADE-Grande observatory
J.C. Arteaga-Velasquez, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Nuclear and Particle Physics Proceedings Vol. 291-293 (2017) 152

286. Neutrino properties determined in the T2K oscillation experiment
E. Rondio
Nuclear and Particle Physics Proceedings No 285-286 (2017) 26

287. Characterization of some modern scintillators recommended for use on large fusion facilities in γ-ray spectroscopy and tomographic measurements of γ-emission profiles
P. Sibczyński, ... , **A. Brosławski**, **A. Gójska**, **S. Korolczuk**, **R. Kwiatkowski**, **S. Mianowski**, **M. Moszyński**, **J. Rzadkiewicz**, **Ł. Świderski**, **A. Szydłowski**, **I. Zychor**, ... et al.
Nukleonika Vol. 62 No 3 (2017) 223-228

288. Compositional dependence of hyperfine interactions and magnetoelectric coupling in $(BiFeO_3)_x$-$(BaTiO_3)_{1-x}$ solid solutions
K. Kowal, P. Guzdek, M. Kowalczyk, E. Jartych
Nukleonika Vol. 62 No 2 (2017) 117-122

289. Crystal Structure and Mossbauer Effect in Multiferroic $0.5BiFeO_3$-$0.5Pb(Fe_{0.5}Ta_{0.5})O_3$ Solid Solution
A. Stoch, **J.K. Maurin**, **P. Stoch**, J. Kulawik, D. Szwagierczak
Nukleonika Vol. 62 (2017) 177

290. Identification of Zirconia phases by means of Raman spectroscopy for specimens prepared by FIB lift-out techniqe
Ł. Kurpaska, **M. Frelek-Kozak**, J-L. Grosseau-Poussard, **I. Jóźwik**, L. Lahoche, J. Favergeon, **J. Jagielski**
Oxid Met Vol. 88 (2017) 521

291. Energy scale of Lorentz Violation in Rainbow Gravity
Nils A. Nilsson, **M.P. Dąbrowski**
Phys Dark Universe Vol. 18 (2017) 115-122

292. Energy-dependent scintillation pulse shape and proportionality of decay components in CsI:Tl - modeling with transport and rate equations
X. Lu, ... , **A. Syntfeld-Każuch**, **Ł. Świderski**, **M. Moszyński**, ... et al.
Phys Rev Appl Vol. 7 (2017) 014007

293. Centrality dependence of the pseudorapidity density distribution for charged particles in Pb-Pb collisions at $\sqrt{s_{NN}}$=5.02 TeV
J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 772 (2017) 567-577

294. Coherent J/ψ photoproduction in ultra-peripheral PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with the CMS experiment
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Traczyk**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 772 (2017) 489

295. Combination of searches for heavy resonances decaying to WW, WZ, ZZ, WH, and ZH boson pairs in proton–proton collisions at $\sqrt{s}$= 8 and 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 774 (2017) 533

296. Constraints on anomalous Higgs boson couplings using production and decay information in the four-lepton final state
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 775 (2017) 1

297. Cross section measurement of t-channel single top quark production in pp collisions at $\sqrt{s}$= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 772 (2017) 752

298. Evidence for collectivity in pp collisions at the LHC
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 765 (2017) 193

299. Final COMPASS results on the deuteron spin-dependent structure function g_1^d and the Bjorken sum rule
C. Adolph, ... , **W. Augustyniak**, **K. Klimaszewski**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Phys. Lett. B Vol. 769 (2017) 034

300. First measurement of the Sivers asymmetry for gluons from SIDIS data
C. Adolph, ... , **W. Augustyniak**, **K. Klimaszewski**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Phys. Lett. B Vol. 772 (2017) 854

301. Isoscalar Single-Pion Production in the Region of Roper and d^*(2380) Resonances
P. Adlarson, ... , **W. Augustyniak**, **M. Berłowski**, **A. Kupść**, **B. Mariański**, **H.P. Morsch**, **D. Pszczel**, **J. Stepaniak**, **A. Trzciński**, **J. Zabierowski**, **P. Żuprański**, ... et al.
Phys. Lett. B Vol. 774 (2017) 599-607

302. J/ψ suppression at forward rapidity in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 766 (2017) 212-224

303. Linear and non-linear flow mode in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
S. Acharya, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 773 (2017) 68-80

304. Measurement of B0, B0s, B+ and Λ0b production asymmetries in 7 and 8 TeV proton-proton collisions
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 774 (2017) 139

305. Measurement of CP asymmetries in D±→η′π± and D±s→η′π± decays
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 771 (2017) 21

306. Measurement of CP asymmetry in $D^0 \to K^- K^+$ decays
V. Batozskaya, ... , **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 767 (2017) 177-187

307. Measurement of forward tt¯, W+bb¯ and W+cc¯ production in pp collisions at s√=8 TeV
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 767 (2017) 110

308. Measurement of the cross section for electroweak production of Zγ in association with two jets and constraints on anomalous quartic gauge couplings in proton–proton collisions at √s= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 770 (2017) 380

309. Measurement of the differential inclusive B^+ hadron cross sections in pp collisions at √s= 13 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 771 (2017) 435

310. Measurement of the mass difference between top quark and antiquark in pp collisions at √s= 8 TeV
S. Chatrchyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **G. Wrochna**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 770 (2017) 50

311. Measurement of the production of high-p_T electrons from heavy-flavour hadron decays in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 771 (2017) 467-481

312. Measurement of the running of the fine structure constant below 1 GeV with the KLOE detector
A. Anastasi, ... , **W. Krzemień**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 767 (2017) 485-492

313. Measurement of the WZ production cross section in pp collisions at √s= 13 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 766 (2017) 268

314. Measurement of the $\omega \to \pi^+ \pi^- \pi^0$ Dalitz plot distribution
P. Adlarson, ... , **W. Augustyniak**, **M. Berłowski**, **W. Krzemień**, **A. Kupść**, **B. Mariański**, **H.P. Morsch**, **D. Pszczel**, **J. Stepaniak**, **A. Trzciński**, **J. Zabierowski**, **P. Żuprański**, ... et al.
Phys. Lett. B Vol. 770 (2017) 418-425

315. Measurement of vector boson scattering and constraints on anomalous quartic couplings from events with four leptons and two jets in proton–proton collisions at $\sqrt{s}$= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 774 (2017) 682

316. Measurements of the charm jet cross section and nuclear modification factor in pPb collisions at $\sqrt{s_{NN}}$= 5.02 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 772 (2017) 306

317. Measuring K^0_S $K^{\pm}$ correlations using Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
S. Acharya, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 774 (2017) 64-67

318. Multiplicities of charged kaons from deep-inelastic muon scattering off an isoscalar target
C. Adolph, ... , **W. Augustyniak**, **K. Klimaszewski**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Phys. Lett. B Vol. 767 (2017) 133

319. Multiplicities of charged pions and charged hadrons from deep-inelastic scattering of muons off an isoscalar target
C. Adolph, ... , **W. Augustyniak**, **K. Klimaszewski**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Phys. Lett. B Vol. 764 (2017) 1

320. Multiplicity and rapidity dependence of strange hadron production in pp, pPb, and PbPb collisions at the LHC
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 768 (2017) 103

321. Observation of the decay $B^+ \to \psi(2S)\phi(1020)K^+$ in pp collisions at $\sqrt{s}$= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 764 (2017) 66

322. Observation of the $\Xi-b \to J/\psi \Lambda K-$ decay
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 772 (2017) 265

323. Observation of $\eta c(2S) \to p\bar{p}$ and search for $X(3872) \to p\bar{p}$ decays
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 769 (2017) 305

324. Production of muons from heavy-flavour hadron decays in p–Pb collisions at $\sqrt{s_{NN=5.02\ TeV}}$
S. Acharya, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 770 (2017) 459-472

325. Prompt and nonprompt J/ψ production and nuclear modification in pPb collisions at $\sqrt{sNN}$=8.16 TeV
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 774 (2017) 159

326. Running of the Charm-Quark Mass from HERA Deep-Inelastic Scattering Data
A. Gizhko, ... , **T. Tymieniecka**, ... et al.
Phys. Lett. B Vol. 775 (2017) 233-238

327. Search for a heavy composite Majorana neutrino in the final state with two leptons and two quarks at √s= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 775 (2017) 315

328. Search for anomalous couplings in boosted WW/WZ→lνqqbar production in proton-proton collisions at √s= 8 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 772 (2017) 21

329. Search for black holes and other new phenomena in high-multiplicity final states in proton–proton collisions at √s = 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 774 (2017) 279

330. Search for CP violation in the phase space of D0→π+π−π+π− decays
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 769 (2017) 345

331. Search for dijet resonances in proton–proton collisions at √s= 13 TeV and constraints on dark matter and other models
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 769 (2017) 520

332. Search for heavy gauge W' bosons in events with an energetic lepton and large missing transverse momentum at √s= 13 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 770 (2017) 278

333. Search for heavy resonances decaying into a vector boson and a Higgs boson in final states with charged leptons, neutrinos, and b quarks
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 768 (2017) 137

334. Search for high-mass diphoton resonances in proton–proton collisions at 13 TeV and combination with 8 TeV search
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 767 (2017) 147

335. Search for high-mass Zγ resonances in proton–proton collisions at √s= 8 and 13 TeV using jet substructure techniques
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 772 (2017) 363

336. Search for leptophobic Z′ bosons decaying into four-lepton final states in proton–proton collisions at √s= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 773 (2017) 563

337. Search for narrow resonances in dilepton mass spectra in proton–proton collisions at √s= 13 TeV and combination with 8 TeV data
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 768 (2017) 57

338. Search for new phenomena in events with high jet multiplicity and low missing transverse momentum in proton–proton collisions at √s= 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 770 (2017) 257

339. Search for single production of a heavy vector-like T quark decaying to a Higgs boson and a top quark with a lepton and jets in the final state
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 771 (2017) 80

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 772 (2017) 634

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 772 (2017) 336

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 769 (2017) 391

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 764 (2017) 233

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 765 (2017) 307

345. Search for top squark pair production in compressed-mass-spectrum scenarios in proton–proton collisions at √s= 8 TeV using the α_T variable
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 767 (2017) 403

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C. Adolph, ... , **W. Augustyniak**, **K. Klimaszewski**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Phys. Lett. B Vol. 770 (2017) 138

347. Suppression of Υ(1S), Υ(2S), and Υ(3S) quarkonium states in PbPb collisions at $\sqrt{s_{NN}}$= 2.76 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 770 (2017) 357

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O. Hrycyna
Phys. Lett. B Vol. 768 (2017) 218

349. ϕ -meson production at forward rapidity in p–Pb collisions at $\sqrt{s_{NN}}$=5.02 TeV and in pp collisions at $\sqrt{s}$=2.76 TeV
J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 768 (2017) 203-217

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L. Raczyński, ... , **W. Wiślicki**, **W. Krzemień**, **P. Kowalski**, ... et al.
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P. Kubes, ... , **M.J. Sadowski**, **D. Załoga**, ... et al.
Phys. of Plasmas Vol. 24 (2017) 032706

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P. Kubes, ... , **M.J. Sadowski**, **D. Załoga**, ... et al.
Phys. of Plasmas Vol. 24 (2017) 092707

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P. Kubes, ... , **M.J. Sadowski**, **D. Załoga**, ... et al.
Phys. of Plasmas Vol. 24 (2017) 072706

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St. Mrówczyński, B. Schenke, M. Strickland
Phys. Rep. Vol. 682 (2017) 1

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K. Kozioł, **J. Rzadkiewicz**
Phys. Rev. A Vol. 96 (2017) 031402(R)

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P. Jachimowicz, **M. Kowal**, **J. Skalski**
Phys. Rev. C Vol. 95 (2017) 014303

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V. Soukeras, ... , **N. Keeley**, ... et al.
Phys. Rev. C Vol. 95 (2017) 054614

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S.Yu. Mezhevych, ... , **N. Keeley**, ... et al.
Phys. Rev. C Vol. 95 (2017) 034607

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J. Perkowski, ... , **M. Kisieliński**, **J. Kownacki**, **A. Korman**, ... et al.
Phys. Rev. C Vol. 95 (2017) 014305

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P. Jachimowicz, **M. Kowal**, **J. Skalski**
Phys. Rev. C Vol. 95 (2017) 034329

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O. Sgouros, ... , **N. Keeley**, **I. Strojek**, ... et al.
Phys. Rev. C Vol. 95 (2017) 054609

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J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Rev. C Vol. 96 (2017) 034904

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A. Pakou, ... , **N. Keeley**, ... et al.
Phys. Rev. C Vol. 95 (2017) 044615

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A. Pakou, ... , **N. Keeley**, ... et al.
Phys. Rev. C Vol. 96 (2017) 034615

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G. Marquínez-Durán, **N. Keeley**, K.W. Kemper, R.S. Mackintosh, I. Martel, K. Rusek, A.M. Sánchez-Benítez
Phys. Rev. C Vol. 95 (2017) 024602

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S.K. Pandit, ... , **N. Keeley**, ... et al.
Phys. Rev. C Vol. 96 (2017) 044616

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J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Rev. C Vol. 95 (2017) 064606

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S. Acharya, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Rev. C Vol. 96 (2017) 064613

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S.A. Kuvin, ... , **N. Keeley**, ... et al.
Phys. Rev. C Vol. 96 (2017) 045812

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. C Vol. 96 (2017) 015202

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. C Vol. 96 (2017) 064902

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. C Vol. 96 (2017) 014915

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M. Polasik, K. Słabkowska, J.J. Carroll, C.J. Chiara, Ł. Syrocki, E. Węder, **J. Rzadkiewicz**
Phys. Rev. C Vol. 95 (2017) 034312

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B.P. Abbott, ... , **O. Dorosh**, ... et al.
Phys. Rev. D Vol. 96 (2017) 062002

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A. Królak, ... , **A. Kutynia**, **A. Zadrożny**, ... et al.

Phys. Rev. D Vol. 95 (2017) 042003

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. D Vol. 95 (2017) 012002

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B. Pire, K. Semenov-Tian-Shansky, **L. Szymanowski**
Phys. Rev. D Vol. 95 (2017) 034021

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E. Czuchry, D. Garfinkle, J.R. KLauder, **W. Piechocki**
Phys. Rev. D Vol. 95 (2017) 024014

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I.V. Anikin, **L. Szymanowski**, O.V. Teryaev, N. Volchanskiy
Phys. Rev. D Vol. 95 (2017) 111501

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B. Pire, **L. Szymanowski**
Phys. Rev. D Vol. 96 (2017) 114008

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B. Pire, **L. Szymanowski**, **J. Wagner**
Phys. Rev. D Vol. 95 No 9 (2017) 094001

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B. Singh, ... , **A. Chłopik**, **G. Kęsik**, **D. Melnychuk**, **B. Słowiński**, **A. Trzciński**, **M. Wojciechowski**, **S. Wronka**, **B. Zwięgliński**, ... et al.
Phys. Rev. D Vol. 95 (2017) 032003

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M. Kabirnezhad, ... , **J. Łagoda**, **P. Mijakowski**, **P. Przewłocki**, **E. Rondio**, **J. Zalipska**, ... et al.
Phys. Rev. D Vol. 95 No 1 (2017) 012010

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B. Pire, **L. Szymanowski**, **J. Wagner**
Phys. Rev. D Vol. 95 (2017) 114029

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A. Pędrak, B. Pire, **L. Szymanowski**, **J. Wagner**
Phys. Rev. D Vol. 96 (2017) 074008

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 95 (2017) 012003

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S. Robles-Perez, **M.P. Dąbrowski**, A. Balcerzak, M. Kraemer
Phys. Rev. D Vol. 95 (2017) 083505

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P. Małkiewicz, A. Miroszewski
Phys. Rev. D Vol. 96 No 4 (2017) 046003

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K. Abe, ... , **M. Kabirnezhad**, **K. Kowalik**, **J. Łagoda**, **P. Przewłocki**, **E. Rondio**, **J. Zalipska**, ... et al.
Phys. Rev. D Vol. 96 No 5 (2017) 052001

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 96 (2017) 112003

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 95 (2017) 092001

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K. Abe, ... , **M. Kabirnezhad**, **K. Kowalik**, **J. Łagoda**, **P. Przewłocki**, **E. Rondio**, **J. Zalipska**, ... et al.
Phys. Rev. D Vol. 96 (2017) 092006

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. D Vol. 95 (2017) 052005

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 96 (2017) 072005

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 96 (2017) 032002

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 95 (2017) 052002

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. D Vol. 95 No 3 (2017) 032005

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. D Vol. 96 No 05 (2017) 051103

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. D Vol. 96 (2017) 011101

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. D Vol. 95 (2017) 012006

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K. Deja, K. Kutak
Phys. Rev. D Vol. 95 No 11 (2017) 114027

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C. Adolph, ... , **W. Augustyniak**, **K. Klimaszewski**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Phys. Rev. D Vol. 95 (2017) 032004

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A. Królak, ... , **A. Kutynia**, **A. Zadrożny**, ... et al.
Phys. Rev. D Vol. 95 (2017) 122003

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 96 (2017) 072004

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A. Królak, ... , **A. Kutynia**, **A. Zadrożny**, ... et al.
Phys. Rev. D Vol. 96 (2017) 022005

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A. Królak, ... , **A. Kutynia**, **A. Zadrożny**, ... et al.
Phys. Rev. D Vol. 96 (2017) 022001

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. D Vol. 95 No 7 (2017) 071101

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K. Abe, ... , **K. Kowalik**, **J. Łagoda**, **P. Mijakowski**, **P. Przewłocki**, **E. Rondio**, **J. Zalipska**, ... et al.
Phys. Rev. D Vol. 95 No 11 (2017) 111101

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K. Abe, ... , **P. Mijakowski**, **K. Frankiewicz**, ... et al.
Phys. Rev. D Vol. 96 No 1 (2017) 012003

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M. Miura, ... , **P. Mijakowski**, **K. Frankiewicz**, ... et al.
Phys. Rev. D Vol. 95 No 1 (2017) 012004

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**,

K. Nawrocki, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 95 (2017) 012009

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 95 (2017) 012011

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 96 (2017) 032003

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. D Vol. 96 (2017) 012004

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H. Bergeron, **E. Czuchry**, J.-P. Gazeau, **P. Małkiewicz**
Phys. Rev. D Vol. 96 No 4 (2017) 043521

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H. Abramowicz, ... , **M. Adamus**, **T. Tymieniecka**, ... et al.
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L. Darme, J. Jaeckel, M. Lewicki
Phys. Rev. D Vol. 96 No 5 (2017) 056001

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K. Abe, ... , **M. Kabirnezhad**, **K. Kowalik**, **J. Łagoda**, **P. Mijakowski**, **P. Przewłocki**, **E. Rondio**, **J. Zalipska**, ... et al.
Phys. Rev. D Vol. 96 No 1 (2017) 011102

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J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
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D. Adamova, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 222301

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K. Abe, ... , **M. Kabirnezhad**, **K. Kowalik**, **J. Łagoda**, **P. Mijakowski**, **P. Przewłocki**, **E. Rondio**, **J. Zalipska**, ... et al.
Phys. Rev. Lett. Vol. 118 No 15 (2017) 151801

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 021801

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M. Aghasyan, ... , **W. Augustyniak**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 112002

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 119 No 4 (2017) 041802

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J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 162302

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A. Królak, ... , **A. Kutynia**, **A. Zadrożny**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 221101

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S. Acharyya, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 242301

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 101801

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 No 5 (2017) 052002

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 152301

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 No 19 (2017) 191801

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 26

434. Next-to-leading order computation of exclusive diffractive light vector meson production in a saturation framework
R. Boussarie, A.V. Grabovsky, D.Yu. Ivanov, **L. Szymanowski**, S. Wallon
Phys. Rev. Lett. Vol. 119 (2017) 072002

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 No 11 (2017) 111803

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 122301

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**,

A. Ukleja, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 119 No 18 (2017) 181805

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 182001

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 022003

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 081801

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 No 7 (2017) 071801

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 062001

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 119 No 11 (2017) 112001

444. Precise measurement of the χc1 and χc2 resonance parameters with the decays χc1,c2→Jψμ+μ−
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **D. Melnychuk**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 119 No 22 (2017) 221801

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 162301

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 119 No 18 (2017) 181807

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 141802

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V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 021802

449. Search for evidence of the type-III seesaw mechanism in multilepton final states in proton-proton collisions at √s= 13 TeV
A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 221802

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 111802

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 151802

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 No 25 (2017) 251802

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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Rev. Lett. Vol. 118 (2017) 192001

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A. Sirunyan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Fruboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 082301

455. Upper Limits on the Stochastic Gravitational-Wave Background from Advanced LIGO's First Observing Run
A. Królak, ... , **A. Kutynia**, **A. Zadrożny**, ... et al.
Phys. Rev. Lett. Vol. 119 (2017) 029901

456. Superheavy nuclei: From predictions to discovery
Yu.Ts. Oganessian, **A. Sobiczewski**, G.M. Ter-Akopian
Phys. Scr. Vol. 92 (2017) 023003

457. A Distributed Data Acquisition System for the Sensor Network of the TAWARA_RTM Project
C. Fontana, ... , **Ł. Świderski**, **M. Moszyński**, **T. Batsch**, ... et al.
Physcs Proc Vol. 90 (2017) 271

458. Detection System of the First Rapidly Relocatable Tagged Neutron Inspection System (RRTNIS), Developed in the Framework of the European H2020 C-BORD Project
C. Fontana, ... , **K. Grodzicki**, **M. Moszyński**, **P. Sibczyński**, **Ł. Świderski**, ... et al.
Physcs Proc Vol. 90 (2017) 279

459. Temperature oscillations and sound waves in hadronic matter
G. Wilk, Z. Włodarczyk
Physica A Vol. 486 (2017) 579-586

460. Current status of Polish Fireball Network.
M. Wiśniewski, ... , **Z. Tymiński**, ... et al.
Planetary and Space Sci. Vol. 143 (2017) 12-20

461. Meteor studies in the framework of the JEM-EUSO program
G. Abdellaoui, ... , **T. Batsch**, **J. Karczmarczyk**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**,

T. Wibig, ... et al.
Planetary and Space Sci. Vol. 143 (2017) 245-255

462. Novel scintillating material 2-(4-styrylphenyl) benzoxazole for the fully digital and MRI compatible J-PET tomograph based on plastic scintillators
A. Wieczorek, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
PLOS One Vol. 12 (2017) e0186728

463. Pi of the Sky in LSC-Virgo\'s EM follow-up in O1 science run
A. Zadrożny, L. Mankiewicz, A.F. Żarnecki, **M. Sokołowski**
Proc. SPIE Vol. 10445 (2017) 104454I

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R. Opiela, ... , **T. Batsch**, **A. Ćwiek**, **A. Majcher**, **K. Małek**, **M. Sokołowski**, **G. Wrochna**, ... et al.
Proc. SPIE Vol. 104454C (2017)

465. A new analysis of the combined data from bothKASCADE and KASCADE-Grande
S. Schoo, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Proceedings of Science Vol. ICRC2017 (2017) 339

466. A new release of the KASCADE Cosmic Ray DataCentre (KCDC)
D. Kang, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Proceedings of Science Vol. ICRC2017 (2017) 452

467. Interferometric Radio Measurements of Air Showers with LOPES: Final Results
F.G. Schroeder, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Proceedings of Science Vol. ICRC2017 (2017) 458

468. Latest Results of KASCADE-Grande
A. Haungs, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Proceedings of Science Vol. ICRC2017 (2017) 545

469. Mesurement of the muon content of EAS in KASCADE-Grande compared with SIBYLL 2.3 predictions
J.C. Arteaga-Valasquez, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Proceedings of Science Vol. ICRC2017 (2017) 316

470. Nauka – edukacja – przemysł: synergiczna współpraca dlainnowacyjności
M. Bartosik, ... , **A. Strupczewski**, ... et al.
Przegląd Elektrotechniczny Vol. 93 No 1 (2017) 339--345

471. Badania materiałów i elementów techniki jadrowej przez Laboratorium Badań Materiałowych NCBJ
B. Zając, **Ł. Kurpaska**
Przegląd Spawalnictwa Vol. 89 No 11 (2017) 50

472. The Taipan Galaxy Survey: Scientific Goals and Observing Strategy
E. DaCunha, ... , **M. Bilicki**, ... et al.
Publ Astron Soc Aust Vol. 34 (2017) e047

473. Hyper Suprime-Camera Survey of the Akari NEP Wide Field
T. Goto, ... , **K. Małek**, ... et al.
Publ Kor Astron Soc Vol. 32 No 1 (2017) 225-230

474. NEP-AKARI: evolution with redshift of dust attenuation in 8 μm selected galaxies
V. Buat, ... , **K. Małek**, ... et al.
Publ Kor Astron Soc Vol. 32 No 1 (2017) 257-261

475. Overview of North Ecliptic Pole Deep Multi-Wavelength Survey Nep-Deep
H. Matsuhara, ... , **K. Małek**, **A. Solarz**, **A. Pollo**, ... et al.
Publ Kor Astron Soc Vol. 32 (2017) 213

476. Nanodosimetry: towards a new concept of radiation quality
V. Conte, ... , **A. Bancer**, **M. Pietrzak**, **S. Pszona**, ... et al.
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477. State of The Art of Instrumentation in The Experimental Nanodosimetry
A. Bancer, ... , **M. Pietrzak**, **S. Pszona**, ... et al.
doi:10.1093/rpd/ncx263

478. Social Simulation Models at the Ethical Crossroads
P. Sobkowicz
Sci Eng Ethics Vol. - (2017) -

479. Approximate Bayesian Computation Methods in the Identification of Atmospheric Contamination Sources for DAPPLE Experiment
P. Kopka, **A. Wawrzyńczak-Szaban**, **M. Borysiewicz**
Springer P Math Stat: Bayesian Statistics in Action Vol. 194 (2017) 161-171

480. Unusual visible-light photolytic cleavage of tertiary amides during the synthesis of cyclolignans related to podophyllotoxin
K. Lisiecki, K.K. Krawczyk, P. Roszkowski, **J.K. Maurin**, **A. Budzianowski**, Z. Czarnocki
Tetrahedron Vol. 73 No 44 (2017) 6316

481. Convenient synthesis of selected meta- and ortho-substituted pentaarylpyridines via the Suzuki-Miyaura cross-coupling reaction
P. Pomarański, P. Roszkowski, **J.K. Maurin**, **A. Budzianowski**, Z. Czarnocki
Tetrahedron Lett Vol. 58 No 5 (2017) 462

482. New N,N-diamine ligands derived from (-)-menthol and their application in the asymmetric transfer hydrogenation
P. Roszkowski, **J.K. Maurin**, Z. Czarnocki
Tetrahedron-Asym. Vol. 28 (2017) 532

483. Atomic layer deposited ZnO films implanted with Yb: The influence of Yb location on optical and electrical properties
E. Guziewicz, ... , **R. Ratajczak**, **C. Mieszczyński**, **A. Turos**, ... et al.
Thin Solid Films Vol. 643 (2017) 7-15

484. Reactive sputtering of titanium compounds using the magnetron system with a grounded cathode
R. Chodun, **K. Nowakowska-Langier**, B. Wicher, S. Okrasa, R. Minikayev, K. Zdunek
Thin Solid Films Vol. 640 (2017) 73-80

485. Structural and optical studies of Pr implanted ZnO films subjected to a long-time or ultra-fast thermal annealing
R. Ratajczak, ... , **C. Mieszczyński**, **A. Turos**, ... et al.
Thin Solid Films Vol. 643 (2017) 24-30

486. Modelling of the Radiation Carcinogenesis: The Analytic and Stochastic Approaches
K.W. Fornalski, **L. Dobrzyński**, **J. Reszczyńska**
Trends in Mathematics Vol. 7 (2017) 95

487. Simulation of the influence of the interface roughness on the residual stresses induced in $(ZrO_2+Y_2O_3)$+NiAl-type composite coatings deposited on Inconel 713C
T. Bolek, R. Sitek, J. Sienkiewicz, R. Dobosz, J. Mizera, A. Kobayashi, K.J. Kurzydlowski
Vacuum Vol. 136 (2017) 221-228

488. The effect of Ar-ion irradiation on nanomechanical and structural properties of ODS RAF steels manufactured by using HIP technique
Ł. Kurpaska, I. Jozwik, M. Lewandowska, **J. Jagielski**
Vacuum Vol. 145 (2017) 144-152

489. Ogień z wodą - czyli o optymalizacji głowicy terapeutycznej mobilnego akceleratora do radioterapii śródoperacyjnej
P. Adrich
Zeszyty Naukowe WCO, Letters in Oncology Science Vol. 14 No S1 (2017) 29-30

Publications related to physics education and popularization of physics

1. Atomowe mity Fukushimy
A. Strupczewski
Biznes Alert Vol. - No 03 (2017)

2. Bardzo szybki dostęp, i to na zimno, prosto z Białegostoku // Egzotyczne trajektorie przez trzy szczeliny
P. Zalewski
Delta Vol. 516 No 5 (2017) 21

3. Napięcie powierzchniowe języka
P. Zalewski
Delta Vol. 521 No 10 (2017) 24

4. Nieparzystość kombinowana neutrin?
P. Zalewski
Delta Vol. 522 No 11 (2017) 24

5. Rozwiązła bezwładność sznurówek
P. Zalewski
Delta Vol. 517 No 6 (2017) 21

6. Topologiczny Nobel
P. Zalewski
Delta Vol. 512 No 1 (2017) 21

7. Wieści z ciekłych pułapek na ciemną materię
P. Zalewski
Delta Vol. 520 No 9 (2017) 18

8. Wybuchowe uodpornianie
P. Zalewski
Delta Vol. 513 No 2 (2017) 18

9. Wyplatanie komputera kwantowego
P. Zalewski
Delta Vol. 523 No 12 (2017) 21

10. Fukushima - wszystko o co chciałeś zapytać
A. Strupczewski
Energetyka No 3 (2017)

11. Analizy ryzyka awarii przemysłowych
S. Potempski, **M. Borysiewicz**
Rynek Inwestycji Vol. 14 (2017) 26-29

Publications without peer review

1. Cosmic-Ray Extremely Distributed Observatory: a global cosmic ray detection framework, Volume 7, Issue 1-2, PP. 23-29 (2017) doi: 10.17721/2227-1481.7.23-29
O. Sushchov, ... , **T. Wibig**, **M. Kasztelan**, ... et al.
ADV ASTRON and Space Physics Vol. 7 No 1-2 (2017) 23-29

2. Cherenkov Telescope Array Contributions to the 35th International Cosmic Ray Conference (ICRC2017)
F. Acero, ... , **A. Majczyna**, **A. Durkalec**, **A. Pollo**, ... et al.
ArXiv Vol. 1709.03483 (2017) 1

3. The Single-Phase ProtoDUNE Technical Design Report
P. Przewlocki, ... , **D. Stefan**, **R. Sulej**, ... et al.
ArXiv Vol. 1 No 1706.07081 (2017) 1

4. Światowe rozwiązania dla współczesnej energetyki jądrowej
A. Strupczewski
Biuletyn Informacyjny Stowarzyszenia Elektryków Polskich No 1 (2017)

5. Problemy zasad ochrony radiologicznej w obszarze małych dawek promieniowania
J. Reszczyńska, **L. Dobrzyński**,
Biuletyn PAA Bezpieczeństwo Jądrowe i Ochrona Radiologiczna Vol. 1 (2017) 32

6. Spokojnie uranu wystarczy
A. Strupczewski
Energetyka Cieplna i Zawodowa No 4 (2017)

7. Average fast neutron flux in three energy ranges in the Quinta assembly irradiated by two types of beams
E. Strugalska-Gola, **M. Bielewicz**, **S. Kilim**, **M. Szuta**, S. Tyutyunnikov
European Physical Journal Web of Conferences Vol. 138(2017) No 10007 (2017)

8. Comparison of neutron induced fission and capture in Np-237 and Pu-239 irradiated in Quinta assembly with 660 MeV proton beam
S. Kilim, **E. Strugalska-Gola**, **M. Szuta**, **M. Bielewicz**, S. Tyutyunnikov, V. Stegailov
European Physical Journal Web of Conferences Vol. 138(2017) No 10004 (2017)

9. Comparison of two fast neutron fluence measurement methods based on Np-237 fission-capture ratio measurement (spectral index) and a reverse dark current measurement in a planar silicon detector
M. Szuta, **S. Kilim**, **E. Strugalska-Gola**, **M. Bielewicz**, N. Zamiatin, A. Shafronovskaia, S. Tyutyunnikov
European Physical Journal Web of Conferences Vol. 138(2017) No 10006 (2017)

10. Experimental results on multi-nucleonic K^- absorption in nuclei
O. VasquezDoce, ... , **S. Wycech**, ... et al.
European Physical Journal Web of Conferences Vol. 137 (2017) 09010

11. Investigation of the low-energy kaons hadronic interactions in light nuclei
K. Piscicchia, ... , **S. Wycech**, ... et al.
European Physical Journal Web of Conferences Vol. 137 (2017) 09005

12. Monte carlo simulations of Yttrium reaction rates in Quinta uranium target
M. Suchopar, ... , **M. Bielewicz**, **S. Kilim**, **E. Strugalska-Gola**, **M. Szuta**, ... et al.
European Physical Journal Web of Conferences Vol. 138 No 10003 (2017)

13. Search for Deeply Bound Kaonic Nuclear States with AMADEUS
M. Skurzok, ... , **S. Wycech**, ... et al.
European Physical Journal Web of Conferences Vol. 165 (2017) 01046

14. Study of the Σ^o p Final State from K^- absorption
O. VasquezDoce, ... , **S. Wycech**, ... et al.

JPS Conf.Proc Vol. 17 (2017) 082001

15. Performance of the RASNIK Optical Alignment Monitoring System for the LHCb Outer Tracker Detector
M. Szczekowski, ... , **A. Ukleja**, ... et al.
LHCb-PUB Vol. 2017 (2017) 020

16. Optymalizacja parametrów cewki napędowej urządzenia miotającego typu Inductance Coil Gun
A. Horodeński, **C. Pochrybniak**, **K. Namyślak**
Materiały konferencyjne (2017)

17. Akcelerator intraline-ioert do radioterapii śródoperacyjnej
J. Pracz, ... , **A. Syntfeld-Każuch**, **K. Kosiński**, **E. Kulczycka**, **P. Adrich**, **J. Pracz**, **B. Meglicki**, **A. Misiarz**, ... et al.
Postępy Techniki Jądrowej Vol. 60 No 3 (2017) 21-29

18. Konieczności zmiany paradygmatu ochrony radiologicznej - komentarz SARI - Stowarzyszenia Uczonych dla Rzetelnej Informacji o Promieniowaniu
L. Dobrzyński, M. Janiak, **A. Strupczewski**, M. Waligórski
Postępy Techniki Jądrowej Vol. 60 No 3 (2017) 2-11

19. Praca reaktora badawczego Maria w 2016 roku.
A. Gołąb, **E. Borek-Kruszewska**
Postępy Techniki Jądrowej Vol. 60 No Z.1 (2017) 24-30

20. Warstwy metaliczne Mo otrzymywane metodą PMS
B. Wicher, ... , **K. Nowakowska-Langier**, **G. Strzelecki**, ... et al.
Prace XLV Szkoły Inżynierii Materiałowej Vol. 1 No 1 (2017) 143

21. Wpływ częstotliwości modulującej na syntezę cienkich warstw metodą PMS
G. Strzelecki, **K. Nowakowska-Langier**, R. Chodun, S. Okrasa, B. Wicher, K. Zdunek
Prace XLV Szkoły Inżynierii Materiałowej Vol. 1 No 1 (2017) 149

22. Airglow dynamics observations by MINI- EUSO
P. Bobik, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 408

23. Ancillary detectors for the Mini-EUSO telescope:control software development and expected science
S. Turriziani, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 431

24. Antikaon Interactions with Nucleon and Nuclei- AMADEUS at DAΦNE
J. Marton, ... , **S. Wycech**, ... et al.
Proceedings of Science (PoS) Vol. INCP2016 (2017) 290

25. Calibrating and Testing EUSO-SPB in Flight using a Laser and LEDs on an Aircraft
M. Mastafa, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 448

26. COMPASS results on hard exclusive muoproduction
A. Sandacz
Proceedings of Science (PoS) Vol. QCDEVO2016 (2017) 018

27. EUSO-SPB1 Mission and Science
L. Wiencke, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 1097

28. Expected number of Extensive Air Showers observable by EUSO-SPB
F. Fenu, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 426

29. HVPS system for *-EUSO detectors
Z. Plebaniak, ... , **J. Karczmarczyk**, **W. Marszał**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 378

30. Implications for space-based UHECR observation from UV background studies by JEM-EUSO pathfinders
K. Shinozaki, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 425

31. KLYPVE-EUSO: Science and UHECR observational capabilities
M. Casolino, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 368

32. Mini-EUSO data processing and quasi-real time analysis
L. Piotrowski, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 373

33. Mini-EUSO flight software and operations on ISS
F. Capel, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 454

34. Mini-EUSO optics design and tests
Y. Takizawa, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 367

35. Mini-EUSO photodetector module data processing system
A. Belov, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 409

36. Mini-EUSO: a precursor mission to observe and study Atmosphere and Earth UV emission from the International Space Station
M. Ricci, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 440

37. Muon g-2 and dark matter in models with vector-like fermions
E. Sessolo, **K. Kowalska**
Proceedings of Science (PoS) Vol. EPS-HEP201 (2017) 338

38. New simulation and reconstruction software for the EUSO pathfinders, with example applications
T. Paul, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 464

39. Point Spread Function of EUSO-TA detector
Z. Plebaniak, ... , **T. Wibig**, **J. Karczmarczyk**, **W. Marszał**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 460

40. Preflight calibration and testing of EUSO- SPB in the lab and the desert
J. Eser, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 457

41. Results of the EUSO-Balloon flight
M. Bertaina, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 445

42. Schmidt type optical system for the KLYPVE-EUSO UHECR detector
P. Sandri, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 451

43. Science of Mini-EUSO experiment on the International Space Station
M. Casolino, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.

Proceedings of Science (PoS) Vol. ICRC2017 (2017) 369

44. SiECA: Silicon Photomultiplier Prototype for Flight with EUSO-SPB
W. Painter, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 442

45. Simulation study of the detected and expected events for the EUSO-TA fluorescence detector
F. Bisconti, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 463

46. Simulations of Mini-EUSO observations of UV phenomena in the atmosphere
G. Suino, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 421

47. Status of the KLYPVE-EUSO detector for EECR study on board the ISS
P. Klimov, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 412

48. Study of Fast Moving Nuclearite and Meteorite using High Sensitivity CMOS Camera with EUSO-TA
F. Kajino, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 924

49. The Data Processor System of EUSO-SPB
G. Osteria, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 461

50. The EUSO-SPB Instrument
S. Bacholle, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 384

51. The EUSO-TA detector: status and performance
L. Piotrowski, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 374

52. The EUSO@Turlab Project: Results from Phase II
G. Suino, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 422

53. The Hyper-Kamiokande project
J. Łagoda
Proceedings of Science (PoS) Vol. FCPV2017 (2017) 24

54. The Mini-EUSO multi-level trigger algorithm and its performance
F. Capel, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 453

55. The trigger logic of EUSO-SPB and its performance
J. Bayer, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings Of Science (PoS) Vol. ICRC2017 (2017) 443

56. UCIRC: Infrared Cloud Monitor for EUSO- SPB
L. Allen, ... , **J. Karczmarczyk**, **W. Marszał**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2017 (2017) 436

57. [U]LIRG dust luminosity properties with two different dust emission models
A. Herzig, M. Bankowicz, **K. Małek**, **A. Pollo**
Proceedings of the Polish Astronomical Society Vol. 4 (2017) 184-185

58. Cosmology from large-scale structure observations: a subjective review
M. Bilicki, W.A. Hellwing
Proceedings of the Polish Astronomical Society Vol. 4 (2017) 68-84

59. Dust properties of LIRGs and ULIRGs from the AKARI Deep Field-South
M. Bankowicz, **K. Małek**, **A. Pollo**, V. Buat, D. Burgarella, T.T. Takeuchi
Proceedings of the Polish Astronomical Society Vol. 4 (2017) 182-183

60. Radiation Hormesis Should be the Basis for Establishing Radiation Protection Standards
M. Doss, **L. Dobrzyński**, **A. Strupczewski**
Radiation effects (2017)

61. USP Public Standards for Compounded Sterile Radiopharmaceuticals: Recommendations from SNMMI
R.W. Atcher, ... , **R. Mikołajczak**, ... et al.
The Committee on Radiopharmaceuticals (COR) is a committee of the Society of Nuclear (2017)

62. Uran z wody morskiej - niewyczerpalne źródło energii
A. Strupczewski
Wnp-Energetyka No 06 (2017)

63. Nauka – edukacja – przemysł: synergiczna współpraca dla innowacyjności
M. Bartosik, W. Kamrat, M. Kaźmierkowski, W. Lewandowski, M. Pawlik, T. Peryt, T. Skoczkowski, **A. Strupczewski**, A. Szeląg *Przegląd Elektrotechniczny Vol. 93 No 1 (2017) 339—345*

64. Fukushima - wszystko o co chciałeś zapytać
A. Strupczewski
Energetyka No 3 (2017) ; WWW: http://energetyka.wnp.pl/strupczewski-fukushima-wszystko-o-co-chciales-zapytac,293914_1_0_0.html

65. Światowe rozwiązania dla współczesnej energetyki jądrowej
A. Strupczewski
Biuletyn Informacyjny Stowarzyszenia Elektryków Polskich No 1 (2017)
WWW: http://radom.wyborcza.pl/radom/1,48201,20869020,globalne-wyzwania-energetyczne-w-xxi-w-potega-atomu.html?disableRedirects=true

66. Spokojnie uranu wystarczy
A. Strupczewski
Energetyka Cieplna i Zawodowa No 4 (2017)
WWW: https://www.kierunekenergetyka.pl/artykul,39872,spokojnie-uranu-wystarczy.html

67. O konieczności zmiany paradygmatu ochrony radiologicznej - komentarz SARI - Stowarzyszenia Uczonych dla Rzetelnej Informacji o Promieniowaniu
L. Dobrzyński, M.K. Janiak, **A. Strupczewski**, M. Waligórski
Postępy Techniki Jądrowej Vol. 60 No 3 (2017) 2

68. Radiation Hormesis Should be the Basis for Establishing Radiation Protection Standards
M. Doss, **L. Dobrzyński**, **A. Strupczewski**
Radiation effects (2017)
WWW: radiationeffects.org/wp.../SARI-Comments-to-EPA-5.14.17.pdf

Others

1. Analiza tomograficzna dziwerowanego grotu włóczni z Lubanowa (nr kat. II.1) | Tomographic Analysis of Pattern Welded Spearhead from Lubanowo (no. cat. II.1) (208-210) W: Starożytne miejsce ofiarne w jeziorze w Lubanowie (d. Herrn-See) na Pomorzu Zachodnim. Ancient Sacrificial Place in the Lake in Lubanowo (former Herrn-See) in West Pomerania
   T. Kosiński
   Uniwersytet Warszawski (Warszawa)

2. Analizy tomograficzne zabytków z Nidajna | Tomographic analyses of archaeological finds from Nidajno (152-182) W: Starożytne miejsce ofiarne w dawnym jeziorze Nidajno na Mazurach. Wyniki badań laboratoryjnych wybranych zabytków. Ancient Sacrificial Place in Former Lake Nidajno in Masuria. Results of Laboratory Analyses of Selected Finds
   T. Kosiński, A. Rzeszotarska-Nowakiewicz, T. Nowakiewicz
   Uniwersytet Warszawski (Warszawa)

3. Cyclotron Based Production of Technetium-99m
   A.H. Al-Rayyes, F. Al-Rumayan, A. Avetisyan, S. Chattopadhyay, J. Esposito, Y. Fujibayashi, M. Haji-Saied, S. Lapi, S.A. McQuarrie, **R. Mikołajczak,** T.J. Ruth, A. Salvini, S. Takacs, ... et al.
   International Atomic Energy Agency

4. Czarnobyl - fakty i mity
   M. Rabiński
   Institute of Philosophy, University of Warmia and Mazury, Olsztyn

5. Diffusion of helium in the uranium dioxide using the ab initio method
   L. Dąbrowski, **M. Szuta**
   Verlag/Publisher: Lap Lambert Academic Publishing Bahnhofstrase 28, 66111 Saarbrucken, Deutschland/Germany

6. Formowanie wiązek elektronowych. Nowe koncepcje układów formowania i rozwój metod ich projektowania w oparciu o narzędzia współczesnej fizyki subatomowej
   P. Adrich
   National Centre for Nuclear Research

7. IAEA tecdoc serie: use of low enriched uranium fuel in accelerator driven subcritical systems
   S. Kilim, E. Strugalska-Gola, M. Szuta, A. Wojciechowski, ... et al.
   International Atomic Energy Agency, Vienna Austria,

8. Polska atomistyka / Polish Nuclear Science
   I. CieszykowskaK. FornalskiD. GajdaP. GajdaJ. JanczyszynS. Latek, **R. Mikołajczak, M. Rabiński,** K. Rzymkowski, M. Sobieszczak-Marciniak, T. Szreder, S. Wołkowicz, ... et al.
   Wydawnictwo Instytutu Zrównoważonej Energetyki, Kraków

9. Zarys nukleoniki
   L. Dobrzyński, Ł. Adamowski, E. Droste, M. Gąsowska, M. Kirejczyk, M. Marcinkowska-Sanner, M. Pylak, M.P. Sadowski, A. Skwarek, R. Wołkiewicz, K. Żuchowicz, ... et al.
   Polish Scientific Publisher

AUTHOR INDEX