NARODOWE CENTRUM BADAŃ JĄDROWYCH

NATIONAL CENTRE FOR NUCLEAR RESEARCH

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CONTENTS

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MAIN RESEARCH ACTIVITIES

I. Elementary particle physics, astro- & cosmic ray physics and cosmology

1. High-energy hadron-hadron interactions.
2. Elastic and inelastic μ and e interactions. Nucleon structure.
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.

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. Studies of light emitted from hot plasma jet and jets 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).

IV. Accelerators, detectors & electronics

1. Modification of surface properties of solid materials by means of continuous or pulsed ion and plasma beams.
2. R&D of linear accelerators for high-energy electrons.
3. Accelerators for hadron therapy.
4. Small electron accelerators for X-ray therapy.
5. Optimization of TiN coating processes for accelerating structures.
6. New detection methods and their application in physics experiments, nuclear medicine and homeland security.
7. Electronics for large-scale experiments in high-energy physics.
8. Systems for nuclear radiation spectroscopy.
9. 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. Technology of modifying surfaces of industrially used materials.

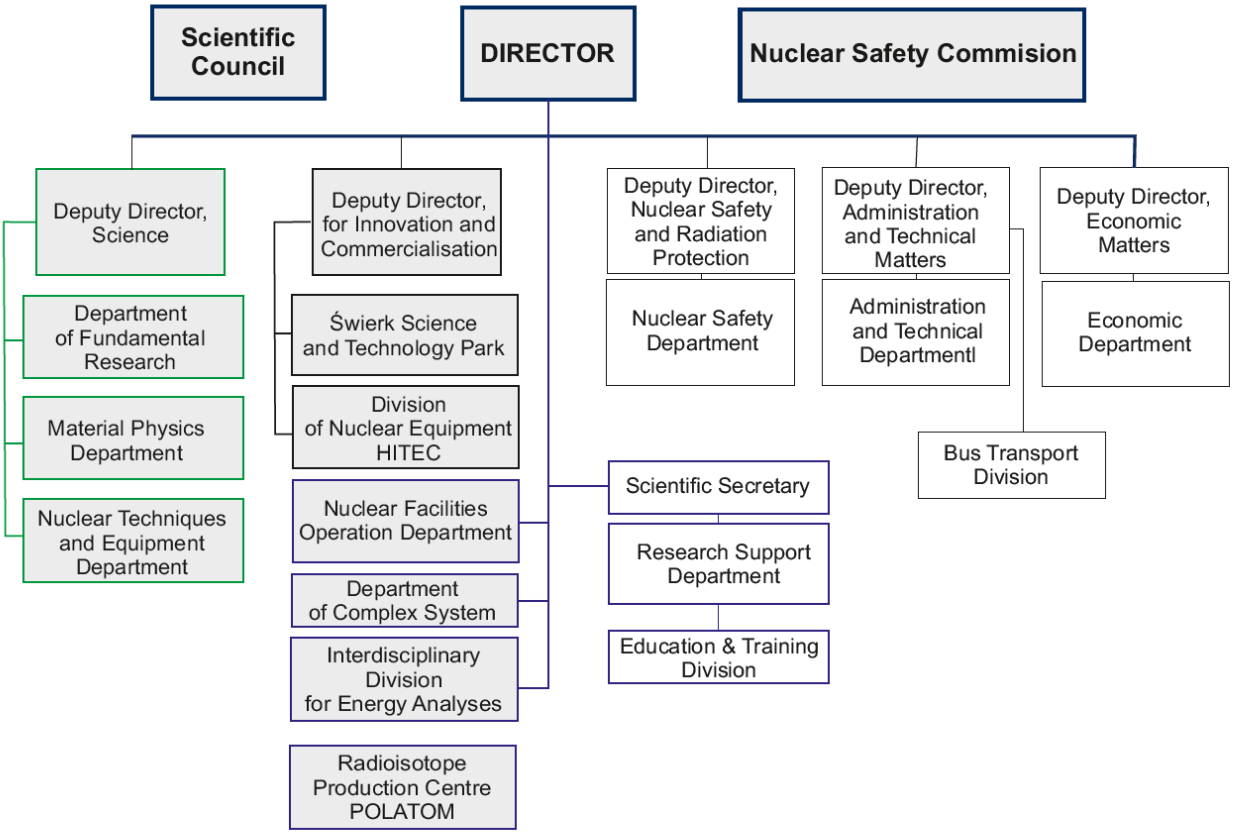
VI. Reactor physics, nuclear technology in energy generation, modelling & calculations

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

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.
6. Methods of assessment and forecasting of environmental threats from nuclear and industrial facilities.

ORGANIZATIONAL SCHEME



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(*) on leave of absence
(**) part-time employee

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1	Alamanos N.	CEA, Saclay, France	15-16.12	BP1
2	Anglart H	KTH Sweden	12.04	UZ3
3	Antinoluk T.	University of Lisbon, Portugal	07-12.10; 04-10.12	BP2
4	Baranasic B.	XFEL GmBH/DESY Hamburg	1-2.08.16	TJ4
5	Bilicki M.	Leiden University, Netherlands	18-19.10	BP4
6	Boissier S.	LAM, Marseille, France	18-23.07	BP4
7	Bonucci A.	XFEL GmBH/DESY Hamburg	1-2.08.16	TJ4
8	Boussarie R.	Universite Paris XI, Orsay, France	07-09.10; 29.09-04.10	BP2
9	Buat V.	LAM, Marseille, France	18-26.07	BP4
10	Burgarella D.	LAM, Marseille, France	18-26.07; 8-10.10	BP4
11	Capdevielle J. N.	APC, Paris-7, France	15-26.04; 17.09-01.10	BP4
12	Carrington M.	Brandon University, Canada	14.05 – 15.07	BP3
13	Choudhury A.	University of Sheffield, Great Britain	17-21.09	BP2
14	Delabrouille J.	APC, France	26-29.10	BP4
15	Deppman A.	University Sao Paolo, Brasil	27-30.06	BP2
16	Fontana C.	Padova University, Italy	20-21.10	TJ3
17	Valls-Gabaud D.	CNRS, Paris, France	19-20.10	BP4
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20	Gessler P.	XFEL GmBH/DESY Hamburg	1-2.08.16	TJ4
21	Heinl H.	Universitet Heidelberg, Germany	25.07	BP4
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23	Hennig D.	Technical University, Dresden	02.12	UZ3
24	Horowitz E.	EDF (Electricité de France), France	13-14.04	UZ3
25	Huke A.	Institut für Festkörper-Kernphysik GmbH, Berlin	15.03; 02.12	UZ3
26	Kędzierska A.	Warsaw University	1-31.07	Polatom
27	Klamra W.	Dep. of Phys. Royal Institute of Technology, Stockholm, Sweden	5-12.12	TJ3
28	Kwidzynski N.	Univeristat zu Koln, Germany	06-12.11	BP2
28	Lansberg J. P.e	Institut de Physique Nucleaire, Orsay, France	31.07–6.08; 4-10.12	BP2
30	Lapenko I.	ZIBJ Dubna	05.07	UZ3
31	Lemerrer J.	LAM, Marseille, France	8-10.10	BP4
32	Levacher P.	LAM, Marseille, France	8-10.10	BP4
33	Macian-Juan R.	Technical University, Munich	02.12	UZ3
34	Magner O.	Institute for Nuclear Research, Kiev, Ukraine	02-16.05; 03-17.09	BP2
35	Marczenko H.	Institute of Plasma Physics, Kharkov, Ukraine	07.11–02.12	TJ5
36	Melcer M.	Technical University, Warsaw	01.07.-31.07	LBM
37	Moretto S.	Padova University, Italy	20-21.10	TJ3
38	Moutarde H.	IRFU, CEA, Saclay, France	29.05-02.06	BP2
39	Peter P.	Instytut d'Astrophysique de Paris, Institut Lagrange de Paris, France	17-21.10	BP2
40	Piątkowski B.	UMCS, Lublin	01.07.-30.09	LBM
41	Poorbaygi H.	Institute of Nuclear Science and Technology Research, Atomic Energy Organization of Iran (AEOI)	14-30.11.17	Polatom
42	Riquet S.	Sodern, France	05-06.04	TJ4
43	Thomas R.	Universidad de Valparaisso, Chile	07.09-04.12	BP4
44	Romanowski S.	Technical University, Warsaw	01.09.-30.09	LBM
45	Rosiński W.	Technical University, Warsaw	01.07.-31.07	LBM
46	Rowlands G.	University of Warwick, Great Britain	24-26.09; 29.09-04.10	BP2
47	Ruprecht G.	Institut für Festkörper-Kernphysik GmbH, Berlin	02.12	UZ3
48	Samasi A.	Italy	12.11	TJ4
49	Scarpe F	Institut de Physique Nucleaire, Orsay, France	28.11-07.12	BP2

50	Starczenko B.	ZIBJ Dubna	05.07	UZ3
51	Takeuchi T.T.	Nagoya University, Japan	3-10.09	BP4
52	Vives S.	LAM, Marseille, France	8-10.10	BP4
53	Valls-Gabaud D.	CNRS, France	19-20.10	BP4

PROJECTS

RESEARCH PROJECTS IMPLEMENTED WITH THE FUNDS FOR SCIENCE

National Science Centre

1. Cosmological models testing with deep galaxy surveys
   Principal Investigator: Assoc Prof. A. Pollo
   No. 2012/07/B/ST9/04425 (OPUS 4)
2. 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 (HARMONIA 4)
3. Critical phenomena in the nuclear nonextensive systems
   Principal Investigator: J. Rożynek, PhD
   No. 2013/09/B/ST2/029897 (OPUS 5)
4. Studies on neutrino properties and proton decay with a large liquid argon detector ICARUS T600
   Principal Investigator: J. Łagoda, PhD
   No. 2012/04/M/ST2/00775 (HARMONIA 2)
5. Studies of proton-proton, hadron-nucleus and nucleus-nucleus collision at relativistic energies in NA61/SHINE experiment at CERN SPS
   Principal Investigator: Prof. J. Stepaniak
   No. 2012/04/M/ST2/00816 (HARMONIA 2)
6. The study of fundamental properties of nuclear matter in the ALICE experiment at the CERN Large Hadron Collider
   Principal Investigator: Prof. T. Siemiarczuk
   No. 2013/08/M/ST2/00598 (HARMONIA 4)
7. Study of CP symmetry breaking and search for New Physics in LHCb experiment
   Principal Investigator: Prof W. Wiślicki
   No. 2013/10/M/ST2/00629 (HARMONIA 5)
8. Study of electroweak processes involving heavy quarks and participation in LHCb detector maintenance
   Principal Investigator: prof. W. Wiślicki
   No. 2015/18/M/ST2/00123 (HARMONIA 7)
9. Multiple choice problem in quantum cosmology
   Principal Investigator: P. Małkiewicz, PhD
   No. 2013/09/D/ST2/03714 (SONATA 5)
10. Classification if z~1
    Principal Investigator: K. Małek, PhD
    No. 2013/09/D/ST9/04030 (SONATA 5)
11. Studies of CPT symmetry violation
    Principal Investigator: W. Krzemień, PhD
    No. 2014/12/S/ST2/00459 (FUGA 3)
12. Axino dark matter in scenarios with low reheating temperature of the Universe after
    Principal Investigation: S. Trojanowski, PhD
    No. 2014/13/N/ST2/02555 (PRELUDIUM 7)

13. 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. 214/13/B/ST2/02543 (OPUS 7)

14. Participation in the upkeep, data collection and data analysis of the CMS experiment at the LHC in CERN (2015-2016)
    Principal Investigator: Assoc. Prof. P. Zalewski
    No. 2014/14/M/ST2/00428 (HARMONIA 6)

15. Participation of Poland in the Advanced Virgo project
    Partner: Prof. Andrzej Królak
    No. 2014/14/M/ST9/00707 (HARMONIA 6)

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

17. 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 (OPUS 8)

18. 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 (OPUS 8)

19. The nitride semiconductor stuctures for long-lived betavoltaic nuclear batteries on galium nitride substrates with reduced of dislocations
    Principal Investigator: P. Laskowski, MSc
    No. 2014/15/D/ST7/05288 (SONATA 8)

20. T2K - the second generation neutrino experiment
    Principal Investigator: Prof. E. Rondio
    No. 2014/14/M/ST2/00850 (HARMONIA 6)

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

22. 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 (PRELUDIUM 9)

23. Indirect search for dark matter with the Super-Kamiokande detector
    Principal Investigator: K. Frankiewicz, M.Sc.
    No. 2015/17/N/ST2/04064 (PRELUDIUM 9)

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

25. 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, MSc.
    No. 2015/17/N/ST9/03556 (PRELUDIUM 9)

26. Study of electroweak procesess involving heavy quarks and participation in LHCb detector maintenance
    Partner: Prof. W. Wiślicki
    No. 2015/18/M/ST2/00123 (HARMONIA 7)

27. Study of proton-proton, hadron-nucleus and nucleus-nucleus relatyvistic collisions in theNA61/SHINE experiment at the CERN SPS - second stage
    Partner: Prof. J. Stepaniak
    No. 2015/18/M/ST2/00125 (HARMONIA 7)

28. Nuclear studies with radioactive beams at the CERN-ISOLDE laboratory
    Partner: Prof. Z. Patyk
    No. 2015/18/M/ST2/00523 (HARMONIA 7)

29. Experiment COMPASS - study of the three-dimensional and spin structure of the nucleon
    Principal Investigator: Prof. A. Sandacz
    No. 2015/18/M/ST2/00550 (HARMONIA 7)

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

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

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

33. 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
    Partner: R. Mikołajczak, Assoc. Prof
    No. 2015/19/B/NZ7/02166 (OPUS 10)

34. 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, MSc.
    No. 22015/19/N/ST9/03708 (PRELUDIUM 10)

35. 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 (ETIUDA 4)

Ministry of Science and Higher Education

1. Search for cosmological singularity resolutions by means of coherent states and with special emphasis on the ambiguity in the choice of internal clock
   Principal Investigator: P. Małkiewicz, PhD
   No. DPN/MOB132/III/2013 (2014 -.2016)

2. **GBAR -** The development and construction of an Electron Linear Accelerator for the GBAR Experiment
   Principal Investigator: S. Wronka, PhD
   No. 3399/GBAR/2015 /0 (2015-2019)

3. **SPIRIT -** Intermediate bands produced by pulsed electron melting of Ti implanted GaAs and GaP
   Principal Investigator Z. Werner, PhD
   No. 3419/SPIRIT/2015/0 (2015-2016)

4. Mobilnośc Plus – IV edycja programu
   Principal Investigator: S. Trojanowski, PhD
   No. 1309/MOB/IV/2015/0 (2016-2018)

5. **ZnOTrans –** Structural transformations in RE-ion bombarded ZnO epitaxial layers
   Principal Investigator: R. Ratajczak, PhD
   No. 3418/SPIRIT/2015/0 (2015-2016)

6. **ASAMPSA_E** - Advanced Safety Assessment: Extended PSA
Principal Investigator: M. Borysiewicz, PhD
No. 3041/7.PR EURATOM/2014/2 (2014-2016)

7. **BENICE -** Beryllium poisoning model development and experimental validation in research reactors with exploitation in MARIA and Jules Horowitz Reactor
Principal Investigator: Z.Marcinkowska, PhD
No. 3526/JHR CEA/15/2016/0 (2016-2018)

8. **QUACO -** QUAdrupoleCOrrector
Principal Investigator: P. Krawczyk, PhD
No. 328598/PnH/2016 (2016-2020)

9. **VINCO –**Visegrad Initiative for Nuclear Cooperation
Principal Investigator: Prof. J. Jagielski
No. 328538/PnH/2016 (2016-2028)

10. **BRILLIANT –** Baltic Region Initiative for Long Lasting InnovAtive Nuclear Technologies
Principal Investigator: Prof. J. Jagielski
No. 328540/PnH/2016 (2016-2018)

11. **IVMR -** In-Vessel Melt Retention Severe Accident Management Strategy for Existing and Future NPPs
Principal Investigator: E. Skrzypek, MSc.
No. 3555/H2020-EURATOM/2016/2 (2016-2019)

12. **IVMR -** In-Vessel Melt Retention Severe Accident Management Strategy for Existing and Future NPPs
Principal Investigator: E. Skrzypek, MSc.
No. 328610/PnH/2016 (2016-2019)

13. **ESS –** Monte-Carlo studies to support radiation safety studies for the ESS libac operations
Principal Investigator: M. Jarosz, MSc.
No. 3587/ESS/2016/0 (2016)

14. **C-BORD –** effective Container inspection at BORDer control points
Principal Investigator: A. Syntfeld-Każuch, PhD.
No. 328682/PnH/2016 (2016-2018)

15. **SKPLUS –** Super-Kamiokande plus
Principal Investigator: P. Mijakowski, PhD.
No. 328780/PnH/2016 (2016-2018)

16. **JENNIFER –** Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research
Principal Investigator: J. Łagoda, PhD.
No. 328686/PnH/2016 (2016-2019)

17. **EUROfusion** – Implementation of activities described in the Roadmap to Fusion during Horizon 2020 through a Joint programme of the members of the EUROfusion consortium
Principal Investigator I. Zychor, PhD.
No. 329717/PnH/2016 (2016-2018)

National Centre for Research and Development

1. **ALTECH -** Alternative methods of technetium-99m production
Applied Research Programme – programme path A
No PBS1/A9/2/2012 (2012-2016)

2. **ZNOLUM -** Light emitting photonic structures based on ZnO implanted with rare earth elements (research network leader – Institute of Physics Polish Academy of Sciences)
Applied Research Programme – programme path A
No PBS2/A5/34/2013 (2013-2017)

3. **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
No ERA-NET-TRANSCAN/01/2013 (2013-2017)

4. **ATOMSHIELD -** Trwałość i skuteczność betonowych osłon przed promieniowaniem jonizującym w obiektach energetyki jądrowej (leader - Institute of Fundamental Technological Research Polish Academy of Sciences)
Applied Research Programme – programme path A
No PBS2/A2/15/2014 (2014-2017)

5. **INTRA-DOSE -** Kompleksowy System do Radioterapii Śródoperacyjnej (leader – National Centre for Nuclear Research)
Applied Research Programme – programme path B
No PBS2/B9/26/2014 (2014-2016)

6. **RaM-scaN -** System kontrolujący skład chemiczny surowców do produkcji cementu, pracujacy w trybie ciągłym (online), oparty o neutronową analizę aktywacyjną i generator neutronów (leader – National Centre for Nuclear Research)
Applied Research Programme – programme path B
No PBS2/B2/11/2013 (2014-2016)

7. **SMOC -** Opracowanie pikselowego detektora radiograficznego w oparciu o technologię Multi-Pore-Optics (leader – Imagine RT Sp. z o.o.)
Programme INNOTECH programme path IN-TECH
No INNOTECH-K3/IN3/6/225974/NCBR/14 (2014-2016)

8. **MCAS -** Universal, multichannel control and data acquisition system (leader – National Centre for Nuclear Research)
No TANGO1/267932/NCBR/2015 (2015-2017)

9. **GRAFEL -** Zaawansowane uszczelnienia połączeń ruchomych na baize kompozytów elastromerowo-grafenowych (leader – Institute of Electronic Materials Technology)
Applied Research Programme – programme path B
No PBS3/B6/24/2015 (2015-2017)

10. **EVARIS –** Program do oceny ryzyka wystapienia awarii w obiektach przemysłowych stwarzających zagrożenie poza swoim terenem (leader – Centrum Naukowo Badawcze Ochrony Przeciwpożarowej)
Program na rzecz obronności i bezpieczeństwa państwa
No DOB-BIO7/09/03/2015 (2015-2018)

11. **PET-SKAND -** Preparation of radiopharmaceuticals based on scandium radionuclides for positron emission tomography
Applied Research Programme – programme path B
No PBS3/A9/28/2015 (2015 – 2017)

12. **BIOTECHNET** - Innovative ^{99}Mo/^{99m}Tc technetium generator with microporous sorbent, chitosan based, using ^{99}Mo molybdenum, designed for use in isotope diagnostics
No STRATEGMED2/269080/8/NCBR/2015 (2015 – 2018)

RESEARCH PROJECTS GRANTED BY FOREIGN INSTITUTIONS

1. **IAEA -** Nanosized Delivery Systems for Radiopharmaceuticals
Principal Investigator: M. Maurin, MSc.
IAEA No. 18475/R0 (2014-2017)

2. **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
AEA No 18869 (2015 – 2018)

3. **IAEA -** Therapeutic Radiopharmaceuticals Labelled with New Emerging Radionuclides (67Cu, 186Re, 47Sc) in Poland"
Principal Investigator: R. Mikołajczak, PhD
IAEA No 20496 (2016 – 2019)

4. **CERN –** The development and construction of an Electron Linear Accelerator for the GBAR Experiment
Principal Investigator: S. Wronka, PhD
GBAR 2545/DG (2014-2019)

5. **CEA –** 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)

6. **ESS –** Monte-Carlo studies to support radiation safety studies for the ESS libac operations
Principal Investigator: M. Jarosz, MSc.
ESS_MC 23000595 (2016)

7. **ZnOTrans –** Structural transformations in RE-ion bombarded ZnO epitaxial layersPrincipal Principal
Principa Investigator: R. Ratajczak, PhD
HZDR 15100222 – ST (2015-2016)

8. **SPIRIT -** Intermediate bands produced by pulsed electron melting of Ti implanted GaAs and GaP
Principal Investigator Z. Werner, PhD
HZDR 15100298 (2015-2016)

9. **CERN** Contract KE3291/00 01-10-2016
Principal Investigator: D. Stefan, PhD
CERN KE3291/RCS (2016-2019)

10. **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)

RESEARCH PROJECTS CO-FINANCED BY 7TH FRAMEWORK PROGRAMME, HORIZON 2020

1. **ASAMPSA_E** - Advanced Safety Assessment: Extended PSA
(7PR)Contract No. 605001 (2013-2016)

2. **ARCADIA -** Assessment of Regional CApabilities for new reactors Development through an Integrated Approach
(7PR)Contract No. 605116 (2013-2016)

3. **EuCARD-2 -** Enhanced European Coordination for Accelerator Research & Development
(7PR)Contract No. 312453 (2013-2017)

4. **TAWARA_RTM** - TAP WATER RADIOACTIVITY REAL TIME MONITOR
(7PR)Contract No. 312713 (2013-2016)

5. **ESNII plus -** Preparing ESNII for HORIZON 2020
(7PR)Contract No. 605172 (2013-2017)

6. **JENNIFER –** Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research
(H2020)Contract No. 644294 (2015-2019)

7. **SKPLUS –** Super-Kamiokande plus
(H2020)Contract No. 641540 (2015-2019)
8. **C-BORD –** effective Container inspection at BORDer control points
(H2020)Contract No. 653323 (2015-2018)

9. **VINCO –** Visegrad Initiative for Nuclear Cooperation
(H2020)Contract No. 662136 (2015-2018)

10. **BRILLIANT –** Baltic Region Initiative for Long Lasting InnovAtive Nuclear Technologies
(H2020)Contract No. 662167 (2015-2018)

11. **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)

12. **OPERRA –** Open Project for the European Radiation Research Area
(7PR)Contract No. 604984 (2013-2017)

13. **IVMR -** In-Vessel Melt Retention Severe Accident Management Strategy for Existing and Future NPPs
(H2020)Contract No. 604984 (2015-2019)

14. **QUACO -** QUAdrupoleCOrrector
(H2020)Contract No. 689359 (2016-2020)

COST ACTIONS

1. **COST CM1105** - Functional metal complexes that bind to biomolecules (2012 – 2016)

2. **COST CM1207** - GLISTEN: GPCR – Ligand Interactions, Structures and Transmembrane Signalling: a European Research Network. (2015-2017)

3. **COST BM1403** - Native Mass Spectrometry and Related Methods for Structural Biology (2014-2018).

PARTICIPATION IN NATIONAL CONSORTIA AND SCIENTIFIC NETWORKS

	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	Warsaw Science Consortium	G. Wrochna/M. Juszczyk
9	Polish Synchrotron Consortium	R. Nietubyć
10.	Consotrium EAGLE	J. Skalski

11	National Consortium 'PL-TIARA'	S. Wronka
12*	National Consortium 'COMPASS-PL'	A. Sandacz
13.*	National Consortium 'NEUTRINA-T2K'	E. Rondio
14.	National Consortium 'HADRONY-NA61/SHINE'	J. Stepaniak
15.	Polis Consortium VIRGO	A. Królak
16.	Consortium "Polish Particle Physics"	E. Rondio
17.	Polish Consortium ALICE-PL	T. Siemiarczuk
18.	Consortium ISOTTA	J. Szabelski
19.	Consortium NEUTRINA – ICARUS T600	E. Rondio
20.	Consortium ELA-MAT Polska	G. Wrochna
21.	Consortium CMS-Polska	P. Zalewski
22.	Consortium Polska@ISOLDE	Z. Patyk
23.	Consortium "E-RIHS PL"	E. Miśta
24.	Consortium "LHCb – PL" and "LHCb-PL-Upgrade"	W. Wiślicki
25.	Consortium "ELI-Polska"	A. Malinowska
26.	Consortium on "Cherenkov Telescope Array" Project	L. Roszkowski
27.	Scientific-Industrial Centre New Energetic Technologies	J. Rzadkiewicz, J. Żebrowski

	SCIENTIFIC NETWORKS:	**Institute representative:**
1.*	Polish Astroparticle Physics Network	G. Wrochna
2.*	Polish Neutrino Physics Network	E. Rondio
3.	Polish Nuclear Physics Network	G. Wrochna
4.	Polish Network of Physics of Relativistic Ion Collisions	St. Mrówczyński
5.	Polish Network of Neutrons-Emission-Detection	J. Szydłowski
6.	Polish Network of Neutron Scatterers (NeutroNET)	L. Dobrzyński
7.	Polish Network of Radiation Protection and Nuclear Safety	L. Dobrzyński

* Coordinator: NCBJ

DEGREES

Habilitation

1. *Paweł Sobkowicz:* (National Centre for Nuclear Research)
   “Modelling of the processes of opinion and emotion changes in various social environments, using methods of statistical physics and multi-agent dynamics”

PhD theses

1. *Paweł Sibczyński* (National Centre for Nuclear Research)
   “Photofission of nuclear materials and fission signatures detection with application in border monitoring”

2. *Joanna Iwanowska-Hanke* (National Centre for Nuclear Research)
   “The comparative studies of neutron detectors in the crisis of ^{3}He supply”

3. *Katarzyna Deja* (National Centre for Nuclear Research)
   ”Patron’s Energy loss in unstable quark-gluon plasma”

4. *Edyta Jakubowska* (National Centre for Nuclear Research)
   ”Microdosimetric recombination methods for mixed radiation fields monitoring in radiotherapy facilities”

5. *Krzysztof Pyszniak* (UMCS)
   ”Wykorzystanie zjawisk towarzyszących bombardowaniu jonowemu w diagnostyce procesu implementacji”

6. *Adam Szabelski* (NCBJ PhD student)
   ”The gluon contribution to the Sivers effect measurement ar the COMPASS experiment”

7. *Władysław Surała* (NCBJ PhD student)
   ”Badania wiązek elektronowych i promieniowania rentgenowskiego w układach typu Plasma-Focus”

DEPARTMENTS AND DIVISIONS OF THE INSTITUTE

NUCLEAR FACILITIES OPERATION DEPARTMENT

Director of Department: Grzegorz Krzysztoszek, MSc Eng
Phone: +48 22 273 10 80
e-mail: Grzegorz.Krzysztoszek@ncbj.gov.pl

Overview

In 2016 the MARIA Research Reactor was operational for 4862 hours with power varying between 18 and 25 MW. The reactor was used for irradiation of materials for radioisotope production requested by OR Polatom (Radioisotopes Centre Polatom) and Mallinckrodt Pharmaceuticals. It was also used for physical examinations at the outlets of the horizontal channels.

Due to the planned withdrawal of highly enriched (HEU) targets used for molybdenum production, at the turn of September and October 2016 a test irradiation of low enriched targets (LEU) was performed. This irradiation was preceded by physical and thermo-hydraulic calculations, upon which the appropriate permission of the President of the NAEA was granted. As expected, the specific activities of Mo-99 obtained were about 20% lower compared to HEU targets.

In the past year irradiation of target materials for RC Polatom was very intense, dominated by materials such as: TeO_2, KCl, $LuCl_3$, S, Yb_2O_3, Sm_2O_3 etc.

Under the international Global Threat Reduction Initiative programme, the last batch of highly enriched spent nuclear fuel (51 pcs.) was sent from the MARIA reactor to the Russian Federation. This time, due to air transport from Polish territory to the Russian Federation, the spent fuel elements were specially protected, i.e. encapsulated in sealed containers.

During the reactor operation only 2 unplanned shutdowns were recorded. They did not affect the 2016 work schedule. Releases of radioactive substances were minor and amounted to 0.9 % of the limit for noble gases and 0.5 % for iodine.

Grzegorz Krzysztoszek

MARIA REACTOR OPERATIONS DIVISION

Head of Division: Andrzej Gołąb, MSc Eng

Phone: +48 22 2731088

e-mail: a.golab@ncbj.gov.pl

REPORTS

Safety Analysis of MR Type Spent Fuel Shipment in 2016 from MARIA Reactor to Russian Federation in TUK-19 Cask
E. Borek-Kruszewska, **J. Lechniak**, **K. Pytel**
NCBJ, Report No B-13/2016

Planning of an irradiation campaign in the MARIA reactor for electrical heaters and radiation sensors
R. Prokopowicz, ... , **K. Pytel**, **M. Tarchalski**, **G. Madejowski**, **M. Dorosz**, **T. Witkowski**, **A. Małkiewicz**, **I. Wilczek**, **A. Zawadka**, **M. Lipka**, **P. Nowakowski**, **K. Szewczak**, ... et al.
NCBJ, Świerk

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Self-Assessment as a Tool for Research Reactor Safety
A. Gołąb
Workshop on Self-Assessment of Research Reactor Safety (Austria, Wiedeń, 2016-02-22 - 2016-02-26)

Self-Assessment as a Tool for Research Reactor Safety
A. Gołąb
Workshop on Self-Assessment of Research Reactor Safety (Austria, Wiedeń, 2016-02-22 - 2016-02-26)

Self-Assessment as a Tool for Research Reactor Maria Safety Improuvement
A. Gołąb
Workshop on Self-Assessment of Research Reactor Safety (Austria, Wiedeń, 2016-02-22 - 2016-02-26)

Application of a Graded Approach in the Safety Requirements for Polish Research Reactor Maria
A. Gołąb
Technical Meeting on Use of a Graded Approach in the Application of the Safety Requirements for Research REactors (Austria, Wiedeń, 2016-05-23 - 2016-05-27)

Fission neutrons for fusion applications - fusion researches in the MARIA nuclear reactor
R. Prokopowicz, **K. Pytel**, **M. Dorosz**, **A. Zawadka**, **J. Lechniak**, **M. Lipka**, **Z. Marcinkowska**, **M. Wierzchnicka**, **A. Małkiewicz**, **I. Wilczek**, **T. Krok**, **M. Migdal**, **A. Kozieł**, **A. Gołąb**, **K. Grzenda**
Italy –Poland 5th Workshop Jointly organized by IPPLM and NCBJ (Poland, Otwock-Świerk, 2016-07-14 - 2016-07-15)

Current and future utilisation of MARIA reserach reactor
G. Krzysztoszek
European Research Reactor Conference - RRFM/IGORR 2016 (Germany, Berlin, 2016-03-13 - 2016-03-17)

The results of spent LEU fuel sipping tests after conversion in MARIA reactor
G. Krzysztoszek

The 10-th Technical Meeting on Lessons Learned from the RRRFR Programme (USA, Charlston, South Carolina, 2016-06-20 - 2016-06-23)

Conversion of MARIA research reactor from HEU to LEU fuel
G. Krzysztoszek
International Conference on Nuclear Security: Commitments and Actions (Austria, Vienna, 2016-12-05 - 2016-12-09)

LECTURES, COURSES AND EXTERNAL SEMINARS

Status report and future of MARIA research reactor[b]
G. Krzysztoszek
Vienna , International Atomic Energy Agency, 2016-01-27

[b)] in English

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

G. Krzysztoszek
Deputy Chairman of Council for Nuclear Safety and Radiation Protection, National Atomic Energy Agency

PERSONNEL

Research and technical staff

Krzysztof Majchrowski
Rober Marczak
Adrian Michalski
Dariusz Mucha
Paweł Nowakowski, MSc Eng
Ireneusz Owsianko, MSc Eng
Mariusz Ostanek
Krzysztof Sierański
Wiesław Sikorski
Stefan Skorupa
Mieczysław Skwarczyński
Ryszard Stanaszek, MSc Eng
Jan Suchocki
Piotr Szaforz, MSc Eng
Paweł Święch
Piotr Witkowski, Eng
Tomasz Witkowski, Eng
Paweł Wojtczuk
Marcin Wójcik
Jarosław Zienkiewicz, MSc Eng
Krzysztof Żołądek

Technical staff

Marian Bąk
Sylwester Bąk
Regina Bąk
Zdzisław Bąk
Bolesław Broda
Wiesław Ćwiek
Jadwiga Dąbrowska
Cezary Dąbrowski
Andrzej Frydrysiak, MSc Eng
Marcin Gadoś
Andrzej Gołąb, MSc Eng
Kazimierz Grzenda
Ireneusz Hora
Magdalena Hajdacka
Jacek Idzikowski, MSc Eng
Ireneusz Iwański, Eng
Tomasz Jaworski
Krzysztof Jezierski, MSc Eng
Dariusz Krawczyński
Waldemar Kultys
Edward Kurdej
Dariusz Kwiatkowski
Rober Laskus
Franciszek Lech
Jan Lechniak, MSc Eng
Krzysztof Lechnik
Alina Łysiak
Halina Majszczyk
Mateusz Łysiak
Jan Macios
Mariusz Pietrasik
Piotr Pytlarczyk
Stefan Rosłaniec
Angelika Szmyd

REACTOR RESEARCH AND TECHNOLOGY DIVISION

Head of Division: Janusz Jaroszewicz, MSc Eng

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Overview

The Reactor Research and Technologies Division has 33 employees including researchers (5 with a PhD degree), engineers and technicians. The new organisation of the Division was established in 2016 and includes 5 Groups:

- 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 was support of the MARIA Reactor Operation Division in safety operations for the reactor and irradiation facilities. In 2016 the division's activities were strongly related to support of new programmes dedicated to full utilisation of the MARIA rector, mainly for irradiation of targets used as radioactive sources in nuclear medicine. The research and development conducted are primarily oriented towards applications and lead to the implementation of innovative irradiation technologies. Recently the Division has launched new irradiation technology for different uranium targets used for 99Mo production. The Division's activities cover safety analyses, numerical calculations and 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 with foreign institutions taking part in international projects and research programmes. Among these are collaboration with such institutions as CEA, ANL, CCFE and others. The collaboration with academic institutions was concerned with organising and providing training for students (Technical University of Warsaw).

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

- safety analyses and numerical calculations;
- reactor measurements: neutron parameters (activation measurements, SPND), gamma heating / dose rate (calorimeters, ionisation 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);
- operational measurements, e.g. reactivity measurements of control rods, temperature reactivity coefficient measurements;
- failed fuel detection system (control and data acquisition, processing);
- experiments and completed monitoring software;
- design and manufacture of new elements and facilities for reactor operation systems and for irradiation facilities;
- technology of irradiation of materials for radioisotope production in cooperation with the Radioisotope Centre Polatom; in addition the production of ^{192}Ir seeds used for Intravascular Radiation Therapy and low activity ^{192}Ir source ribbon for oncology applications and recently neutron irradiation of ^{165}Ho-PLLA Microspheres (radioembolisation of the liver);

Janusz Jaroszewicz

REPORTS

Safety Analysis of MR Type Spent Fuel Shipment in 2016 from MARIA Reactor to Russian Federation in TUK-19 Cask
E. Borek-Kruszewska, **J. Lechniak**, **K. Pytel**
NCBJ, Report No B-13/2016

Geometry of the MARIA reactor core
K. Pytel, **G. Madejowski**, **A. Małkiewicz**, **R. Prokopowicz**, **Z. Przybysz**, **M. Tarchalski**, **M. Wierzchnicka**
Department of Research and Technology reactor EJ3 NCBJ, Otwock

Report on the encapsulation of MR type spent fuel for VIII shipment from MARIA research reactor to Russian Federation in 2016.
E. Borek-Kruszewska, **J. Piąstka**, **R. Keler**, **I. Wilczek**, **A. Zawadka**
NCBJ, Report nr B-19/2016

Origins and production of silver objects in Early Medieval Poland
E. Miśta, ... , **A. Turos**, **A. Gójska**, **M. Dorosz**, ... et al.
Annual Report NCBJ 2015, Otwock-Świerk

Quality Assurance Program for MR Type Spent Fuel Shipment in a TUK-19 Container from the MARIA Reactor to the Russian Federation in brief PZJ WYWOZ_MR_2016
E. Borek-Kruszewska, **J. Piąstka**
NCBJ-Report No B-15/2016

Planning of an irradiation campaign in the MARIA reactor for electrical heaters and radiation sensors
R. Prokopowicz, ... , **K. Pytel**, **M. Tarchalski**, **G. Madejowski**, **M. Dorosz**, **T. Witkowski**, **A. Małkiewicz**, **I. Wilczek**, **A. Zawadka**, **M. Lipka**, **P. Nowakowski**, **K. Szewczak**, ... et al.
NCBJ, Świerk

Report of the IAEA Technical Meeting on Role of Research Reactors in providing support to Nuclear Power Programmes.
A. BoriodiTigliole, ... , **M. Lipka**, ... et al.
IAEA, Vienna, Austria

Results of Inspection of MARIA Research Reactor Spent Fuel Assemblies to be Transported to the Russian Federation in 2016
E. Borek-Kruszewska, **J. Piąstka**, **I. Wilczek**, **A. Zawadka**
NCBJ, Report No B-10/2016

Report of the MR Type Spent Fuel Shipment from MARIA Research Reactor to Russian Federation in 2016 (VIII Shipment).
E. Borek-Kruszewska, **J. Piąstka**, **R. Keler**, **A. Małkiewicz**, **I. Wilczek**, **A. Zawadka**
NCBJ

Technology of MR Type Spent Fuel Encapsulation for Shipment in 2016
E. Borek-Kruszewska, **J. Piąstka**, **Z. Przybysz**, **M. Wierzchnicka**, **I. Wilczek**, **A. Zawadka**
NCBJ, Report No C-11/2016

Technology of MR Type Spent Fuel Shipment in 2016 from MARIA Reactor to Russian Federation in TUK-19 Cask Technological Documentation No EJ3/1/2016
E. Borek-Kruszewska, **J. Piąstka**, **Z. Przybysz**, **M. Wierzchnicka**, **I. Wilczek**, **A. Zawadka**
NCBJ-Report No C-14/2016

Subtask ENS-4.4.1.1-T10-03 Concept of STUMM, pre-selection of instrumentation : Review of available sensors and commercial availability
M. Gierlik, **R. Kwiatkowski**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**, **I. Zychor**
Madrid (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Fission neutrons for fusion applications - fusion researches in the MARIA nuclear reactor
R. Prokopowicz, **K. Pytel**, **M. Dorosz**, **A. Zawadka**, **J. Lechniak**, **M. Lipka**, **Z. Marcinkowska**, **M. Wierzchnicka**, **A. Małkiewicz**, **I. Wilczek**, **T. Krok**, **M. Migdal**, **A. Kozieł**, **A. Gołąb**, **K. Grzenda**
Italy –Poland 5th Workshop Jointly organized by IPPLM and NCBJ (Poland, Otwock-Świerk, 2016-07-14 - 2016-07-15)

Molybdenum-99. Production in Polish Research Reactor MARIA. Current Status and Development
J. Jaroszewicz
8th International Symposium on Material Testing Reactors, Sydney, Australia, October 2016 (Australia, Sydney, 2016-10-28 - 2016-10-30)

Oral Presentation

Neutronic Characteristics of PWR Core with Accident Tolerant Fuel
A. Boettcher, **Z. Marcinkowska**
European Nuclear Conference (Poland, Warszawa, 2016-10-09 - 2016-10-13)
European Nuclear Society, Brussels, Belgium No. (2016) p. 19-24

Development of the GEM-based SXR tomography:current status
M. Chernyshova, T. Czarski, K. Malinowski, E. Kowalska-Strzęciwilk, S. Jabłoński, B. Bieńkowska, **R. Prokopowicz**, A. Ziółkowski, S. Jednoróg, W. Figacz, K. Poźniak, G. Kasprowicz, W. Zabołotny, A. Wojeński, P. Zienkiewicz, R. Krawczyk, P. Kolasiński, M. Polasik, K. Słabkowska, Ł. Syrocki, D. Mazon, F. Faisse, J.M. Verger, C. Coston, A. Jardin, P. Malard, S. Larroque, D. Vezinet, S. Eder, A. Herrmann
Italy –Poland 5th Workshop Jointly organized by IPPLM and NCBJ (Poland, Otwock-Świerk, 2016-07-14 - 2016-07-15)

The Idea of Using Heat from Maria reactor as a Heat Source for Heat Pump
M. Lipka, **M. Migdal**, **M. Tarchalski**
3rd Research Coordination Meeting on Application of Advanced Low Temperature Desalination Systems to Support Nuclear Power Plants and Non-electric Applications (Austria, Wiedeń, 2016-11-27 - 2016-12-30)

Country Presentation - Poland
M. Lipka
IAEA Technical Meeting on Role of Research Reactors in Providing Support of Nuclear Power Programmes. (Austria, Wiedeń, 2016-06-21 - 2016-06-24)

Poster

Long-lived radionuclide activity formed in ITER steel composites in 6Li-D converter neutron field
W. Pohorecki, P. Jodłowski, **K. Pytel**, **R. Prokopowicz**
29th Symposium on Fusion Technology (SOFT 2016) (Czech Republic, Prague, 2016-09-05 - 2016-09-09)
Fusion Eng. Des. (2016)

STUMM Test module for a high intensity neutron stripping
W. Wiacek, A. Igielski, B. Gabanska, **M. Gierlik**, **R. Kwiatkowski**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**, **I. Zychor**
Zakopane Conference on Nuclear Physics (Poland, Zakopane, 2016-08-28 - 2016-09-04)

Circumstances Surrounding Switch between MC003 and MR123/08 Fuel Elements (Experimental Verification of MARIA Core Numerical Models)
M. Migdal, **M. Tarchalski**
RERTR-2016 - 37th International Meeting on Reduced Enrichment for Research and Test Reactors (Belgium, Antwerpen, 2016-10-23 - 2016-10-27)

USAGI 1-D thermohydraulic code
M. Lipka
European Nuclear Conference ENC-2016 (Poland, Warsaw, 2016-10-09 - 2016-10-13)

LECTURES, COURSES AND EXTERNAL SEMINARS

Research Reactor MARIA. Security of nuclear fuel supply[b]
J. Jaroszewicz
Paris, Commissariat a l\'Energy Atomique (CEA), 2016-04-25

[b)] in English

INTERNAL SEMINARS

Research Reactor MARIA[a]
Z. Marcinkowska
Warsaw, University of Warsaw, Faculty of Physics, 2016-01-07

Thermal-flux Investigations Performed in WIW-300 Test Facility[a]
E. Borek-Kruszewska
NCBJ, NCBJ, 2016-06-29

Reactor Accidents caused by human error or natural causes[a]
M. Lipka
Otwock-Świerk, National Centre for Nuclear Research, 2016-10-11

Temperature coefficient of reactivity.[a]
M. Lipka
Otwock-Świerk, National Centre for Nuclear Research, 2016-11-23

Blocking of coolant flow in a fuel channel, course for Iranian Interns[b]
M. Migdal
Otwock-Świerk, National Centre for Nuclear Research, 2016-12-06

Nuclear Reactor Accidents caused by human error or natural causes, course for Iranian Interns[b]
M. Lipka
Otwock-Świerk, National Centre for Nuclear Research, 2016-12-09

[a)] in Polish
[b)] in English

DIDACTIC ACTIVITY

E. Borek-Kruszewska - Lectures during the R-O type course of reactor operators and shift managers

M. Dorosz - Exercise of the neutron flux measurements for the students of the Faculty of Physics, Warsaw University of Technology, 15 I 2016

M. Dorosz - Exercise of the neutron flux measurements for the students of the Faculty of Physics, Warsaw University of Technology, 2 XII 2016

M. Dorosz - Exercise of the neutron flux measurements for the students of the Institute of Heat Engineering, Warsaw University of Technology, 10 VI 2016

M. Dorosz - Exercise of the neutron flux measurements for the students of the Institute of Heat Engineering, Warsaw University of Technology, 21 I 2016

J. Jaroszewicz - Lecture for reactor MARIA operation staff. Reactor Physics and Research and Production Utilization of Reactor MARIA.

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

M. Lipka - Supervision of the Student Engineering Project "Structural analysis of the irradiation tube for the humid concrete samples" in the Faculty of Power and Aeronatical Engineering, Warsaw University of Technology

Z. Marcinkowska - Measurement of temperature coefficients in the MARIA nuclear reactor.

M. Migdal - Running classes out of Theory of Heat Machines at the Faculty of Power and Aeronautical Engineering, Warsaw University of Technology

R. Prokopowicz - Auxiliary supervisor,
Nuclear heating measurements in the MARIA reactor and implementation of neutron and photon calculation scheme,
Eng. Mikołaj Tarchalski, MSc,
National Centre for Nuclear Research,
AixMarseille Université,
Commissariat à l'énergie atomique

R. Prokopowicz - The lectures on reactor physics in the course of the R-O-type course for the MARIA reactor operators

R. Prokopowicz - The measurement of tritium release from nuclear reactor, University of Warsaw

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

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

Z. Marcinkowska
NCBJ Scientific Council

PERSONNEL

Research scientists
Zuzanna Marcinkowska, PhD
Krzysztof Pytel, PhD
Rafał Prokopowicz, PhD Eng
Mikołaj Tarchalski, MSc Eng

Rersearch-technical staff
Elżbieta Borek-Kruszewska, PhD Eng
Janusz Jaroszewicz, MSc Eng
Małgorzata Wierzchnicka, MSc Eng

Technical and administrative staff
Wiesława Bąk
Wacław Czajka
Michał Dorosz, MSc
Marcin Januchta MSc Eng
Ryszard Góralski
Danuta Kaczyńska
Robert Keler
Alina Kozieł, MSc
Jadwiga Kurdej
Maciej Lipka, MSc Eng
Tomasz Machtyl, MSc Eng
Adam Małkiewicz, Eng
Marek Migdal, MSc Eng
Janusz Piąstka, MSc Eng
Jerzy Polak, MSc Eng
Zbigniew Przybysz
Beatrycze Pytel, MSc
Elżbieta Sobiech
Bogdan Święch
Wiesław Wróbel
Emil Wilczek, MSc
Ireneusz Wilczek
Janusz Wilczek
Mieczysław Wójcik
Zbigniew Zduńczyk
Antoni Zawadka
Adam Żurawski

RADIATION PROTECTION MEASUREMENTS LABORATORY (LPD)

Head of Division: Tomasz Pliszczynski, MSc Eng
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Overview

The activities of the Radiation Protection Measurements Laboratory are focused on environmental monitoring and assessment of the radiation exposure of people. 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 in section 1o)
- Setting up a neutron station at the MARIA reactor (described below in section 2o) – internal project "Neutrony H2".

In 2016 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 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 six PhDs, three graduate physicists and one engineer.

1. The main subjects of scientific studies concern:

- 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;
- 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 under pressures up to 5 MPa;
- Metrology of mixed radiation fields (including pulsed and high energy fields);
- Neutron dosimetry in a wide energy spectrum (passive neutron spectrometry)
- Verification of installed dosimetry systems (medical applications);
- Child and Adult Thyroid Monitoring After Reactor Accident CAThyMARA project carried out within the framework of the Open Project for the European Radiation Research Area OPERRA 2014;
- High sensitivity gamma spectroscopy of radionuclide concentrations in ambient air, spectroscopy of radioactive sources and neutron activated materials;
- Radiological measurements of soils from polar regions;
- Radiological survey of meteorites;
- Developing the concept of absorbed dose distribution assessment based on PET and SPECT imaging, computer simulations and Monte Carlo calculations for SIRT therapy;
- Shield testing: testing concrete samples for radiation shielding.

2. The second form of activity was dedicated to forming a research-training stand at the MARIA reactor:

- Constructing a uranium neutron converter for a dense neutron beam (109 n cm-2s-1);
- 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) – filter/moderator, shutter, shielding;
- Forming frames for the new Laboratory for Biomedical Research based on international collaboration. The research work was partly financed by research grants from the Polish Ministry of Science and Higher Education and from the National Centre for Research and Development (Poland);

Tomasz Pliszczyński

REPORTS

Geometry of the MARIA reactor core
K. Pytel, **G. Madejowski**, **A. Małkiewicz**, **R. Prokopowicz**, **Z. Przybysz**, **M. Tarchalski**, **M. Wierzchnicka**
Department of Research and Technology reactor EJ3 NCBJ, Otwock

Assessment of the condition of radiological protection in the territory and in the vicinity of the National Radioactive Waste Repository in Różan, 2015.
T. Pliszczyński, **M. Dymecka**, **M. Feczko**, **Z. Haratym**, **B. Snopek**, **W. Śniegoń**, **D. Zielińska**
NCBJ

Estimation of radiological protection on the territory of Nuclear Centre Świerk and its vicinity (2015).
B. Filipiak, ... , **Z. Haratym**, **J. Ośko**, **T. Pliszczyński**, **B. Snopek**, **B. Boimski**, **S. Domański**, **M. Dymecka**, **R. Ejsmont**, **M. Feczko**, **A. Garboliński**, **B. Karpińska**, **A. Pawełczuk**, **B. Piotrkowicz**, **K. Rzemek**, **R. Sosnowiec**, **W. Śniegoń**, **M. Prusińska**, **M. Umaniec**, **K. Wiśniewska**, **K. Wojdowska**, **J. Wojnarowicz**, **Z. Worch**, **D. Zielińska**, ... et al.
National Centre for Nuclear Research

Planning of an irradiation campaign in the MARIA reactor for electrical heaters and radiation sensors
R. Prokopowicz, ... , **K. Pytel**, **M. Tarchalski**, **G. Madejowski**, **M. Dorosz**, **T. Witkowski**, **A. Małkiewicz**, **I. Wilczek**, **A. Zawadka**, **M. Lipka**, **P. Nowakowski**, **K. Szewczak**, ... et al.
NCBJ, Świerk

IPPLM contribution to preliminary engineering design of irradiated materials and dismantling, project ENS, subtask ENS-4.1.2.0-T1-02, Document Id.:ENS-4.1.2.0-T1-02N1
J. Szewiński, **I. Petrenko**, **K. Szewczak**
EuroFusion, https://idm.euro-fusion.org/, Report IDM Ref. No.:2MSRJJ (in press)

IPPLM contribution to preliminary systems definition of DONES Liquid Radioactive Waste Treatment System (L-RWTS). Subtask ENS-3.4.2.0-T7-07-N1.
K. Szewczak, **M. Maciak**, **Ł. Bartosik**, **A. Burakowska**, **S. Domański**
Euro-fusion, Power Plant Physics & Technology, Report IDM (in press)

Management strategies and treatment technologies for Li, NaK and T contaminated wastes. Subtask ENS-3.4.1.0-T11-06.
K. Szewczak, **M. Maciak**, **Ł. Bartosik**, **A. Burakowska**, **S. Domański**
Euro-fusion, Power Plant Physics & Technology, Report IDM , 2016 (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Badanie osłonności radiacyjnej betonów specjalnych
A. Burakowska, **M. Maciak**, **Ł. Murawski**, **S. Domański**, **M.A. Gryziński**
62. Konferencja Naukowa Komitetu Inżynierii Lądowej i Wodnej PAN (KILiW PAN) i Komitetu Nauki PZITB (KN PZITB) (Poland, Krynica Zdrój, 2016-09-11 - 2016-09-16)
Czasopismo Inżynierii Lądowej Vol. XXXIII No 63 (2016) 87-96

Konfiguracja wiązki neutronowej
K. Tymińska
II warsztat BNCT (Poland, Wrocław, 2016-02-22 - 2016-02-23)

Heat exchange modelling in uranium fuel assembly – operating pressure case.
M. Wielgosz, **T. Kwiatkowski**, **P. Prusiński**, **D. Zgorzelski**
European Nuclear Conference ENC-2016 (Poland, Warsaw, 2016-10-09 - 2016-10-13)

Oral Presentation

Early Measurements of General Publicafter the Fukushima Daiichi NPP accident, EURADOS WG7 Survey
P. Fojtík, M.A. Lopez, D. Franck, **J. Ośko**, **T. Pliszczyński**
14th Congress of the IRPA (South Africa, Cape Town, 2016-05-09 - 2016-05-13)

Poster

Oznaczanie aktywności Am-241 w próbkach moczu
K. Rzemek, A. Czerwiński, **J. Ośko**, **T. Pliszczyński**
VII Krajowa Konferencja Radiochemii i Chemii Jądrowej (Poland, Lublin, 2016-04-17 - 2016-04-20)

Determination of Pu-238, Pu-(239+240) and Am-241 in air filters
K. Rzemek, A. Czerwiński, **J. Ośko**, **T. Pliszczyński**
International Conference on Radioanalytical and Nuclear Chemistry RANC-2016 (Hungary, Budapest, 2016-04-10 - 2016-04-15)

Development of a method of tritium activity determination in water samples by electrolytic enrichment
M. Dymecka, **K. Rzemek**, **T. Pliszczyński**, **J. Ośko**
International Conference on Radioanalytical and Nuclear Chemistry RANC-2016 (Hungary, Budapest, 2016-04-10 - 2016-04-15)

Zastosowanie dwóch metod oznaczania aktywności ^{210}Po w próbkach moczu.
M. Prusińska, **M. Dymecka**, **K. Rzemek**, **T. Pliszczyński**
VII Krajowa Konferencja Radiochemii i Chemii Jądrowej (Poland, Lublin, 2016-04-17 - 2016-04-20)

Analiza metod oznaczania Ra-226 oraz Ra-228 w wodzie pitnej.
Ł. Bartosik, **T. Pliszczyński**, **M. Dymecka**, **K. Rzemek**, **M. Prusińska**
VII Krajowa Konferencja Radiochemii i Chemii Jądrowej (Poland, Lublin, 2016-04-17 - 2016-04-20)

Wzorce referencyjne o niestandardowych geometriach do pomiaru aktywności radionuklidów w przemyśle i środowisku
Z. Tymiński, **T. Dziel**, **A. Listkowska**, **R. Broda**, **E. Kołakowska**, **P. Saganowski**, **E. Lech**, **D. Cacko**, **A. Jęczmieniowski**, **T. Ziemek**, **M. Nowicka**, **J. Wojnarowicz**, **R. Sosnowiec**, **K. Tymińska**
VII Krajowa Konferencja Radiochemii i Chemii Jądrowej (Poland, Lublin, 2016-04-17 - 2016-04-20)

^{60}Co isotope content in iron meteorites
Z. Tymiński, **A. Burakowska**, **K. Tymińska**, A. Olech, M. Stolarz, P. Żołądek, M. Wiśniewski
79th Annual Meeting of the Meteoritical Society (Germany, Berlin, 2016-08-07 - 2016-08-12)
MAPS, Wiley No.51(S1) (2016)

"Neobor" – European/international scientific network for BNCT research and medical training at MARIA reactor (Poland)
M.A. Gryziński, **M. Maciak**, **M. Wielgosz**, J. Boratyński, Z. Leśnikowski
17th International Congress on Neutron Capture Therapy (USA, Columbia, 2016-10-02 - 2016-10-07)

Occupational exposure during fusion research on PF-1000 unit
K. Szewczak, S. Jednoróg
14th Congress of the IRPA (South Africa, Cape Town, 2016-05-09 - 2016-05-13)

LECTURES, COURSES AND EXTERNAL SEMINARS

Construction of BNCT stand in National Centre for Nuclear Reseach[a]
M. Maciak
Wrocław, Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, 2016-02-23

Dosimetry in BNCT[a]
P. Tulik
Wrocław, Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, 2016-02-23

How does a nuclear power plant work?[a]
K. Tymińska
Bialystok, University of Bialystok, 2016-04-21

a) in Polish

DIDACTIC ACTIVITY

B. Boimski - Prowadzenie ćwiczeń z zakresu bezpieczeństwa jądrowego i ochrony radiologicznej. Kurs typu A, 7 kwietnia 2016

B. Boimski - Prowadzenie ćwiczeń z zakresu bezpieczeństwa jądrowego i ochrony radiologicznej. Kurs typu A, 8 grudnia 2016

B. Boimski - Wykłady i ćwiczenia z zakresu sprzętu dozymetrycznego i pomiarów dla Jednostki Wojskowej Komandosów z Lubieńca 30-31.03.2016

S. Domański - Konsultant pracy inżynierskiej:
U. Nowakowska, "Optymalizacja procedur wygrzewania w piecach laboratoryjnych do anilacji detektorów termoluminescencyjnych" - praca dyplomowa inżynierska, Politechnika Warszawska, 2016.

S. Domański - Konsultant pracy magisterskiej:
M. Wywiałek, "Badanie równomierności natężenia emisji powierzchniowej cząsteczek beta o energii powyżej 150 keV wielkopowierzchniowych źródeł kalibracyjnych" - praca dyplomowa magisterska, Politechnika Warszawska, 2016.

S. Domański - NCBJ staff training

S. Domański - NCBJ staff training

J. Ośko - Radiation protection training course for NCBJ staff, 15-18 April 2016

J. Ośko - Radiation protection training course for NCBJ staff, 4-6 April 2016

J. Ośko - Radiation protection training course for NCBJ staff, 5-9 December 2016

J. Ośko - Supervisor of Alicja Olesińska bachelor thesis "Estimation of the uncertainty of the iodine activity in thyroid assessment ", Warsaw University, Faculty of Physics

J. Ośko - Supervisor of Sebastian Szymański bachelor thesis "Uncertainty evaluation of radioisotopes activity measurements", Warsaw University, Faculty of Physics

A. Pawełczuk - Prowadzenie szkoleń z zakresu ochrony radiologicznej w ramach instruktażu wstępnego dla nowoprzyjmowanych pracowników oraz praktykantów i doktorantów.

K. Tymińska - Lecturing "Introduction to nuclear power" at Faculty of Chemistry of Warsaw University

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

S. Domański
Polish Society of Medical Physics

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

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

M. Maciak
Polish Society of Medical Physics
The International Society for Neutron Capture Therapy

Ł. Murawski
Polish Society of Medical Physics

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

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

P. Tulik
Member, Polish Society of Medical Physics
Polish Society for Biomedical Engineering
Komitet Fizyki Medycznej, Radiobiologii i Daignostyki Obrazowej PAN
Polish Journal of Medical Physics and Engineering, Editorial Advisory Board Polish Society of Medical Physics
Polish Society of Medical Physics
Polish Journal of Medical Physics and Engineering, V-ce Editors Polish Society of Medical Physics

K. Tymińska
Member, Polish Society of Medical Physics
Corresponding member EURADOS WG6 - Computational dosimetry

M. Wielgosz
Polish Society of Medical Physics
The International Society for Neutron Capture Therapy

PERSONNEL

Research scientist

Agnieszka Burakowska, PhD
Michał A. Gryziński, PhD Eng
Zbigniew Haratym, PhD
Jakub Ośko, PhD Eng
Piotr Tulik, PhD Eng.
Katarzyna Tymińska, PhD
Monika Wielgosz, PhD Eng
Katarzyna Rzemek, MSc. Eng

Technical research
Szymon Domański, MSc
Tomasz Pliszczyński, MSc Eng

Technical and administrative staff
Agnieszka Araszkiewicz, MSc
Łukasz Bartosik, PhD Eng
Małgorzata Bogusz, MSc Eng
Błażej Boimski, Eng
Milena Budzińska, Eng
Małgorzata Dymecka, MSc Eng
Ryszard Ejsmont
Maciej Feczko
Andrzej Garboliński,
Edyta Jakubowska, MSc Eng
Barbara Karpińska
Marzena Korab
Łukasz Krzemiński, MSc Eng
Alicja Kurdej
Aneta Leszko
Maciej Maciak, MSc Eng
Gaweł Madejowski, Eng
Magdalena Mądry, MSc Eng
Edyta Michaś, Eng
Łukasz Murawski, Eng
Aleksandra Niepokólczycka-Fenik, MSc Eng
Piotr Okniński, Eng.
Katarzyna Osiecka, MSc Eng
Andrzej Pawełczuk, Eng
Barbara Piotrkowicz
Michał Piotrowski
Maria Prusińska, MSc Eng
Bożydar Snopek, Eng
Renata Sosnowiec
Wiesława Śniegoń-Reterska, MSc Eng
Marianna Umaniec
Kazimiera Wiśniewska
Katarzyna Wojdowska, MSc.
Zofia Worch
Grzegorz Zagórski,
Danuta Zielińska

MATERIAL PHYSICS DEPARTMENT

Director of Department: Professor Jacek Jagielski

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e-mail: Jacek.Jagielski@ncbj.gov.pl

Overview

In 2016 the Material 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 Cezary Pochrybniak. The Department staff is composed of 64 persons, among them 24 Ph.D. or D.Sc.

In 2016 the priorities of the Material Physics Department were focused on three axes: preparation for participation in the Polish Nuclear Energy Programme, modernisation of the thermal neutron beam laboratory of the MARIA reactor and fundamental and applied research into materials with special emphasis on nuclear techniques used for modification and/or analysis. The main research topics were:

- Molecular dynamic simulations of defect transformation 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.
- Archaeometry: materials studies of archaeological objects using physical methods.
- Neutron scattering physics in solid state analyses.
- Modification of materials using ion beam and plasma pulses.

Among the main achievements of MPD in 2016 one may list the acquisition of four neutron spectrometers from HZB Berlin; the first device was received by NCBJ in 2017, the successful realisation of three EU projects: VINCO, BRILLIANT and EUCARD2 (MPD is a coordinator of the VINCO project), preparation of two EU proposals: GEMMA and M4F (both projects were granted in 2017) and the realisation of three national grants. Department scientists published 54 papers in referred international journals and participated in 54 conferences giving 8 lectures.

Continuous development of MPD's capabilities in studies of materials for nuclear applications allowed the preparation of the European Teaming project NOMATEN. The proposal for the first phase was accepted in 2017.

Research and organisational activities of MPD were carried out within numerous international collaboration programmes, among these are particularly close relations with French organisations (CEA and CNRS), 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 its research activities MPD carried out actions related to the 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 completed in 2016. Commercial services, e.g. assessment of mechanical parameters of cast steel for the railway system, were also carried out.

MPD's plans for the near future include continuation of European projects, modernisation of the neutron beam laboratory and further development of nuclear materials, from atomic-scale simulations made with Molecular Dynamics and Monte Carlo methods to measurements of functional properties. 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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Overview

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 atomic 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). Some specialised techniques such as high pressure systems, rapid quenching and the sol-gel method have also been applied. A few theoretical and computational studies on the properties of fluorescence have also been carried out.

In 2016 the Department comprised two laboratories:

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

There were 14 employees with three full professors and 8 researchers with PhD degrees.

The main work performed in 2016 dealt with:

X-ray diffraction studies of active pharmaceutical compounds.

The effect of phase decomposition on the phonon spectra in Mn0.3Ni0.3Cu0.4 pseudo-binary alloy.

Small angle neutron scattering studies of Cr doped ODS steels.

Spontaneous wetting and drying in quasi-2-dimensional systems.

Application of neutron imaging in cultural heritage and paleontological research.

Preparation of the MARIA reactor experimental hall for installation of the neutron diffractometers from the Ber-II reactor of the Helmholtz-Zentrum Berlin.

Jacek J. Milczarek

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Stereoselective Synthesis of (-)-Podophyyllotoxin and Related Lignans
P. Roszkowski, K. Krawczyk, K. Lisiecki, **J.K. Maurin**, Z. Czarnocki
International Conference on Stereochemistry (Brazil, Sao Paulo, 2016-08-18 - 2016-08-19)

Badania naukowe w bliskiej przestrzeni kosmicznej i na niskiej orbicie Ziemi
A. Budzianowski
Near Space Conference (Poland, Toruń, 2016-04-16 - 2016-04-16)

Badania naukowe, edukacja i radiokomunikacja w przestrzeni kosmicznej
A. Budzianowski
Konferencja Badań Kosmicznych 2016 (Poland, Gdańsk, 2016-10-21 - 2016-10-21)

Oral Presentation

Stereoselective Synthesis of Selected Important Nitrogen Heterocycles
P. Roszkowski, D. Błachut, K. Krawczyk, J. Szawkało, K. Lisiecki, P. Pomarański, **J.K. Maurin**, Z. Czarnocki
International Conference on Stereochemistry (Brazil, Sao Paulo, 2016-08-18 - 2016-08-19)

Poster

L-shell X-ray emission from atoms multiple ionized by fast S^{q+} ions with energy of 0,4 -3,8 MeV/amu
M. Jaskóła, **I. Fijał-Kirejczyk**, **A. Korman**, D. Banaś, J. Braziewicz, J. Choiński, U. Majewska, M. Pajek, J. Semaniak, W. Kretschmer, G. Lapicki, T. Mukoyama, D. Trautmann
18th International Conference on the Physics of Highly Charged Ions (Poland, Kielce, 2016-09-11 - 2016-09-16)

Biotransformation of 3-aryl-4,5-dihydroisoxazol-5-yl acetates
J. Główczyk-Zubek, J. Kliszewicz, E. Kosińska, **J.K. Maurin**, M. Wielechowska
Biotransformations for Pharmaceutical and Cosmetic Industry. Biotransformations 2016 (Poland, Warsaw, 2016-06-30 - 2016-07-02)

DIDACTIC ACTIVITY

J. Jankowska-Kisielińska - Supervision of student internship of 2 students of Chemistry Division of the Warsaw University: Sylwia Rytelewska and Agnieszka Prus at NCBJ.

J.J. Milczarek - Lecture on
"Applications of thermal neutrons in materials research and technology"
winter term
Faculty of Materials Science and Engineering
Warsaw University of Technology

J.J. Milczarek - Supervision of Mr. Piotr Baranowski student internship at NCBJ

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

PERSONNEL

Research scientists

Budzianowski Armand, PhD
Andrzej Czachor,Professor
Izabela Fijał-Kirejczyk, PhD
Joanna Jankowska-Kisielińska, PhD
Jan Maurin, PhD DSc
Jacek J. Milczarek, PhD
Karolina Świderska, MSc
Joanna Żołądek-Nowak, MSc

Technical staff

Zdzisław Jurkowski
Tadeusz Wójcik
Jan Żołądek

PLASMA/ION BEAM TECHNOLOGY DIVISION

Head of Division: Cezary Pochrybniak, PhD

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e-mail: cezary.pochrybniak@ncbj.gov.pl

Overview

The activities of the FM2 Division are focused on plasma physics applications in materials engineering science, solid state physics, microanalysis in photonics materials and ancient archaeological objects, also computer simulation of defects in solids. As in 2016, our main topics of activity were as follows:

1. Development of new semiconductors for photovoltaics – GaP single crystals Ti ion implanted: structural feature investigations.
2. Study of PMS plasma pulse features under various conditions of frequency modulation.
3. Superconductive cathodes for efficient electron gun - optimisation of thin film Pb on Nb photocathodes.
4. Molecular dynamics simulations of defect transformation at various stress levels.
5. The ZNOLUM project – detailed investigations of light emitting photonics structures.
6. Archaeometry – materials study of archaeological objects using non- and microinvasive methods.
7. High Intensity Plasma Ion Beams in technological applications.
8. A study of the process of applying kinetic energy to a projectile made of non-magnetic electrically conductive material and located inside an induction coil live with alternating current.

We also started new investigations on multi band gap semiconductors. Our first results – highly doped GaP with titanium ions looks very interesting. We rebuilt the crystalline structure of the semiconductor doped with a high dose of titanium. Attempts were made to manufacture a semiconductor material suitable for impurity band solar cells (IBSC). In such a material, an additional impurity related conduction band is formed after the impurity concentration exceeds a limit referred to as the “Mott transition”. The additional band widens the spectral response of the cell and may lead to a significant increase of the cell efficiency. Howevers the Mott transition usually occurs above the solubility limit of the impurity and special methods are required to raise this limit such as pulse annealing of the implanted impurity.

Cu-N layers were synthesized by the use of the Pulsed Magnetron Sputtering method (PMS), operating with various conditions of frequency modulation. We studied how this parameter affects the mechanism of layer growth. Changing conditions of plasma generation resulting from the possibility of controlling its frequency and life time have a strong effect on the quantity and activity of plasma particles and their interaction between the plasma components with the substrate. This allows the mechanism of layer growth, its microstructure, and phase composition to be controlled.

A thin film Pb photocathode is a promising material, planned to be used in superconducting electron linear accelerators. Work on lead-layer photocathode preparation on a niobium substrate, destined for XFEL-type, 16-cell, superconducting RF electron injectors was continued in 2016. Our previous activities in this field resulted in the selection of methods of lead deposition and smoothing [1]. Ultrahigh vacuum arc lead coating followed by pulsed plasma ion treatment in a rod plasma injector were found to be promising in this context. The smoothing procedure was optimized by performing a heat transfer computation from pulsed plasma ion beams. The calculation results were verified experimentally by treating arc deposited layers with Ar+ ion pulses in the IBIS multi-rod plasma generator at NCBJ followed by SEM observation of film surfaces. A thick film of Pb is needed to be deposited on the back wall of a modified electron gun resonator.

We focused on thedevelopment of efficient tools for the simulation of defects in a single crystal – the McChassy code. This is a very useful tool for our searches in solid state crystalline structures in NRA and RBS investigations.

RBS was especially usedin the project ZNOLUM – light emitting photonic structures basic on ZnO implanted with rare earth elements. This year we focused on optimization of the annealing process for ZnO single crystals and layers implanted with Re ions. High-quality wurtzite ZnO was deposited by the Atomic Layer Deposition (ALD) method on a GaN/Al2O3 substrate and commercial single crystals (MaTecK) were implanted at room temperature with different RE ions: Yb, Eu, Er, Pr, Dy to fluencies ranging from 5x1014 to 2x1015ions/cm^2. After ion implantation, two different types of annealing were used: rapid thermal annealing (RTA) and flash lamp annealing

(FLA). Subsequently, Photoluminescence (PL) studies of these samples were performed. It is expected that the control of the crystalline quality, damage recovery, RE-atom lattice site location and optical efficiency study after FLA annealing will lead to important progress of ZnO in optical applications.

The Nidajno Project has been carried out since 2010 when this unique archaeological site was discovered within the area of the former lake Nidajno (north-eastern Poland) [1]. The results of the field-works situate the site as one of the most important offering-places (next to the famous Jutland sacrificial bogs at Illerup, Thorsberg and others), which is proved by gold and silver artifacts of probable Eastern Mediterranean provenance (among them gold sword fittings, figurines of a vulture and others). The aim of the archaeometallurgical research was to recognize the execution method, ancient metallurgical workmanship: conditions of ancient casting and ornamentation techniques and the impact of environmental factors on the form and texture of the objects observed at present.The research project is focused on studies of silver coins and jewelry from Xth and XIth century Poland (Piast Dynasty). Until now there was no certain knowledge about sources of silver and manufacturing used for making these objects. Of great need are data from ornaments which are a very large material, one of the largest in Europe, consisting of female earrings, pendants and other pieces of various types formally with origin in late antique art and further development in the first Slav state of Great Moravia in the ninth century AD. Based on materials research modern archaeometallurgy gives answers about the technological and deposit provenance of these objects. This kind of precious object needs special treatment by non- and microinvasive methods, such as SEM, EDS, EDX, XRD, Raman Spectroscopy and neutronography. The above mentioned methods allow wide-ranging studies of archaeological relics. Archaeometry is the subject of a PhD thesis.

Cellulose is the most popular natural polymer and the main structural component of wood. As a polymer with a high degree of polymerization, it is characterized by excellent strength properties. Properties of lignocellulosic materials can be improved by modifying the basic component of wood, which is mainly cellulose. As a part of the material research, it is proposed to study surface modification of lignocellulosic particles (chips), especially by electron beam irradiation of the surface. Based on reports in the literature, the proposed idea has not been used thus far in forest sciences in the field of wood technology. Implementation of the proposed methods of wood particle modification aims to improve the surface properties owing to significant increase of free surface energy. This approach allows us to develop methods for producing wood particles with minimum adhesive binders. Adopting the proposed methods in the manufacturing of wood materials leads to the development of ecological, low-carbon, formaldehyde-free materials for furniture production.

The subject of these studies is an analysis of the process of applying kinetic energy to a projectile made of non-magnetic electrically conductive material and located inside an induction coil live with alternating current. An experimental verification was carried out of the analytical conclusions that were pertinent to the design and technology of an inductance coil gun, which is a ranged weapon type.

In 2016 the FM2 Division employed 28 persons, twelve members constituted the scientific staff, seven belonged to the research-technical staff, eight constituted the technical and the rest - administrative staff.

Cezary Pochrybniak

REPORTS

Origins and production of silver objects in Early Medieval Poland
E. Miśta, ... , **A. Turos**, **A. Gójska**, **M. Dorosz**, ... et al.
Annual Report NCBJ 2015, Otwock-Świerk

Technical study of tiles (XIII to XV AC) from Aveh, Qom and Masshad in Iran
E. Miśta, ... , ... et al.
Annual Report NCBJ 2015, Otwock-Świerk

VINCO Project, Visegrad Initiative for Nuclear Cooperation, Deliverable 1.1
Ł. Kurpaska, **J. Jagielski**,
VINCO wewnętrzny raport (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Detektory typu Czerenkowa w badaniach tokamaków
J. Żebrowski, **L. Jakubowski**, **M. Rabiński**, **M.J. Sadowski**, **M.J. Jakubowski**, **K. Malinowski**, **R. Mirowski**, **R. Kwiatkowski**
Sympozjum Narodowego Centrum Badań Jądrowych NCBJ-2016 (Poland, Otwock-Swierk, 2016-10-05 - 2016-10-05)

Highlights of recent high-temperature plasma studies at the NCBJ, Poland
M.J. Sadowski, **E. Składnik-Sadowska**, **R. Kwiatkowski**, **A. Malinowska**, **K. Malinowski**, **K. Nowakowska-Langier**, **A. Szydłowski**, **J. Żebrowski**, **K. Czaus**, **W. Surała**, **D. Załoga**, M. Kubkowska, M. Paduch, R. Miklaszewski, E. Zielinska, P. Kubes, D. Margarone, J. Krasa, I. Garkusha, V. Makhlay, M. Ladygina
Annual Meeting of International Centre for Dense Magnetized Plasmas (ICDMP-2016) (Poland, Warsaw, 2016-10-14 - 2016-10-15)

Re-melting technique with high intense pulsed plasma beams applied for surface modification of steel. Own investigations
B. Sartowska, **M. Barlak**, L. Waliś, W. Starosta
International Conference on Processing & Manufacturing of Advanced Materials - Processing, Fabrication, Properties, Applications - THERMEC 2016 (Austria, Graz, 2016-05-29 - 2016-06-03)
Mat. Sci. Forum Vol. 879 (2016) 1668-1674

Electron pulse annealed Ti-implanted GaP
Z. Werner, **M. Barlak**, **R. Ratajczak**, P. Konarski, A.M. Markov, R. Heller
XI-th International Conference (Poland, Kazimierz Dolny, 2016-06-13 - 2016-06-16)

Multipactor in RF components and remedies against it
J. Lorkiewicz
XXXVIII-th IEEE-SPIE Joint Symposium on Photonics, Web Engineering, Electronics for Astronomy and High Energy Physics Experiment, Wilga 2016 (Poland, Wilga, 2016-05-30 - 2016-06-06)

HOM Couplers and Absorbers - NCBJ In-kind Contribution to European XFEL
E. Pławski, J. Sekutowicz, **W. Grabowski**, **K. Kosiński**, **J. Lorkiewicz**, **M. Wojciechowski**, Z. Gołębiewski
Superconductivity & Particle Accelerators (Poland, Kraków, 2016-12-06 - 2016-12-07)
IFJ PAN, Kraków No. (2016) p. 17

Oral Presentation

Superconducting test injector and THz-IR source
R. Nietubyć, **J. Lorkiewicz**, J. Sekutowicz
Superconductivity and Particle Accelerators 2016 (Poland, Kraków, 2016-12-06 - 2016-12-07)

Ion implantation changes of tribological and corrosion resistance properties of materials used in wood industry
M. Barlak, J. Wilkowski, **Z. Werner**
XXX-th International Scientific Conference of Faculty of Wood Technology WOOD-MATERIAL OF THE XXI-st CENTURY (Poland, Rogów, 2016-11-15 - 2016-11-16)
Annals of Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology Vol. 94 (2016) 19-27

Radiation stability of urania implanted with low-energy ions – Role of foreign species and temperature
Y. Haddad, A. Gentils, C. Bachelet, J. Bourçois, A. Debelle, L. Delauche, T.H. Nugyen, **L. Nowicki**, S. Picard, S. Renouf, G. Sattonnay, L. Thomé, F. Garrido
The 20th International Conference on Ion Beam Modification of Materials - IBMM 2016 (New Zealand, Wellington, 2016-11-30 - 2016-11-04)

Structure of Cu-N layers synthesized by pulsed magnetron sputtering with variable frequency of plasma generation
K. Nowakowska-Langier, R. Chodun, **Ł. Kurpaska**, Ł. Skowroński, S. Okrasa, K. Zdunek
The 20th International Conference on Ion Beam Modification of Materials - IBMM 2016 (New Zealand, Wellington, 2016-11-30 - 2016-11-04)

IBIS II - Plasma Device Highly Suitable for Solar Wind Simulation
C. Pochrybniak
International Symposium On Reliability of Optoelectronics for Systems (Poland, Otwock, 2016-06-06 - 2016-06-09)

Experiments with zirconium alloy coatings using Si based compound
B. Sartowska, W. Starosta, L. Waliś, **M. Barlak**
22 International Quench Workshop (Germany, Karlsruhe, 2016-10-18 - 2016-10-20)
Proceedings of the 22nd International QUENCH Workshop (in press)

Mechanizm akceleracji obiektów makroskopowych w polu magnetycznym cewki indukcyjnej z wykorzystaniem prądów wirowych
A. Horodeński, **C. Pochrybniak**, **K. Namyślak**
XI międzynarodowa konferencja uzbrojeniowa „Naukowe aspekty techniki uzbrojenia i bezpieczeństwa" (Poland, Ryn, 2016-09-19 - 2016-09-22)

Properties of ion-irradiated elastomers reinforced with graphene filler
J. Jagielski, **A. Kosińska**, U. Ostaszewska, R. Kozinski, M. Romaniec, **Ł. Kurpaska**, I. Jozwik
The 20th International Conference on Ion Beam Modification of Materials - IBMM 2016 (New Zealand, Wellington, 2016-11-30 - 2016-11-04)

Ion Implantation into Wide Band-gap Semiconductors GaN and ZnO
A. Turos, **R. Ratajczak**, **C. Mieszczyński**, **A. Stonert**, E. Guziewicz, S. Prucnal
Science & Applications of Thin Films. Conference & Exhibition. (Turkey, Izmir, 2016-09-19 - 2016-09-23)

Structural and mechanical properties of Ar-ion irradiated YSZ single-crystals grown in different crystallographic orientations.
Ł. Kurpaska, **M. Frelek-Kozak**, **K. Nowakowska-Langier**, M. Lesniak, J. Jasinski, **J. Jagielski**
The 20th International Conference on Ion Beam Modification of Materials - IBMM 2016 (New Zealand, Wellington, 2016-11-30 - 2016-11-04)

Yb-ion beam modification of ZnO epilayers for optoelectronic applications
A. Turos, **R. Ratajczak**, **C. Mieszczyński**, **A. Stonert**, E. Guziewicz, S. Prucnal
5th International Conference on Materials Science and Engineering (CMSE 2016) (Taiwan, Province of China, Taichung, 2016-11-08 - 2016-11-11)

Modyfikacja powierzchni stopów cyrkonu intensywnymi impulsami plazmowymi
B. Sartowska, W. Starosta, **M. Barlak**, L. Waliś
VI Ogólnopolska Konferencja Naukowa Nowoczesne Technologie w Inżynierii Powierzchni Łódź-Spała 2016 (Poland, Łódź - Spała, 2016-09-25 - 2016-09-28)

Poster

Research on interaction of pulsed plasma-ion streams with different energy fluxes with SiC and CFC samples
R. Kwiatkowski, **K. Nowakowska-Langier**, **E. Składnik-Sadowska**, **M.J. Sadowski**, **D. Załoga**, M.S. Ladygina
43rd EPS Conference on Plasma Physics (Belgium, Leuven, 2016-07-04 - 2016-07-07)

Silicide/Silicate Coatings on Zirconium Alloys for Improving the High Temperature Corrosion Resistance
M. Barlak, B. Sartowska, W. Starosta, P. Kołodziejczak, L. Waliś, M. Miłkowska
NuMat2016 - The Nuclear Materials Conference (France, Le Corum, Montpellier, 2016-11-07 - 2016-11-10)

Surface layers of steel with improved tribological properties formed using high intense pulse plasma beams (HIPPB)
B. Sartowska, **M. Barlak**, W. Starosta, L. Walis
15th International Conference on Plasma Surface Engineering PSE 2016 (Germany, Garmisch-Partenkirchen, 2016-09-10 - 2016-09-17)

Optimization of annealing process for ZnO implanted with Rare Earth (RE) ions
R. Ratajczak, S. Prucnal, E. Guziewicz, M. Stachowicz, **C. Mieszczyński**, D. Snigurenko, T. Krajewski, K. Kopalko, A. Zagojski, W. Skorupa, **A. Turos**
XI-th International Conference (Poland, Kazimierz Dolny, 2016-06-13 - 2016-06-16)

RBS/c and PL studies of Pr implanted ZnO thin films deposited by ALD
R. Ratajczak, S. Prucnal, **C. Mieszczyński**, E. Guziewicz, M. Stachowicz, D. Snigurenko, K. Kopalko, B.S. Witkowski, T.A. Krajewski, W. Skorupa, **A. Turos**
E-MRS 2016 Fall Meeting (Poland, Warsaw, 2016-09-19 - 2016-09-22)

Non equilibrium thermal processing of highly implanted ZnO:Yb
M. Stachowicz, **R. Ratajczak**, S. Prucnal, W. Skorupa, T.A. Krajewski, B.S. Witkowski, D. Snigurenko, **A. Turos**, E. Guziewicz
E-MRS 2016 Fall Meeting (Poland, Warsaw, 2016-09-19 - 2016-09-22)

Technology secrets of precious metal artifacts from Nidajno bog site in Poland
A. Gójska, **E. Miśta**, A. RzeszotarskaNowakiewicz, T. Nowakiewicz, P. Kalbarczyk, J. Dudek
41st International Symposium on Archaeometry (ISA2016) (Greece, Kalamata, 2016-05-15 - 2016-05-21)

Mechanical (nano vs micro) and structural properties of ODS RAF steels submitted to low-energy ions irradiation
W. Pawlak, **Ł. Kurpaska**, **M. Frelek-Kozak**, **J. Jagielski**, M. Lewandowska, M. Chmielewski, I. Jóźwik
3rd ODISSEUS Workshop - Oxide DIspersion Strenghened Steels group of EUropean Scientists (Germany, Dresden, 2016-04-19 - 2016-04-20)

Ytterbium valence states in implanted ZnO films
E. Guziewicz, **R. Ratajczak**, M. Stachowicz, D. Snigurenko, T.A. Krajewski, P. Dłużewski, K. Morawiec, **A. Turos**
9th International Workshop on Zinc Oxide and Related Materials (IWZnO 2016) (Taiwan, Province of China, Taipei, 2016-10-30 - 2016-11-02)

X-ray Computed Tomography study of ancient objects
E. Miśta, **T. Kosiński**, W. Weker
6th Meeting X-ray and other techniques in investigations of the objects of cultural heritage, Krakow, 19-21 May 2016 (Poland, Kraków, 2016-05-19 - 2016-05-21)

Mechanical (nano vs micro) and structural properties of ODS RAF steels submitted to low-energy ions irradiation
W. Pawlak, **Ł. Kurpaska**, **M. Frelek-Kozak**, **J. Jagielski**, M. Lewandowska, M. Chmielewski, I. Jóźwik
3rd International Workshop on ODS Materials (Germany, Dresden, 2016-04-21 - 2016-04-22)

ZnO-ALD films implanted with Yb
E. Guziewicz, **R. Ratajczak**, M. Stachowicz, D. Snigurenko, T.A. Krajewski, B.S. Witkowski, **A. Turos**
33rd International Conference on the Physics of Semiconductors (ICPS 2016) (China, Beijing, 2016-07-31 - 2016-08-05)

Lead layer photocathodes for XFEL-type superconducting RF electron injectors - coating and processing at NCBJ Świerk
J. Lorkiewicz, **R. Nietubyć**, J. Sekutowicz, **A. Kosińska**, D. Kostin, **M. Barlak**, R. Barday, R. Xiang, J. Smedley, P. Kneisel, **R. Mirowski**, **J. Witkowski**
European XFEL Users Meeting 2016 (Germany, Hamburg, 2016-01-27 - 2016-01-29)

In-kind contribution of Polish institutions to European X-ray free electron laser (Eu-XFEL) - status in. Dec. 2015
E. Pławski, J. Sekutowicz, **W. Grabowski**, **K. Kosiński**, **J. Lorkiewicz**, **M. Wojciechowski**, Z. Gołębiewski, K. Meissner, **G. Wrochna**, M. Duda, E. Górnicki, M. Jeżabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Sienkiewicz, M. Stodulski, J. Świerblewski, M. Więcek, M. Chorowski, E. Rusiński, J. Fydrych, A. Iluk, K. Malcher, J. Poliński, P. Duda, J. Głowinkowski, P. Wilk, M. Winkowski, P. Grzegory, G. Michalski
European XFEL Users Meeting 2016 (Germany, Hamburg, 2016-01-27 - 2016-01-29)

Origins of silver and production of coins and jewelry in early medieval Poland
E. Miśta, **A. Gójska**, W. Duczko, **A. Turos**, P. Kalbarczyk, J. Dudek, A. Kędzierski, Wyczółkowski, R. Czech, M. Widawski, **T. Kosiński**, J. Gaca
41st International Symposium on Archaeometry (ISA2016) (Greece, Kalamata, 2016-05-15 - 2016-05-21)

Origins of silver and production of coins and jewelry in early medieval Poland
E. Miśta, **A. Gójska**, W. Duczko, **A. Turos**, P. Kalbarczyk, J. Dudek, A. Kędzierski, Wyczółkowski, R. Czech, M. Widawski, **T. Kosiński**, J. Gaca
Inspiracje i funkcje sztuki pradziejowej i wczesnośredniowiecznej (Poland, Biskupin, 2016-06-27 - 2016-06-29)

Modyfikacja powierzchni stopów cyrkonu metodą TIG
W. Starosta, **M. Barlak**, P. Kołodziejczak
VI Ogólnopolska Konferencja Naukowa Nowoczesne Technologie w Inżynierii Powierzchni Łódź-Spała 2016 (Poland, Łódź - Spała, 2016-09-25 - 2016-09-28)

Synthesis of Cu-N layers by pulse magnetron sputtering method
K. Nowakowska-Langier
European XFEL Users Meeting 2016 (Germany, Hamburg, 2016-01-27 - 2016-01-29)

LECTURES, COURSES AND EXTERNAL SEMINARS

Thin films issues - Cathodic Arc Deposition[a]
R. Nietubyć
Otwock - Swierk, NCBJ, 2016-06-08

Advances in thin film lead photocathodes[b]
R. Nietubyć
Daresbury, Cockroft Institute, 2016-04-04

a) in Polish
b) in English

INTERNAL SEMINARS

Coating and processing of superconducting lead photo-cathodes on niobium - status of activities at National Centre for Nuclear Research, division FM-2[a]
J. Lorkiewicz
Otwock-Swierk, National Centre for Nuclear Research (NCBJ), 2016-01-13

Material analysis using RBS/C technique[a]
L. Nowicki
Otwock-Swierk, National Center for Nuclear Research (NCBJ), 2016-02-24

RBS/c study of defect structure transformation in Zn implanted with rare earth ions[a]
R. Ratajczak
Otwock-Swierk, National Centre for Nuclear Research (NCBJ), 2016-02-24

The use of ion, plasma and electron beams in processes of improving the performance of materials[a]
M. Barlak
Otwock-Świerk, National Centre for Nuclear Research, 2016-04-06

Electrodynamic Acceleration of Macroscopic Bodies[a]
A. Horodeński
Świerk, National Centre for Nuclear Research, 2016-04-27

The Witch Tomb in the light of equipment analysis -an archaeological site in the Bodzia near Wloclawek[a]
E. Miśta
Otwock-Świerk, Narodowe Centrum Badań Jądrowych (National Centre for Nuclear Research), 2016-12-15

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 - Supervisor of student's practice of Aleksandra Łysik - attendant of the 3-rd course of stationary study of first degree of The Faculty of Materials Science and Engineering of Warsaw University of Technology (18.07-12.08.2016) - Agreement No 404/52/1090/2016/IM

K. Nowakowska-Langier - Bachelor degree - advisor
"Effect of Morphology and phase structure on properties of copper nitride layers"
National Centre for Nuclear Research (NCBJ)
.

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

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

R. Nietubyć
Polish Synchrotron Radiation Society

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

C. Pochrybniak
Member Polish Solar Energy Society
Member Polish Photovoltaics Society
Chairman of Economics Council Institute of Atomic Energy Polatom

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

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

PERSONNEL

Scientific staff

Marek Barlak, PhD
Jacek Jagielski, Professor
Jerzy Lorkiewicz, PhD Eng.
Cyprian Mieszczyński, PhD
Robert Nietubyć, PhD
Katarzyna Nowakowska-Langier, PhD Eng
Lech Nowicki, PhD
Cezary Pochrybniak, PhD
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Anna Stonert, PhD
Andrzej Turos, Professor
Zbigniew Werner, Professor

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Mirosław Kuk
Bogdan Staszkiewicz
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Angelika Krawczyk

MATERIALS RESEARCH LABORATORY

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Overview

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 materials irradiated in nuclear reactor. All studies performed in the MRL are conducted according to the 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 relative 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 theMRL 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°C to 1000°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°C to 800°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 the 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 chemical composition of metals.

The devices are fully automated, remotely operated and instrumented.

The remaining equipment of the hot cell complex allows us to perform:

- Cutting out of the 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 at the MRL. The non-destructive laboratory is equipped with state-of-the-art equipment and employs 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 have been performed from the end of 2016.

The MRL holds the Accreditation Certificate of Testing Laboratory No AB 025 which confirms fulfillment of the ISO/IEC 17025:2001 criteria and since 1995 has held 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 MRL is in accordance with international standards widely used by research laboratories worldwide.

Since 2015 several research projects funded by MNiSW, IAEA, FNP (Foundation for Polish Science) and NCBJ have been conducted in MRL. Currently, besides projects funded by the European Commission in 2015: VINCO and BRILLIANT new project are being opened. The MRL performs nanomechanical investigations of materials and is involved in two projects recently funded by EC R&D – GEMMA and M4F. Both projects are aimed at developing materials dedicated to Generation IV Nuclear Reactors.

In 2016 the main areas of research were: zirconium oxidation, zirconium alloys, SiC, pyrochlores, mechanical investigation of 316 SS steels, fabrication and mechanical properties of ODS RAF steels and stress corrosion of steels. Among these tests, special attention was given to the invesstigation of the mechanical properties of irradiated layers. In 2016 MRL researchers published 13 high impact journal papers and participated in several international conferences and symposia. Among them the most important are:

- ChemSession 16
- 3rd ODISSEUS Workshop - Oxide DIspersion Strenghened Steels group of EUropean Scientists
- The 20th International Conference on Ion Beam Modification of Materials - IBMM 2016
- 3rd International Workshop on ODS Materials
- International Symposium on Relability of Optoelectronics for Systems 2016
- European XFEL User Meeting

Currently, MRL employs 18 people of whom 2 are working in scientific positions, 1 works in a research position, 14 work in engineering positions and 1 works as a laboratory person.

Łukasz Kurpaska

REPORTS

IAEA Coordinated Research Project on Demonstrating Performance of Spent Fuel and Related Storage Components during Very Long Term Storage. The investigation of the gamma irradiation influence on the mechanical and corrosion properties of stainless steel used for spent fuel containers and canisters.
Ł. Kurpaska
IAEA (in press)

VINCO Project, Visegrad Initiative for Nuclear Cooperation, Deliverable 1.1
Ł. Kurpaska, **J. Jagielski**,
VINCO wewnętrzny raport (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Nanoindentation technique as a tool for new materials investigation
Ł. Kurpaska
International Symposium on Relability of Optoelectronics for Systems 2016 (Poland, Swierk - Otwock, 2016-06-06 - 2016-06-09)

Oral Presentation

Structure of Cu-N layers synthesized by pulsed magnetron sputtering with variable frequency of plasma generation
K. Nowakowska-Langier, R. Chodun, **Ł. Kurpaska**, Ł. Skowroński, S. Okrasa, K. Zdunek
The 20th International Conference on Ion Beam Modification of Materials - IBMM 2016 (New Zealand, Wellington, 2016-11-30 - 2016-11-04)

Properties of ion-irradiated elastomers reinforced with graphene filler
J. Jagielski, **A. Kosińska**, U. Ostaszewska, R. Kozinski, M. Romaniec, **Ł. Kurpaska**, I. Jozwik
The 20th International Conference on Ion Beam Modification of Materials - IBMM 2016 (New Zealand, Wellington, 2016-11-30 - 2016-11-04)

Nanomechanical investigation of irradiated thin layers – challenges, possibilities and pitfall traps.
Ł. Kurpaska
The 20th International Conference on Ion Beam Modification of Materials - IBMM 2016 (New Zealand, Wellington, 2016-11-30 - 2016-11-04)

Structural and mechanical properties of Ar-ion irradiated YSZ single-crystals grown in different crystallographic orientations.
Ł. Kurpaska, **M. Frelek-Kozak**, **K. Nowakowska-Langier**, M. Lesniak, J. Jasinski, **J. Jagielski**
The 20th International Conference on Ion Beam Modification of Materials - IBMM 2016 (New Zealand, Wellington, 2016-11-30 - 2016-11-04)

Poster

Assesment toxicity an active optical nanoparticles YAB:Cr in chemical form by in vitro test
I. Cieślik, **T. Bolek**, **Z. Rozenblicki**, S. Hirano
ChemSession 16 (Poland, Warszawa, 2016-06-10 - 2016-06-10)
Polskie Towarzystwo Chemiczne No. (2016) p. 68

Mechanical (nano vs micro) and structural properties of ODS RAF steels submitted to low-energy ions irradiation
W. Pawlak, **Ł. Kurpaska**, **M. Frelek-Kozak**, **J. Jagielski**, M. Lewandowska, M. Chmielewski, I. Jóźwik
3rd ODISSEUS Workshop - Oxide DIspersion Strenghened Steels group of EUropean Scientists (Germany, Dresden, 2016-04-19 - 2016-04-20)

Mechanical (nano vs micro) and structural properties of ODS RAF steels submitted to low-energy ions irradiation
W. Pawlak, **Ł. Kurpaska**, **M. Frelek-Kozak**, **J. Jagielski**, M. Lewandowska, M. Chmielewski, I. Jóźwik
3rd International Workshop on ODS Materials (Germany, Dresden, 2016-04-21 - 2016-04-22)

Współczesne badania mechaniczne - kierunek i rozwój
Ł. Kurpaska
Polish Scientific Network (Poland, Wrocław, 2016-06-30 - 2016-07-02)

LECTURES, COURSES AND EXTERNAL SEMINARS

Demonstrating Performance of Spent Fuel and Related System Components during Very Long Term Storage[b]
Ł. Kurpaska
Santander, Spain, International Atomic Energy Agency, 2016-04-11

[b)] in English

DIDACTIC ACTIVITY

T. Bolek - Teaching courses at Faculty of Materials Science and Engineering, Warsaw Univeristy of Technology from "Inormation Technology"

I. Cieślik - Coordinating "Young scientist"project
Title: "Composite protective coatings based on ceramic nano and micropowders"

I. Cieślik - Title of the masters thesis: "Synthesis of Al_2O_3-TiO_2 nanocomposites by sol-gel method" Military University of Technology

B. Zając - Conduct and evaluation of the certification exam 8 students at level 2 in the PT method in the resort exam UDT-CERT

B. Zając - Teaching classes (2016)
Course NDT, Magnetic particle method , level 2 according to EN ISO 9712 for the Staff Training Center "INTERPROFESJA" Warsaw, 24.10-29.10.2016

B. Zając - Teaching classes (2016)
Course NDT, Penetrant Testing method, level 2 according to EN ISO 9712 for the Staff Training Center "INTERPROFESJA" Warsaw, 05.12-10.12.2016

B. Zając - the course using magnetic-particle testing, level 2 according to EN ISO 9712 for the Staff Training Center "INTERPROFESJA" 11-16.04.2016r.

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, Corrosion Science
Mechanics of Materials, Mechanics of Materials

PERSONNEL

Research staff

Łukasz Kurpaska, PhD
Iwona Cieślik, PhD Eng

Research and technical staff

Małgorzata Frelek-Kozak, MSc Eng
Tomasz Bolek, MSc Eng
Konrad Ćwiek
Zdzisław Jagoda, Eng.
Mirosław Jagodziński
Zbigniew Kozioł, PhD Eng
Grzegorz Olszewski, Eng
Wioleta Pawlak, MSc Eng
Martyna Przyborska, MSc Eng
Zbigniew Rozenblicki
Elżbieta Szulim
Tadeusz Wagner, MSc Eng
Edyta Wyszkowska, MSc Eng
Bogdan Zając, MSc Eng
Tadeusz Zych

Laborant
Alicja Ostrowska

DEPARTMENT OF FUNDAMENTAL RESEARCH

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Overview

An activity of the department in 2016 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 are only highlighted two main achievements of the department in 2016.

On 11th February the first direct detection of gravitational waves was announced. The detection was made by two detectors of Laser Interferometer Gravitational wave Observatory (LIGO). The registered signal is in perfect agreement with the gravitational waves coming from the merger black hole binary with masses of 29 and 36 solar masses. The general theory of relativity has been thus verified in a new extreme regime. Through the discovery a new field was initiated – gravitational wave astronomy. A Polish group POLGRAW actively participates in the project. The team leader – prof. Andrzej Królak and two members are employee of NCBJ.

POLAR is a space experiment designed for a measurement of polarization of photons originating from Gamma Ray Bursts – one of the most energetic events observed in the Universe. Polarization measurements are hoped to resolve their enigma. The POLAR detector was launched on the 15th September with the Chinese Tian-Gong 2 Space Station and a few days later POLAR was successfully turned on. The NCBJ group has contributed to the construction of the detector and now is involved in data analysis.

Stanisław Mrówczyński

In Memoriam: Janusz Dąbrowski (1927-2017)

Janusz Dąbrowski was born in the Wielkopolska region. That fact had some known consequences – being systematic almost pedantic, stubborn and well organized, politically neutral with a very slight inclination toward national-democratic views. At the same time, he presented himself as a bit disorganized and absent minded scientist with an unique and sometimes weird sense of humor. His parents wished him to continue as an educated landowner, the war decided his life to be different. Expelled to Kraków studied agro-sciences, in the open as well as in the underground educational system, until a well known mathematician prof. Krzyżanowski discovered his talent for science. That started his peregrinations as a physicist. Universities and Technical Universities in Kraków, Wrocław, Warszawa prepared him to be a theorist. Granted Ph.D. under Prof. Wojciech Rubinowicz Janusz decided to become a nuclear theoretician. Continued his travels and activities at Universities of Birmingham, Princeton, Seattle, Kopenhagen, La Jolla, McMaster, Warszawa and Institutes in Dubna, Trieste. In this way he collected scientific results, degrees, distinctions and fast cars. Let me list only his professorship at Polish Academy of Science (1962), his participation in the editorial board of Physics Letters, and strong American connections.

Janusz Dąbrowski made his name in physics with several papers. In his early works, performed mostly in Warsaw, he studied direct nuclear reactions and nuclear optical model, used to collaborate with J. Sawicki and A. Sobiczewski. In Birmingham he initiated studies of light nuclei by a variational description of the short range nucleon-nucleon correlations. Later these evolved into studies of correlations in nuclear matter. He joined, a classical now, line of research and collaborated with K.A. Brueckner the authority of the so-called K-matrix method. These nuclear matter methods were used also to understand an interesting and difficult question of symmetry energy which he studied also with his students (P.Haensel). The next extension was an application of nuclear matter theory to systems with strange Lambda and Sigma hyperons in nuclear matter. His results established the limit of Lambda hyperon binding in large nuclei. In the last decades Janusz was involved in a more practical, phenomenological studies of few body systems, in particular those including hyperons. This activity attracted a number of his younger collaborators (J. Borysowicz, M. Dworzecka, E. Fedoryńska, J. Rożynek) and brought Janusz a definite recognition in this field.

Within the Nuclear Theory Department of NCNR, Janusz Dąbrowski is remembered as a helpful, warm and careful head. Some still remember collaboration of this department with the University of Tucson organized by him. In those days it offered an unique chance to work in the USA.

S. Wycech

NUCLEAR PHYSICS DIVISION

Head of Division: Professor Zygmunt Patyk

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Overview

Our scientific activities in 2016 concentrated mainly on two subjects: low energy nuclear physics and medium energy physics.

Activities of the low-energy direct reactions group in 2016 resulted in a total of seven publications in Physical Review C, one in Physical Review Letters and an invited talk at the Joint LIA COLL-AGAIN, COPIGAL, and POLITA Workshop held in Catania, Italy. A proposal to measure the near-barrier elastic scattering of ^{15}C from a ^{208}Pb target was accepted by the PAC of the REX-ISOLDE facility at CERN and will be scheduled for the summer of 2017 /N. Keeley/.

Collaboration with GSI-Darmstadt resulted in a direct mass measurement of 25 exotic nuclei for the first time. Masses were determined using isochronous mass spectrometry with an uncertainty of a few keV. The results were published in two papers Eur.Phys.J. A 52, 138 (2016) **)** *and Phys.Lett. B 754, 288 (2016). In collaboration with ISOLDE at CERN, lifetimes for the beta decay of the isotopes $^{148\text{-}150}Cs$ and $^{148\text{-}150}Ba$ were measured. The results were published in two papers (Journal of Physics G) /V. Charviakova, T. Cap, Z. Patyk/.*

In collaboration with the Warsaw FOPI group two papers were published on strange ψ-meson production at GSI: Phys. Rev. C 94, 014901 (2016) and Eur. Phys. J. A52, 177 (2016) /V. Charviakova/.

In 2016 our group continued the analysis of the ternary partitions of the $^{197}Au+^{197}Au$ reaction at 23 MeV/nucleon measured with the CHIMERA detection system at Catania, Italy. A Monte-Carlo code was prepared and used to calculate the CHIMERA detection efficiency. To include the Coulomb three-body interaction in the final stage of the ternary partition we wrote a special code and used its results for the interpretation of the experimentally observed angular distributions. The ratio of dynamical ternary breakup of the Au+Au system to an equilibrated sequential breakup was established. Experimental results were compared to results of two theoretical approaches – quantum molecular dynamics and the classical trajectory with one body dissipation. The results were presented at the XXIII Nuclear Physics Workshop in Kazimierz Dolny and published in one paper /T. Cap/.

The group is involved in the Hermes collaboration at the Deutsches Elektronen Synchrotron (DESY) in Hamburg. The Hermes collaboration ceased basic activity at the end of 2014, however throughout the past year the group has taken part in an analysis and prepared publications on the ratios of helicity amplitudes for exclusive ω-meson electro-production on transversely polarized protons. The group continues an analysis of the decay of the Δ resonance into the lepton pair $^{+}e\ ^{-}e$ at the WASA experiment. The angular distributions of decay products of the virtual photon were studied in order to establish the polarization states of the photon. The WASA experiment has salso ceased taking data and part of the group is involved in an analyses of the Spin Density Matrix Elements (SDMEs) in the exclusive lepto-production of vector mesons in the COMPASS experiment /W. Augustyniak, B. Mariański, P. Żuprański/

The group are engaged in the large-scale international collaboration PANDA (antiProton ANihilations at DArmstadt) at FAIR. In 2016 they continued and completed contracts between FAIR, the Jagiellonian University and NCBJ. The contracts, if signed, will open the funding stream. A technical report (appendix to the contract) was prepared with a detailed description of the slow-control system for the cluster-jet target for the PANDA detector. The group contributed to three papers published in refereed journals, e.g. Nucl. Phys. A954 (2016) 323 /B. Zwięglinski, A. Trzcinski, G. Kęsik/.

Zygmunt Patyk

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Recent results on exclusive processes at Hermes
B. Mariański
4th Workshop on the QCD Structure of the Nucleon (QCD-N 16) (Spain, Bilbao, 2016-07-11 - 2016-07-15)

Fusion-fission Probabilities, Cross Sections and Structure Notes of Superheavy Nuclei
M. Kowal, K. Siwek-Wilczyńska, **T. Cap**, P. Jachimowicz, **J. Skalski**, **J. Wilczyński**
Chemistry and Physics of Heavy and Superheavy Elements (Sweden, Bäckaskog Castle, 2016-05-29 - 2016-06-03)

Direct Reactions With Light Radioactive Beams
N. Keeley
Joint LIA COLL-AGAIN COPIGAL POLITA Workshop (Italy, Catania, 2016-04-26 - 2016-04-29)

Oral Presentation

Time sequence and time scale of heavy fragments emission in ^{197}Au + ^{197}Au collisions at 23A MeV
T. Cap, K. Siwek-Wilczyńska, **J. Wilczyński**
XXlll Nuclear Physics Workshop (Poland, Kazimierz Dolny, 2016-09-27 - 2016-10-02)

Poster

Change in the sensitivity of solid state nuclear track detectors for ions emitted from plasma
A. Malinowska, **M. Jaskóła**, **A. Szydłowski**
18th International Conference on the Physics of Highly Charged Ions (Poland, Kielce, 2016-09-11 - 2016-09-16)

Relative biological effectiveness of double ion beam containing carbon and oxygen ions
J. Czub, J. Braziewicz, D. Banaś, **M. Jaskóła**, U. Kaźmierczak, **A. Korman**, A. Lankoff, H. Lisowska, Z. Szefliński, A. Wójcik
18th International Conference on the Physics of Highly Charged Ions (Poland, Kielce, 2016-09-11 - 2016-09-16)

L-shell X-ray emission from atoms multiple ionized by fast S^{q+} ions with energy of 0,4 -3,8 MeV/amu
M. Jaskóła, **I. Fijał-Kirejczyk**, **A. Korman**, D. Banaś, J. Braziewicz, J. Choiński, U. Majewska, M. Pajek, J. Semaniak, W. Kretschmer, G. Lapicki, T. Mukoyama, D. Trautmann
18th International Conference on the Physics of Highly Charged Ions (Poland, Kielce, 2016-09-11 - 2016-09-16)

LECTURES, COURSES AND EXTERNAL SEMINARS

$\mu p \rightarrow \mu' p \rho 0$ Analysis of Exclusive VM at COMPASS with CAMERA [b]
W. Augustyniak
Geneve, CERN, 2016-01-25

An alternative method of track recognition in the MDC chamber[b]
A. Trzciński
Warsaw, WASA Analysis Meeting, 2016-05-30

SDMEs in exclusive omega production in 2012 data (status report)[b]
B. Mariański
Geneva, CERN, 2016-08-22

Exclusive omega-meson production in 2012 DVCS data[b]
B. Mariański
Closter Seeon, Germany, Compass Collaboration Meeting, 2016-09-09

Status of Exclusive VM analysis at COMPASS with CAMERA:$\mu p \rightarrow \mu' p + \varphi$, $\mu p \rightarrow \mu' p + \rho^0$.[b]
W. Augustyniak
Geneve, CERN, 2016-10-27

SDMEs in exclusive omega production in 2012 data (status report)[b]
B. Mariański
Geneva, CERN, 2016-10-27

SDMEs in exclusive omega production in 2012 data (status report)[b]
B. Mariański
Geneva, CERN, 2016-11-14

Status of Exclusive VM analysis at COMPASS with CAMERA$\mu p \rightarrow \mu' p + \varphi$, $\mu p \rightarrow \mu' p + \rho^0$.[b]
W. Augustyniak
Geneve, CERN, 2016-11-28

[b)] in English

DIDACTIC ACTIVITY

T. Cap - Open physics classes for school students organized by Polish Physics Society and the Faculty of Physics at the University of Warsaw.

T. Cap - Scientific supervision over the bachelor thesis conducted by Ms. Aleksandra Jaskulak at the Physics Department of the University of Warsaw under the guidance of prof. dr hab. Krystyna Siwek-Wilczyńska.

V. Charviakova - Physics Laboratory for students, Faculty of Physics, University of Warsaw

V. Charviakova - Summer School of Physics, Department of Physics, University of Warsaw

N. Keeley - Monographic Lectures in Nuclear Physics "Direct Nuclear Reactions", Faculty of Physics, 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

J. Wilczyński
Member of the Scientific Council of the National Centre for Nuclear Research in Otwock-Świerk

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

PERSONNEL

Research scientists

Witold Augustyniak, PhD*
Volha Charviakova, MSc
Tomasz Cap, MSc
Marian Jaskóła, Professor*
Nicholas Keeley, Assoc. Prof.
Andrzej Korman, PhD
Bohdan Mariański, PhD
Paweł Żuprański, Assoc. Prof.*
Bogusław Zwięgliński, Professor*
Zygmunt Patyk, Professor
Andrzej Trzciński, PhD

Technical and administrative staff

Dorota Dobrowolska
Grażyna Kęsik, Eng

- part-time employee

THEORETICAL PHYSICS DIVISION

Head of Division: Michał Kowal, Professor NCBJ
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Overview

The Theoretical Physics Department consists of 32 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, tring theory and cosmology.

Close collaboration with experimental groups in CERN and in other laboratories (GSI, GANIL, DUBNA, Kamiokande or Frascatti) should be mentioned. Results of our scientific activity in 2016 were presented in 140 publications in total, 18 among them with number of co-authors less than 5. Our results were presented on more than 50 coferences and/or workshops.

Our research effort was mainly concentrated on the following topics:

- properties of heavy and superheavy nuclei;
- properties of nuclear matter and nuclear collisions;
- exotic atoms;
- Bayesian approach to multi-parameter problems in physics;
- phenomenology of collisions of hadrons and leptons;
- dark matter;
- theoretical cosmology;
- string theory;
- nonlinear effects in extended media.

In all of them very inereting results were achived. Of special relevance and interest in 2016 are the following works:

1. "Vibronic framework for quantum mixmaster universe Nonadiabatic bounce and an inflationary phase in the quantum mixmaster universe" by P. Malkiewicz, E. Czuchry at. al.
2. "Nonextensive critical phenomena in the Nambu Jona-Lasinio model" by J. Rożynek and G. Wilk
3. "On the one loop $\gamma^* \rightarrow qq$ impact factor and the exclusive diffractive cross sections for the production of two or three jets" by L. Szymanowski at. al.

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, GSI, JINR, RIKEN).

Michał Kowal

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Hydrodynamics: surveying the scene
M. Spaliński
Mini workshop on collective effects in p+p, p+A and A+A (Poland, Kraków, 2016-05-19 - 2016-05-20)

Clocks and dynamics in Quantum Universe
P. Małkiewicz
II Sympozjum Sekcji Fizyki Oddziaływań Fundamentalnych PTF Collider Physics (Poland, Katowice, 2016-05-13 - 2016-05-15)

Dark matter – what it is and how to determine its properties
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, **A.J. Williams**
IDM-2016 (United Kingdom, Sheffield, 2016-07-18 - 2016-07-22)

Hydrodynamics: surveying the scene
M. Spaliński
Mini workshop on collective effects in p+p, p+A and A+A (Poland, Kraków, 2016-05-19 - 2016-05-20)

Nonadiabatic bounce in quantum cosmology
P. Małkiewicz
31st International Colloquium on Group Theoretical Methods in Physics (Brazil, Rio de Janeiro, 2016-06-19 - 2016-06-25)

Dark matter – what it is and how to determine its properties
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, **A.J. Williams**
Multi-DM (Poland, Warsaw, 2016-06-02 - 2016-06-05)

Nonhydro modes in relativistic hydrodynamics
M. Spaliński
The Big Bang and the little bangs - Non-equilibrium phenomena in cosmology and in heavy-ion collisions (Switzerland, Genewa, 2016-08-15 - 2016-08-26)

Clocks and dynamics in quantum models of gravity
P. Małkiewicz
Eighth International Workshop DICE2016 (Italy, Castiglioncello, 2016-09-12 - 2016-09-16)
J Phys Conf Ser (2016)

Three-tier approach to dark matter
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, **A.J. Williams**
Dark Matter 2016 Symposium (USA, Los Angeles, 2016-02-17 - 2016-02-20)

Toward hydrodynamics as an effective theory
M. Spaliński
XII Polish Workshop on Relativistic Heavy Ion Collisions (Poland, Kielce, 2016-11-04 - 2016-11-06)

Coherent states in a study of time problem
P. Małkiewicz
Coherent states and their applications: A contemporary panorama (France, Marsylia, 2016-11-14 - 2016-11-18)

Dark matter – what it is and how to determine its properties
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, **A.J. Williams**
II Sympozjum Sekcji Fizyki Oddziaływań Fundamentalnych PTF Collider Physics (Poland, Katowice, 2016-05-13 - 2016-05-15)

Candidates for long-lived high-K ground states in superheavy nuclei
P. Jachimowicz, **M. Kowal**, **J. Skalski**
Joint LIA COLL-AGAIN COPIGAL POLITA Workshop (Italy, Catania, 2016-04-26 - 2016-04-29)

Lessons from hydro at large orders
M. Spaliński
Various Faces of QCD 2 (Poland, Otwock-Świerk, 2016-10-08 - 2016-10-09)

Integrable part of the regularized Mixmaster
H. Bergeron, **E. Czuchry**, J.-P. Gazeau, **P. Małkiewicz**
Coherent States and their applications: A contemporary panorama (France, Marsylia, 2016-11-13 - 2016-11-18)

A New Generic Cosmological Scenario without Singularity
O. Hrycyna
The 3rd Conference of the Polish Society on Relativity (Poland, Kraków, 2016-09-25 - 2016-09-29)

Candidates for Long Lived High-K Ground States in Superheavy Nuclei
P. Jachimowicz, **M. Kowal**, **J. Skalski**
IWND16 (China, XingXiang, 2016-05-15 - 2016-05-19)

Probing BFKL dynamics in Mueller-Navelet jet production at the LHC
B. Ducloué, **L. Szymanowski**, S. Wallon
24th Low-x Meeting (Hungary, Gyöngyös, 2016-06-06 - 2016-06-11)

Singularity avoidance in the Mixmaster
H. Bergeron, **E. Czuchry**, J.P. Gazeau, **P. Małkiewicz**
Singularities of general relativity and their quantum fate (Poland, Warszawa, 2016-06-27 - 2016-07-01)

Fusion-fission Probabilities, Cross Sections and Structure Notes of Superheavy Nuclei
M. Kowal, K. Siwek-Wilczyńska, **T. Cap**, P. Jachimowicz, **J. Skalski**, **J. Wilczyński**
Chemistry and Physics of Heavy and Superheavy Elements (Sweden, Bäckaskog Castle, 2016-05-29 - 2016-06-03)

Baryon-to-meson transition distribution amplitudes: formalism and models
B. Pire, K. Semenov-Tian-Shansky, **L. Szymanowski**
Light Cone 2016 (Portugal, Lizbona, 2016-09-05 - 2016-09-08)
Few Body Syst. Vol. 58 No 2 (2017)

GPDs and transverse geometry in high-energy ep/pp/pA collisions
J. Wagner
Electron Ion Collider User Group Meeting 2016 (Usa, Berkeley, 2016-01-06 - 2016-01-09)

Structural effects: High-K ground and isomeric states - chance to increase the stability of superheavy nuclei
P. Jachimowicz, **M. Kowal**, **J. Skalski**
Zakopane Conference on Nuclear Physics 2016 (Poland, Zakopane, 2016-08-28 - 2016-09-04)

Oscillation phenomena in multiparticle production processes
G. Wilk, Z. Włodarczyk
XLVI International Symposium on Multiparticle Dynamics (ISMD2016) (Korea, Seogwipo (Jeju Island), 2016-08-29 - 2016-09-02)
EPJ Web Conf. 141, 01005(2017)

Timelike Compton Scattering
J. Wagner
ECT Trento Workshop : nucleon and nuclear structure through dileptons production (Italy, Trento, 2016-10-24 - 2016-10-28)

Classical dynamics of the Bianchi IX model: space-like and time-like singularities
S. Parnovsky, **W. Piechocki**
Astronomy and Space Physics (Ukraine, Kyiv, 2016-05-24 - 2016-05-27)

Addressing the issue of quantum spikes
W. Piechocki, **G. Plewa**
The 3rd Conference of the Polish Society on Relativity (Poland, Kraków, 2016-09-25 - 2016-09-29)

Investigation of the low-energy kaons hadronic interactions in light nuclei by AMDEUS
A. Scordo, **S. Wycech**
Meson 2016 (Poland, Krakow, 2016-06-02 - 2016-06-07)

Non-extensive critical effects in the nuclear mean field
J. Rożynek
Critical Point and Onset of Deconfinement (CPOD 2016) (Poland, Wrocław, 2016-05-30 - 2016-06-04)

Kaonic atoms and strangeness in nuclei: SIDDHARTA-2 and AMADEUS experiments M. Iliescu (Frascati) et al..
M. Iliescu, **S. Wycech**
XII International Conference on Beauty, Charm, and Hyperons in Hadronic Interactions (BEACH 2016)12–18 June 2016, George Mason University, Fairfax, Virginia, USA (USA, Fairfax, 2016-06-12 - 2016-06-18)

Reconstructing WIMP properties through signal measurements in direct detection, Fermi-LAT, and CTA
L. Roszkowski, **E. Sessolo**, **S. Trojanowski**, **A.J. Williams**
6th Roma International Conference on Astroparticle Physics (Italy, Frascati, 2016-06-21 - 2016-06-24)

Relativistic Nonextensive Mean Field Models
J. Rożynek
XXlll Nuclear Physics Workshop (Poland, Kazimierz Dolny, 2016-09-27 - 2016-10-02)

K- multi-nucleon absorption processes in hadronic interaction studies AMADEUS Collaboration
RaffaeleDelGrande, **S. Wycech**
Proceedings, 54th International Winter Meeting on Nuclear Physics (Bormio 2016) : Bormio, Italy, January 25-29, 2016 2016 PoS BORMIO2016 (2016) SISSA (2016-10-24)Conference: C16-01-25.2Contributions (Italy, Bormio, 2016-01-25 - 2016-01-29)

Dark matter – What it is and how to determine its properties
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, **A.J. Williams**
COSMO-16 (USA, Ann Arbor, 2016-08-08 - 2016-08-12)

Oral Presentation

Adiabatic Fission Barriers
P. Jachimowicz, **M. Kowal**, **J. Skalski**
Zakopane Conference on Nuclear Physics 2016 (Poland, Zakopane, 2016-08-28 - 2016-09-04)

Reconstructing WIMP properties through an interplay of signal measurements in direct detection, Fermi-LAT, and CTA searches for dark matter
L. Roszkowski, **E. Sessolo**, **S. Trojanowski**, **A.J. Williams**
COSMO-16 (USA, Ann Arbor, 2016-08-08 - 2016-08-12)

Trapping of Sigma+ in Nuclei
S. Wycech, K. Pisciccia
Meson 2016 (Poland, Krakow, 2016-06-02 - 2016-06-07)

Reconstructing WIMP properties through signal measurements in direct detection, Fermi-LAT, and CTA
L. Roszkowski, **E. Sessolo**, **S. Trojanowski**, **A.J. Williams**
SUSY2016: 24th International Conference on Supersymmetry and Unification of Fundamental Interactions (Australia, Melbourne, 2016-07-03 - 2016-07-08)

Poster

Wilczynski plot forever?
W. Gawlikowicz, **J. Błocki**
XXlll Nuclear Physics Workshop (Poland, Kazimierz Dolny, 2016-09-27 - 2016-10-02)
Acta Phys. Pol. B (2016)

EAS muons from Strange Quark Matter
M. Rybczyński, **G. Wilk**, Z. Włodarczyk
XLVI International Symposium on Multiparticle Dynamics (ISMD2016) (Korea, Seogwipo (Jeju Island), 2016-08-29 - 2016-09-02)
EPJ Web Conf. 141, 08012 (2017)

Supersymmetric dark matter with low reheating temperature
L. Roszkowski, **S. Trojanowski**, K. Turzyński
II Sympozjum Sekcji Fizyki Oddziaływań Fundamentalnych PTF Collider Physics (Poland, Katowice, 2016-05-13 - 2016-05-15)

LECTURES, COURSES AND EXTERNAL SEMINARS

Flavored gauge mediation in the Peccei-Quinn NMSSM[b]
E. Sessolo
Warsaw, University of Warsaw, 2016-03-01

Candidates for long-lived superheavy nuclei[a]
M. Kowal
Warszawa, Wydzial Fizyki, 2016-03-03

Hydrodynamics as an effective theory[a]
M. Spaliński
Cracow, AGH University of Science and Technology, 2016-03-04

Hydrodynamics as an effective theory[a]
M. Spaliński
Kielce, Jan Kochanowski University, 2016-04-27

Hydrodynamics for QGP[a]
M. Spaliński
Warszawa, Warsaw University, 2016-05-10

Non-thermal dark matter, low reheating temperature and supersymmetry[b]
S. Trojanowski
Warsaw, Department of Physics, University of Warsaw, 2016-05-23

Generation of entangled atom pairs from Bose-Einstein condensate[b]
M. Pylak
Kielce, Institute of Physics, Jan Kochanowski University, 2016-06-15

In search of Baryonium[b]
S. Wycech
Warsaw/Swierk, NCBJ, 2016-09-04

Reconstructing WIMP properties through signal measurements in direct detection, Fermi-LAT, and CTA[b]
E. Sessolo
Warsaw, Poland, University of Warsaw, 2016-11-14

Clocks in quantum gravity[b]
P. Małkiewicz
Paris, France, APC laboratory, Universite Paris Diderot, 2016-01-08

Neutralino dark matter: lessons from the LHC for direct and indirect detection searches[b]
E. Sessolo
Dortmund, TU Dortmund, 2016-01-14

SUSY dark matter: lessons from and for the early Universe[b]
L. Roszkowski
Irvine, Univ. of California at Irvine, 2016-02-16

Clocks and dynamics in quantum models of gravity[b]
P. Małkiewicz
Marseille, France, Centre de Physique Théorique - UMR 7332, 2016-02-24

What is dynamics in quantum gravity?[b]
P. Małkiewicz
Paris, France, LInstitut dAstrophysique de Paris (IAP), 2016-04-11

Reconstructing WIMP properties through signal measurements in direct detection, Fermi-LAT, and **CTA**[b]
E. Sessolo
Louvain, Belgium, Universite Catholique de Louvain, 2016-04-20

Anomalous Sigma+ emission[b]
S. Wycech
Warsaw, Warsaw University, Faculty of Physics, 2016-04-23

What is dynamics in quantum gravity?[b]
P. Małkiewicz
Cologne, Germany, University of Cologne, Gravitation & Relativity Group, 2016-07-12

Dark matter – what it is and how to determine its properties[b]
L. Roszkowski
Sheffield, University of Sheffield, 2016-07-19

Dark matter – what it is and how to determine its properties[b]
L. Roszkowski
London, UCL, 2016-10-07

Dark matter – what it is and how to determine its properties[b]
L. Roszkowski
Geneva, CERN, 2016-10-14

Dark matter – what it is and how to determine its properties[b]
L. Roszkowski
Heidelberg, MPI, 2016-11-07

a) in Polish
b) in English

INTERNAL SEMINARS

Internal clocks in quantum mechanics[b]
P. Małkiewicz
Warszawa, Zakład Fizyki Teoretycznej, Departament Badań Podstawowych, NCBJ, 2016-11-09

b) in English

DIDACTIC ACTIVITY

M. Pylak - Biophysics, practical classes for English Division WUM

L. Szymanowski - coorganizer
Third International Summer School of QCD:
Dense systems in QCD at asymptotical energies,
20.06.2016 - 01.07.2016, Laboratoire de Physique Théorique, Orsay, France

L. Szymanowski - Renaud Boussarie, LPT Orsay
"Perturbative study of selected exclusive QCD processes at high and moderate energies"

defense: 23 September 2016

LPT Universite Paris XI, Orsay

J. Wagner - Course for PhD students "Elements of Quantum Mechanics and Quantum Field Theory"

J. Wagner - Seminar "Foundations of Quantum Chromodynamics"

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
Ordinary member, Polish Society on Relativity

E. Infeld
Fellow of the Institute of Physics, London, UK
fellow
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
Member of Representative of Scientific Staff

J. Mielczarek
Polish Society on Relativity

A. Pędrak
Member of Organizing Committee on Various faces of QCD 2 in Swierk Otwock, Poland

W. Piechocki
Member of Organizing Committee on Singularities of General Relativity and their Quantum Fate in Warszawa, Poland
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
Session chairman on Varying constants and Fundamental Cosmology - Varcosmofun 16 in Szczecin, Poland
Session chairman on Dark Matter 2016 Symposium in Los Angeles, USA
Session chairman on IDM-2016 in Sheffield, United Kingdom
Reports on Progress in Physics, Reports on Progress in Physics, Institute of Physics Publishing

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 Organizing Committee on ECT Trento Workshop : nucleon and nuclear structure through dileptons production in Trento, Italy
member of PANDA Theory Advisoty Group

J. Wagner
Member of Organizing Committee on Various Faces of QCD 2 in Otwock-Świerk, Poland

PERSONNEL

Research scientists

Jan Błocki, Professor
Wojciech Brodziński, MSc
Ewa Czuchry, PhD
Luc Darme, PhD
Piotr Goldstein, PhD
Michał Heller, PhD *on leave*
Orest Hrycyna, PhD
Andrzej Hryczuk, PhD *on leave*
Eryk Infeld, Professor
Michał Kowal, Assoc.Prof.
Kamila Kowalska, PhD *on leave*
Przemysław Małkiewicz, PhD
Marek Pawłowski, 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, Assoc. Prof.
Andrzej Skorupski, PhD
Robert Smolańczuk, Assoc. Prof.
Adam Sobiczewski, Professor
Michał Spaliński, Professor
Lech Szymanowski, Professor
Sebastian Trojanowski, PhD
Jakub Wagner, PhD
Grzegorz Wilk, Professor
Sławomir Wycech, Professor
Paweł Ziń, PhD

PhD students
Varvara Batozskaya, MSc
Wojciech Brodziński, MSc
Palczewski Michal, MSc

Technical and administrative staff
Anna Sidor

HIGH ENERGY PHYSICS DIVISION

Head of Division: Maciej Górski, PhD

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Overview

The Division participates in many experiments in the domain of high energy physics. One may divide them into main three groups:

- Neutrino physics
- Fixed target accelerator experiments
- LHC experiments

We shall briefly describe them here.

The neutrino group of the High Energy Physics Division participates mainly in the T2K (Tokai to Kamioka) experiment and also other activities concerned with dark Matter searches. The main goal of T2K is the investigation of neutrino oscillations by registering them in the Near Detector (ND) close to the production point and 300 km away in the large water Cherenkov detector at the underground Kamioka site.

The T2K experiment presented the first results of a measurement of muon antineutrino disappearance, confirming results obtained previously in other experiments. The Warsaw laboratory participated actively in the data taking and in the analysis of the ND data. The comparison of these results with those obtained from the far detector permits the determination of the neutrino oscillation parameters.

Another important domain of the research of the neutrino group is participation in the NA61/SHINE experiment at the CERN SPS accelerator. One of its aims is a precise study of the secondary spectra of the particles produced in the interaction of protons with the Tokai target replica, crucial for the determination of the parameters of the neutrino beam.

The Compass experiment at the CERN SPS accelerator plays the world-leading role in the determination of the spin decomposition of the proton. By using high energy hadron and muon beams and polarized target the experiment provides information on the origin of the proton spin – how much of it comes from the spin of the quarks and gluons and how much from the orbital momentum of the partons. The group actively investigates exclusive vector meason production in the framework of studies of generalized parton distributions (GPDs) The GPDs give access to a 3-dimensional picture of the proton and to the orbital angular momentu of the quarks.

The KLOE experiment running at the DAΦNE e^+e^- storage ring concentrates on the properties of Φ meson decays with high-statistics. The group presently works on the upgrade of the software from its very old version.

The WASA detector collected large statistics of low energy interactions and the Warsaw group specializes in the study of rare decays of eta mesons, searching for possible deviations from the Standard Model.

The ALICE collaboration is one of four large experiments running at the LHC accelerator at CERN. Its principal aim is the study of the properties of the collisions of heavy ions (lead) at extremely high energies. The experiment also takes data for the proton-proton and lead-proton interactions, which are used to determine whether there are differences between simple predictions for the heavy ion interactions and what is actually obtained. The activities of the Warsaw ALICE group, apart from participation (past and present) in the construction and maintenance of the Electromagnetic Calorimeter PHOS, are mainly centred on the reconstruction of π^0 meson spectra and prompt photon production. The prompt photons are an important tool for determining the properties of early stage of interaction.

The LHCb experiment deals mainly with the analysis of heavy flavor production and properties of such particles. The activities of the Warsaw group are centred mainly on searches for CP violation in their decays. The group also takes an active part in the detector maintenance and alignment as well as in software development.

The Warsaw CMS group takes an active part in this large collaboration. After being responsible for a long time for one of the muon triggering subsystems it now participates in its new stage. The analysis concentrates mainly on decays of the Higgs boson into a pair of τ leptons. Another area of activity is the search for HSCP (Heavy Stable Charged Particles) predicted by certain extensions of the Standard Model. Up to now no such objects have been found and activities concentrate on improving the mass and cross section limits obtained.

During 2016 members of the division published a total of 261 refereed papers, mostly originating from large international collaborations.

Maciej Górski

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Searches for BSM physics in diphoton final state at CMS
M. Kazana
SUSY2016: 24th International Conference on Supersymmetry and Unification of Fundamental Interactions (Australia, Melbourne, 2016-07-03 - 2016-07-08)

Strangeness production at SPS energies from the NA61/SHINE experiment
J. Stepaniak
The Third Strangeness Workshop (Poland, Warsaw, 2016-04-22 - 2016-04-23)

Latest (Anti-)neutrino Oscillation Results from T2K
J. Zalipska
BEACH 2016, XII International Conference on Beauty, Charm and Hyperons in Hadronic Interactions (USA, Fairfax, 2016-06-12 - 2016-06-18)

The PARTONS project and predictions for future GPD programme at COMPASS
P. Sznajder
IWHSS16 - International Workshop on Hadron Structure and Spectroscopy 2016 (Germany, Kloster Seeon, 2016-09-05 - 2016-09-09)

Heavy Ion Results of the CMS Experiment
B. Boimska
Cracow Epiphany Conference 2016 (Poland, Cracow, 2016-01-07 - 2016-01-09)
Acta Phys. Pol. B Vol. 47 No 6 (2016) 1397

Recent results from the LHCb Collabotaion at CERN
W. Wiślicki
Symposium KEK-PH 2016 (Japan, Tsukuba, 2016-02-08 - 2016-02-11)

The KLOE-2 Experiment at DAPHNE
W. Wiślicki
Heavy Quarks and Leptons 2016 (USA, Blackburg, 2016-05-23 - 2016-05-27)
Proceedings of Science Vol. 2016 (2016) 037

Status and perspectives with exotic states at LHCb
D. Melnychuk
Excited QCD 2016 (Portugal, Costa da Caparica, 2016-03-06 - 2016-03-12)

Energy loss in unstable quark-gluon plasma
St. Mrówczyński
Strong and Electroweak Matter 2016 (Norway, Stavanger, 2016-07-11 - 2016-07-15)

Discovery of pentaquarks by the LHCb Collaboration
W. Wiślicki
NA61/SHINE Symposium (Poland, Kielce, 2016-02-18 - 2016-02-19)

Astrophysical Searches with Neutrino Detectors
P. Mijakowski
II Sympozjum Sekcji Fizyki Oddziaływań Fundamentalnych PTF Collider Physics (Poland, Katowice, 2016-05-13 - 2016-05-15)

From Regensburg to Universal Hard-Loop Action
St. Mrówczyński
Workshop to celebrate 60th birthday of Ulrich Heinz (Switzerland, Genewa, 2016-07-18 - 2016-07-21)

Search for CPT symmetry violation in neutral meson oscillations
W. Krzemień
From Vacuum to the Universe, Humboldt Kolleg in Kitzbuehl (Austria, Kitzbuehl, 2016-06-26 - 2016-07-01)

My adventures with Marek event by event
St. Mrówczyński
Critical Point and Onset of Deconfinement (CPOD 2016) (Poland, Wrocław, 2016-05-30 - 2016-06-04)

Multiquark exotics at LHCb
W. Wiślicki
Various Faces of QCD (Poland, Świerk-Otwock, 2016-10-08 - 2016-10-09)

Recent results from the T2K experiment
P. Przewłocki
6th International Workshop on High Energy Physics on the LHC Era (HEP 2016) (Chile, Valparaiso, 2016-01-06 - 2016-01-12)

Neutrinos oscillate, so they have a mass
E. Rondio
XXlll Nuclear Physics Workshop (Poland, Kazimierz Dolny, 2016-09-27 - 2016-10-02)

Entanglement entropy and parity fluctuations
W. Wiślicki
XII Polish Workshop on Relativistic Heavy Ion Collisions (Poland, Kielce, 2016-11-04 - 2016-11-06)

Neutrino properties determined in the T2K oscillation experiment
E. Rondio, OnbehalfofT2KCollaboration
Theory, Phenomenology and Experiments in Flavour Physics - FPCapri2016 (Italy, Anacapri, 2016-06-11 - 2016-06-13)
Nucl Phys B-Proc Sup (2016)

Highlights of LHCb measurement in rare decays and discovery of first pentaquark states with Run1 data
A. Ukleja
XXII Cracow EPIPHANY Conference (Poland, Kraków, 2016-01-07 - 2016-01-09)

Neutrinos - experimental status and prospects
E. Rondio
DISCRETE 2016: Fifth Symposium on Prospects in the Physics of Discrete Symmetries (Poland, Warszawa, 2016-11-28 - 2016-12-03)

Charm mixing and CP violation at the LHCb experiment
A. Ukleja
Heavy Quarks and Leptons 2016 (USA, Blackburg, 2016-05-23 - 2016-05-27)

Neutrinos - experimental status and prospects
E. Rondio
Corfu Summer Institute: Summer School and Workshop on the Standard Model and Beyond (Greece, Corfu, 2016-08-31 - 2016-09-12)

HGTR opportunities in Poland / Europe
G. Wrochna
HTR 2016 - International Topical Meeting on High Temperature Reactor Technology (USA, Las Vegas, 2016-11-07 - 2016-11-10)

Neutrino properties determined in oscillation experiments
E. Rondio
II Sympozjum Sekcji Fizyki Oddziaływań Fundamentalnych PTF Collider Physics (Poland, Katowice, 2016-05-13 - 2016-05-15)

SUSY searches at the CMS
M. Kazana
XXII Cracow EPIPHANY Conference (Poland, Kraków, 2016-01-07 - 2016-01-09)
Acta Phys. Pol. B Vol. 47 No 6 (2016) 1489

Searches for long-lived particles at CMS
M. Kazana
SUSY2016: 24th International Conference on Supersymmetry and Unification of Fundamental Interactions (Australia, Melbourne, 2016-07-03 - 2016-07-08)

The π^o and η meson decays in near threshold production experiments
J. Stepaniak
*Various Faces of QCD, Symposium of the Polish Physical Society (Poland, świerk-*Otwock, *2016-10-08 - 2016-10-09)*

Heavy Stable Charged Particles
M. Kazana, **P. Zalewski**, T. Addams, G. Bruno, J. Zobec, K. Ackert
Exotica Workshop (Switzerland, Zurich, 2016-12-01 - 2016-12-03)

Oral Presentation

Higgs boson parameters and fermionic decays
M. Bluj
28th Rencontres de Blois (France, Blois, 2016-05-29 - 2016-06-03)

Search for physics beyond the Standard Model in light meson decays with WASA detector
D. Pszczel
Invisibles 2016 Workshop (Italy, Padua, 2016-09-12 - 2016-09-16)

Hadron Production Measurements with NA61/SHINE for Neutrino Experiments
K. Kowalik
12th Rencontres du Vietnam (Vietnam, Quy Nhon , 2016-08-21 - 2016-08-27)
to be seen No. (2017)

Production and interaction of the η meson with nucleons and nuclei
W. Krzemień
14th International Workshop on Meson Production, Properties and Interaction (MESON2016) (Poland, Kraków, 2016-06-02 - 2016-06-07)
EPJ Web Conf. Vol. 130 (2016) 1

Search for non-standard nuclear matter with WASA-at-COSY (dibaryons and mesic nuclei)
W. Krzemień
Various Faces of QCD 2 (Poland, Otwock-Świerk, 2016-10-08 - 2016-10-09)

Nuclear energy in Poland - country report
G. Wrochna
Meeting of European Atomic Energy Society (Poland, Warszawa, 2016-06-04 - 2016-06-08)

Main Results from the European NC2I-R Project on Nuclear Cogeneration with High Temperature Reactors
M. Fütterer, **T. Jackowski**, **A. Przybyszewska**, **G. Wrochna**
HTR 2016 - International Topical Meeting on High Temperature Reactor Technology (USA, Las Vegas, 2016-11-07 - 2016-11-10)

COMPASS results on hard exclusive muoproduction
A. Sandacz
QCD Evolution 2016 Workshop (Netherlands, Amsterdam, 2016-05-30 - 2016-06-03)

HTGR - the SMS for UK, Poland and the World
G. Wrochna
Small Modular Reactor UK Summit (United Kingdom, London, 2016-10-18 - 2016-10-19)
Poster

Reconstruction of low momentum protons with fine-grained detector of the T2K experiment
J. Zalipska
XXVII International Conference on Neutrino Physics and Astrophysics (Neutrino 2016) (United Kingdom, Londyn, 2016-07-04 - 2016-07-09)
J Phys Conf Ser (2016)

Front-end electronics and hit position reconstruction methods for the J-PET scanner.
W. Krzemień
International Conference on Translational Research in Radio-Oncology -Physics for Health in Europe 2016 (Switzerland, Genewa, 2016-02-15 - 2016-02-19)
Radiother. Oncol. Vol. 118 (2016) 117

Statistical Analysis of Time Resolution of the J-PET Scanner
L. Raczyński, **W. Wiślicki**, **P. Kowalski**, **W. Krzemień**, D. Alfs, T. Bednarski, P. Białas, C. Curceanu, E. Czerwiński, K. Dulski, A. Gajos, B. Głowacz, M. Gorgol, B. Hiesmayr, B. Jasinska, D. Kaminska, G. Korcyl, T. Kozik, N. Krawczyk, E. Kubicz, M. Mohammed, M. Pawlik-Niedzwiecka, S. Niedzwiecki, M. Palka, Z. Rudy, O. Rundel, N.G. Sharma, M. Silarski, J. Smyrski, A. Strzelecki, A. Wieczorek, B. Zgardzińska, M. Zieliński, P. Moskal
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Indirect Dark Matter Searches with Super-Kamiokande
K. Frankiewicz, K. Choi, **P. Mijakowski**
XXVII International Conference on Neutrino Physics and Astrophysics (Neutrino 2016) (United Kingdom, Londyn, 2016-07-04 - 2016-07-09)

Muon neutrino and antineutrino selection in the tracker of the T2K off-axis near detector
P. Przewłocki, C. Riccio
XXVII International Conference on Neutrino Physics and Astrophysics (Neutrino 2016) (United Kingdom, Londyn, 2016-07-04 - 2016-07-09)
J Phys Conf Ser (2016)

In-kind contribution of Polish institutions to European X-ray free electron laser (Eu-XFEL) - status in. Dec. 2015
E. Pławski, J. Sekutowicz, **W. Grabowski**, **K. Kosiński**, **J. Lorkiewicz**, **M. Wojciechowski**, Z. Gołębiewski, K. Meissner, **G. Wrochna**, M. Duda, E. Górnicki, M. Jeżabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Sienkiewicz, M. Stodulski, J. Świerblewski, M. Więcek, M. Chorowski, E. Rusiński, J. Fydrych, A. Iluk, K. Malcher, J. Poliński, P. Duda, J. Głowinkowski, P. Wilk, M. Winkowski, P. Grzegory, G. Michalski
European XFEL Users Meeting 2016 (Germany, Hamburg, 2016-01-27 - 2016-01-29)

Probing kaon-originated neutrinos with the muons produced outside of T2K Near Detector
J. Łagoda
XXVII International Conference on Neutrino Physics and Astrophysics (Neutrino 2016) (United Kingdom, Londyn, 2016-07-04 - 2016-07-09)
J Phys Conf Ser (2016)

LECTURES, COURSES AND EXTERNAL SEMINARS

Discovery of pentaquarks by the LHCb at CERN[b]
W. Wiślicki
Kraków, Uniwersytet Jagielloński, 2016-01-26

Neutrinos oscillate, so they have mass[a]
E. Rondio
Warsaw, Institute of Physics, Polish Academy of Science, 2016-02-23

Heavy ions in the CMS experiment[b]
B. Boimska
Warsaw, Institute of Experimental Physics, University of Warsaw, 2016-02-26

Search for the CPT symmetry violation in neutral meson system[b]
W. Krzemień
Cracow, Jagiellonian University, 2016-04-05

Analysis of $\eta \rightarrow e^+e^-\gamma$.[b]
D. Pszczel
Warsaw, Warsaw University, 2016-05-31

Universality of Hard-Loop Action[b]
St. Mrówczyński
Warsaw, Seminar of Fundamental Interactions, Faculty of Physics, Warsaw University, 2016-06-13

News in neutrino oscillation world - Neutrino 2016 Conference report[b]
P. Przewłocki
Warsaw, Faculty of Physics, University of Warsaw, 2016-10-07

Pentaquarks and other multiquark exotics at LHCb[b]
W. Wiślicki
Warsaw, University of Warsaw, 2016-11-10

Search for CPT symmetry violation in neutral flavour meson oscillations[b]
W. Krzemień
Warsaw, University of Warsaw, 2016-12-09

Search for a new dark boson in light meson decays.[b]
D. Pszczel
Warsaw, Warsaw University, 2016-12-16

International meeting on High Temperature Gas-cooled Reactors (HTGR): HTGR heat for European Industry[b]
G. Wrochna
Washington, NGNP Industrial Alliance, 2016-03-08

DIRAC Pilots evolution[b]
W. Krzemień
Geneva, CERN, 2016-05-31

Overview of the software architecture and data flow for the J-PET tomography device[b]
W. Krzemień
Kyiv, Shevchenko National University of Kyiv, 2016-09-01

Status of $\eta \rightarrow e^+e^-\gamma$ and $\eta \rightarrow e^+e^-$ analysis.[b]
D. Pszczel
Cracow, H. Niewodniczański Institute of Nuclear Physics PAN, 2016-10-20

Status of the search for $\eta \rightarrow \pi^0 e^+e^-$ decay from pp -> ppη reaction[b]
J. Stepaniak
Cracow, H.Niewodniczański Institute of Nuclear Physics PAN, 2016-10-21

Handlig data from complex detectors using Artificial Inteligence methods[b]
W. Wiślicki
Groningen, Kernfysich Versneller Institut Centre for Advanced Radiation Technologies, 2016-11-15

Status report on Nuclear Cogeneration Industrial Initiative[b]
G. Wrochna
Bratislava, General Assembly of Sustainable Nuclear Energy Technology Platform (SNETP), 2016-11-30
Neutrinos oscillate - so they have mass (Nobel Prize 2015)[a]
J. Łagoda
Świerk, NCBJ, 2016-01-10

From Ockhams razor to unit testing.[b]
W. Krzemień
Cracow, Jagiellonian University, 2016-07-08

[a)] in Polish
[b)] in English

INTERNAL SEMINARS

Discovery of pentaquarks by the LHCb at CERN[b]
W. Wiślicki
Warszawa, Uniwersytet Warszawski, 2016-01-15

Backgrounds in 3-body charm baryons decays[b]
A. Ukleja
Geneva, CERN, 2016-02-10

Upgrade of the presenter[b]
W. Krzemień
Frascati, INFN, Laboratori Natzionali di Frascati, 2016-03-18

Study of Rasnik alignment measurements[b]
A. Ukleja
Geneva, CERN, 2016-05-30

CP sensitive variables in the tau tau -> mu + pi (pi0) final state[b]
M. Bluj
Geneva, CERN, 2016-07-15

The RASNIK performance – study of the z movement[b]
A. Ukleja
Geneva, CERN, 2016-07-29

The RASNIK performance[b]
A. Ukleja
Geneva, CERN, 2016-08-04

Looking for CP asymmetry in prompt three-body charm baryon decays[b]
A. Ukleja
Geneva, CERN, 2016-08-17

Study of Rasnik alignment data[b]
A. Ukleja
Geneva, CERN, 2016-09-09

Status of Tau trigger and reconstruction[b]
M. Bluj
Geneva, CERN, 2016-09-15

NCBJ Symposium - High Temperature Reactors for Polish science and industry[a]
G. Wrochna
Otwock-Świerk, National Centre for Nuclear Research (NCBJ), 2016-10-05

Exotic hadronic states at LHCb[b]
D. Melnychuk
Warsaw, University of Warsaw, 2016-10-28

Baryon acoustic oscillations BAO[a]
M. Szeptycka
Warsaw, NCBJ, 2016-11-08

Status of Rasnik alignment analysis[b]
A. Ukleja
Geneva, CERN, 2016-12-05

[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 Andrzej Pyskir a doctoral student at Physics Department of University of Warsaw (with dr. hab. Artur Kalinowski)

E. Rondio - supervision of PhD student K. Frankiewicz

E. Rondio - supervision of PhD student M. Kabirnezhad

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

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

J. Stepaniak - Supervision of PhD student

J. Stepaniak - Supervision of two student's projects at Physics Faculty, University of Warsaw.

M. Szeptycka - 1. M Kasztelan BP4 experimantal test of the rresults of GEANT simulations for low energy nutrons.

2.W Orzyszczak UW Identification of particles in FGD of ND280 in the experiment T2K.

W. Wiślicki - Guiding PhD student Paweł Kowalski

J. Zalipska - Supervising student during her laboratory work. Winter semester 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
Scientific Council of the National Centre for Nuclear Research, deputy president

St. Mrówczyński
Member of Organizing Committee on Various faces of QCD 2 in Świerk, Poland
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

R. Sosnowski
Corresponding member of Polish Academy of Learning
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
Member Heavy Ion Laboratory

M. Szczekowski
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 Institution Board of the KLOE-2 Experiment
Member of the LHCb Collaboration Board
Member of the National Computing Board in LHCb
NCBJ
Member of the European Technology Platform for High Performance Computing

G. Wrochna
Session chairman on European Nuclear Conference in Warszawa, Poland
Member of Organizing Committee on Meeting of European Atomic Energy Society in Warszawa, Poland
Member of Advisory Board on European Nuclear Conference in Warszawa, Poland
Member of the Polish Nuclear Society
Member of the Physics Committee PAN
President of the Council of XFEL-Polska consortium
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

P. Zalewski
Session chairman on Cracow Epiphany Conference 2016 in Cracow, Poland
Programme Committee Member, Finance/Economics Committee Member; National Centre for Nuclear Research

PERSONNEL

Research scientists

Marek Adamus, PhD
Marcin Berłowski, PhD
Helena Białkowska, Professor*
Michał Bluj, PhD
Bożena Boimska, PhD
Maciej Górski, PhD
Julia Hoffman, PhD — on leave
Małgorzata Kazana, PhD
Katarzyna Kowalik, PhD
Wojciech Krzemień, PhD
Andrzej Kupść, PhD — on leave
Podist Kurashvili, PhD
Justyna Łagoda, PhD
Piotr Mijakowski, PhD
Dmytro Melnychuk, PhD
Stanisław Mrówczyński, Professor*
Adam Nawrot, Eng*
Paweł Przewłocki, PhD
Andrzej Sandacz, Professor
Teodor Siemiarczuk, Professor*
Ryszard Sosnowski, Professor
Dorota Stefan, PhD
Joanna Stepaniak, Professor*
Marek Szczekowski, Assoc. Prof.
Maria Szeptycka, Professor*
Michał Szleper, Assoc. Prof.
Paweł Sznajder, MSc
Piotr Szymański, Assoc. Prof — on leave
Piotr Traczyk, PhD — on leave
Artur Ukleja, PhD
Grzegorz Wrochna, Professor
Piotr Zalewski, PhD
Joanna Zalipska, PhD

PhD students

Katarzyna Frankiewicz, MSc
Monireh Kabirnezhad, MSc
Oleksander Kovalenko, MSc
Nair Rahul, MSc

* part-time employee

Technical and administrative staff

Tadeusz Marszał
Teresa Świerczyńska

ASTROPHYSICS DIVISION

Head of Division: Assoc. Prof. Agnieszka Pollo

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Overview

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 carries out active research in observational cosmology, high-energy astrophysics, and the search for astrophysical transient sources of different origin – from gravitational wave sources to gamma ray bursts (GRBs).

Undoubtly the main scientific event of 2016 was the first detection of gravitational waves and we are proud to have three co-authors of this discovery, members of the POLGRAW – Polish consortium forming part of the international LIGO/VIRGO consortium, 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. It participates and/or actively uses data from the largest projects in the field: VIPERS, VUDS, AKARI, WISE. A significant archievement in 2016 was the final release of the data from the VIPERS project. We co-organized the 2nd International Cosmology Summer School "Introduction to Cosmology" in Kielce and a national workshop on galaxy spectral energy distribution fitting methods in Warsaw.

Another centre of activity is the Pi of the Sky experiment, aiming at prompt detection of optical counterparts of GRBs, as well as other transient phenomena. In 2015 Pi observations were carried out by two observatories using in total five telescopes with 18 detectors operating in optical wavelengths. Their results, in colaboration with other international teams, resulted in publications in top astrophysical journals.

Our teams were involved in two space mission proposals submitted to the ESA M5 call: CORE, aimed at measurements of the polarisation of the CMB, and FLARE, aimed at detection of the highest redshift galaxies.

The Laboratory of Cosmic Ray Physics 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 method for experimental studies of very high energy Cosmic Rays.

In 2016 the main activity focused on participation in two space borne experiments: POLAR and EUSO. We are members of the POLAR Collaboration which built a Compton telescope dedicated to measurements of the polarisation of X rays arriving from Gamma-Ray Bursts (GRB). Polarisation measurements open a new window for studying GRBs. Since GRBs are extremely energetic events in the universe they are being considered as potential sources of ultra high energy cosmic rays. The POLAR detector was launched on the 15th of September 2016 together with the Chinese Space Station TiangGong-2 and has been taking data since then.

We participate in the JEM-EUSO Collaboration which is preparing a large UV space 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 now producing high voltage power supply units for the EUSO photomultipliers. In 2016 we made cosmic ray test measurements in Utah in coincidence with the Telescope Array experiment (EUSO-TA). We prepared power supply units for two other test experiments to be launched in 2017: SPB-EUSO and Mini-EUSO. SPB-EUSO is a NASA mission for a long term balloon flight (SPB - Super Pressure Balloon) and for cosmic ray extensive air shower measurements, and Mini-EUSO is an experiment for the International Space Station to measure the Earth's UV background.

KASCADE-Grande addresses experimentally the problems of the 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

REPORTS

Non-transparent web proxy server based on Squid software and the Linux operating system.
P. Tokarski
NCBJ

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

KASCADE-Grande: Composition studies in the view of the post-LHC hadronic interaction models
A. Haungs, **P. Łuczak**, **J. Zabierowski**
19th International Symposium on Very High Energy Cosmic Ray Interactions (Russia, Moscow, 2016-08-22 - 2016-08-27)
EPJ Web Conf. (in press)

Wielkoskalowa Struktura Wrzechświata
A. Pollo
OSSA 2016 (Poland, Kraków, 2016-09-22 - 2016-09-25)

Oral Presentation

EUSO - cosmic telescope for the highest energy Cosmic Ray and atmospheric phenomena observations.
J. Szabelski
Drugie Polsko-Francuskie Forum Nauki i Innowacji (Poland, Kraków, 2016-06-08 - 2016-06-08)

Review of revised version of paper on SF history in early type galaxies
M. Siudek, **K. Małek**, **A. Pollo**, M. Scodeggio, B. Garilli
XIV VIPERS Science Meeting (France, Marseille, 2016-10-10 - 2016-10-14)

Update on the TD F-stat all-skyfollowup stage
M. Bejger, P. Ciecieląg, **O. Dorosh**, **A. Królak**, M. Sieniawska
LVC Meeting September 2016 (United Kingdom, Glasgow, 2016-08-29 - 2016-09-01)

HVPS unit status (June 20, 2016).
J. Szabelski
19th JEM-EUSO International Meeting (France, Paryż, 2016-06-20 - 2016-06-24)

A new suggestion on a substitute of colour-colour selection
T. Krakowski, **K. Małek**, M. Scodeggio, T.T. Takeuchi
The 13th VIPERS meeting (Italy, Triest, 2016-04-11 - 2016-04-15)

Extrapolation of proton-proton cross section to Cosmic Ray Energies using Geometrical Model
Z. Plebaniak, **T. Wibig**
19th International Symposium on Very High Energy Cosmic Ray Interactions (Russia, Moscow, 2016-08-22 - 2016-08-27)
EPJ Web Conf. (in press)

Data Analysis for Pi of the Sky (a wide field instrument) for LSC-Virgo EM Follow-up project
A. Zadrożny
Virgo Week (Italy, Pisa, 2016-01-27 - 2016-01-29)

SEDfitting with CIGALE
K. Małek
XIV VIPERS Science Meeting (France, Marseille, 2016-10-10 - 2016-10-14)

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**
CRIS 2016 -10th Cosmic Ray International Seminar (Italy, Ischia, 2016-07-04 - 2016-07-08)
Nuclear and Particle Physics Proceedings (in press)

Gravitational waves and what they can tell us about universe
A. Zadrożny
7th Offtopicarium (Poland, Słomczyn, 2016-04-15 - 2016-04-17)

Update on unsupervised galaxy classification
K. Małek, M. Siudek, **T. Krakowski**, M. Scodeggio, T.T. Takeuchi
XIV VIPERS Science Meeting (France, Marseille, 2016-10-10 - 2016-10-14)

KASCADE-Grande Energy Reconstruction Based on the Lateral Density Distribution using the QGSJet-II.04 Interaction Model
A. Gherghel-Lascu, **P. Łuczak**, **J. Zabierowski**
Carpatian Summer School of Physics 2016 (Bulgaria, Sinaia, 2016-06-26 - 2016-07-09)
AIP Conf Proc (in press)

Searching for disappearing red giants (in Milky Way)
A. Zadrożny
Supernova Workshop 2016 (USA, Prescott, 2016-06-02 - 2016-06-03)

Cosmic ray physics with the KASCADE-Grande observatowy
J.C. Arteaga-Velazquez, **P. Łuczak**, **J. Zabierowski**
2016 International Conference on Ultra-High Energy Cosmic Rays - UHERC2016 (Japan, Kyoto, 2016-10-11 - 2016-10-14)
Japan Phys. Soc. Conf. Proceedings (2017)

Pi of the Sky involvement in LSC-Virgo Electromagnetic Follow-up project
A. Zadrożny
XXXVIII-th IEEE-SPIE Joint Symposium Wilga 2016 (Poland, Wilga, 2016-05-29 - 2016-06-06)
Proc. SPIE Vol. 10031 (2016) 1003141

Algorithm for searching for failed supernovae (for Pi of the Sky network)
A. Zadrożny
XXXVIII-th IEEE-SPIE Joint Symposium Wilga 2016 (Poland, Wilga, 2016-05-29 - 2016-06-06)

Searching for ULIRGs in AKARI ADF-S survey
K. Małek, M. Bankowicz, **A. Pollo**, T.T. Takeuchi, V. Buat, D. Burgarella, T. Goto, M. Malkan, H. Matsuhara
HECOLS Meeting (Poland, Warszawa, 2016-01-22 - 2016-01-22)

EM follow-up of LSC-Virgo gravitational wave transient candidates by Pi of the Sky telescope
A. Zadrożny
2nd International Cosmology School Introduction to Cosmology (Poland, Kielce, 2016-07-11 - 2016-07-24)

Star formation history of passive galaxies
M. Siudek, **K. Małek**, **A. Pollo**, M. Scodeggio, B. Garilli
The 13th VIPERS meeting (Italy, Triest, 2016-04-11 - 2016-04-15)

Searching for optical counterparts to gravitational wave events – and how it might be done by wide field surveys
A. Zadrożny
Varying constants and Fundamental Cosmology - Varcosmofun 16 (Poland, Szczecin, 2016-09-12 - 2016-09-17)

Classification and clustering analysis of infrared-selected galaxies in AKARI NEP Deep Field
A. Solarz, **A. Pollo**
Statistical Challenges in 21st Century Cosmology (Greece, Chania, 2016-05-24 - 2016-05-27)

Pi of the Sky - obecne projekty badawcze
A. Zadrożny
Wykorzystanie Małych Teleskopów 2016 (Poland, Kielce, 2016-09-23 - 2016-09-25)

Dark Energy and galaxy clustering - how LSST will gain from the experience of VIPERS and other ESO deep spectroscopic surveys
A. Pollo
LSST@Europe 2 (Serbia and Montenegro, Belgrad, 2016-06-20 - 2016-06-24)

Pi of the Sky - and Algorithms for Multi-messenger Astronomy Era
A. Zadrożny, L. Mankiewicz, A.F. Żarnecki
Astrophysics in the Era of Gravitational Wave and Multimessenger Observations (USA, Annapolis, 2016-11-09 - 2016-11-11)

Digging into polish tax law: or how I stopped worrying and loved data science
A. Zadrożny, M. Zadrozna
Science: Polish Perspectives 2016 (United Kingdom, Oxford, 2016-11-18 - 2016-11-19)

Time Domain F-stat analysis for RDC
A. Królak, M. Bejger, **O. Dorosh**
LSC-Virgo March 2016 Meeting (USA, Pasadena, 2016-03-14 - 2016-03-14)

Poster

Possibility of using archival data from wide field-of-view telescopes for searching for EM counterparts for sub-threshold GW candidates – on example of Pi of the Sky
A. Zadrożny, **A. Ćwiek**, M. Ćwiok, **A. Majcher**, L. Mankiewicz, R. Opiela, M. Zaremba, A. Zarnecki
LSC-Virgo March 2016 Meeting (USA, Pasadena, 2016-03-14 - 2016-03-14)

Development of POLAR experiment for the Gamma-Ray Bursts Polarimetry
A. Zwolińska
The 6th International Symposium on High-Energy Gamma-Ray Astronomy (Gamma2016) (Germany, Heidelberg, 2016-07-11 - 2016-07-15)
AIP Conference Proceedings No. (2016)

Properties and evolution of galaxy clustering at 2<z<5. Based on the VIOMS Ultra Deep Survey
A. Durkalec, **A. Pollo**, O. LeFevre
The galaxy life-cycle. From activity to quiescence, and back, across cosmic times (Italy, Venice, 2016-10-24 - 2016-10-28)

LECTURES, COURSES AND EXTERNAL SEMINARS

Detection of gravitational waves[a]
A. Królak
Warsaw, Faculty of Physics, Warsaw University, 2016-02-23

FLARE (First Light and Reionisation Explorer) satellite project - notes from the first science meeting[a]
K. Małek
Warsaw, National Centre of Nuclear Research, 2016-03-22

VIPERS - the story of the Large Scale Structure of the Universe from z ~ 1[b]
A. Pollo
Kielce, Jan Kochanowski University, 2016-04-20

[Ultra] Luminous Infrared Galaxies: which AGN types contribute to their infrared emission?[b]
K. Małek
Torun, Nicolaus Copernicus Astronomical Center, 2016-04-21

Mathematical aspects of gravitational wave observations[a]
A. Królak
Warsaw, Institute of Mathematics, Polish Academy of Sciences, 2016-04-28

Detection of gravitational wave signal by detectors on Earth[a]
A. Królak
Warsaw, Institute of Geophysics, Polish Academy of Sciences, 2016-09-07

How luminous galaxies trace dark Universe[a]
A. Pollo
Toruń, N. Copernicus University, 2016-11-07

Gravitational waves detected[a]
A. Królak
Krakow, Polska Akademia Umiejetnosci, 2016-11-14

Machine learning and its application to the galaxy science[b]
A. Solarz
Nagoya, Japonia, Nagoya University, 2016-01-15

Ultra Luminous Infrared Galaxies: which AGN types contribute to their infrared emission?[b]
K. Małek
Marseille, France, LAM, 2016-05-24

Ultra/Luminous Infrared Galaxies: which AGN types contribute to their mid infrared emission?[b]
K. Małek
Athens, Institue for Astronomy, Astrophysics, Space Aplications, and Remote Sensing, National Observatory of Athens, 2016-06-22

VIPERS: Universe in 3D at z~1[b]
A. Pollo
Beijing, Beijing Normal University, 2016-11-21

Detection of gravitational waves[a]
A. Królak
Krakow, Faculty of Physics, Jagiellonian Unoversity, 2016-02-22

Observations of gravitational waves from binary black hole merger[a]
A. Królak
Warsaw, Warsaw Polytechnic, Physics Committee of Polish Academy of Sciences, 2016-04-26

POLAR: Dedicated GRB Polarimeter[b]
J. Szabelski
Kobe, Japonia, Konan University, 2016-12-08

[a)] in Polish
[b)] in English

INTERNAL SEMINARS

Significance of the detection of a gravitational wave signal from a binary black hole merger[a]
A. Królak
Warsaw, National Center for Nuclear Research, 2016-04-18

Gravitationalk waves and multi-messenger astronomy[a]
A. Zadrożny
Warsaw, Faculty of Physics, University of Warsaw, 2016-04-18

Analysis of the light curve of the sybiotic X-ray binary GX 1+4[a]
A. Majczyna
Warsaw, National Centre for Nuclear Research, 2016-04-26

[[U]LIRGs: which AGN types contribute to their infrared emission?[a]
K. Małek
Warsaw, National Centre for Nuclear Research, 2016-05-31

Measurement of thermall neutrons. [a]
M. Kasztelan
Warsaw, NCBJ, 2016-08-09

Detection of gravitational wave signal by detectors on Earth[a]
A. Królak
Poznan, Institute of Molecular Physics, Polish Academy of Sciences, 2016-10-12

From analyzing computer logs to network analysis of law[a]
A. Zadrożny
Warszawa, Laboratorium Cyfrowej Humanistyki / Wydział MIMUW, Uniwersytet Warszawski, 2016-11-15

Luminosity and stellar mass dependency of galaxy clustering at z~3[b]
A. Durkalec
Warsaw, National Centre for Nuclear Research, 2016-11-22

a) in Polish
b) in English

DIDACTIC ACTIVITY

A. Pollo - OA UJ, mgr Magdalena Kuszewska, Search for candidates for cD galaxies and other giant elliptical galaxies in the VIPERS catalogue

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

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 the Audit Committee of the Main Board of the Polish Amateur Astronomers Association

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

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

Z. Plebaniak
JEM-EUSO Collaboration
A. Pollo
Member of Organizing Committee on 2nd International Cosmology School Introduction to Cosmology in Kielce, Poland
member, National Council for Astroparticle Physics

B. Szabelska
JEM-EUSO Collaboration memeber

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
Advances in High Energy Physics, Special Issue, Advances in High Energy Physics, Hindawi Publishing Corporation
member of Scientific Advisory Board
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

PERSONNEL

Research scientists

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Andrzej Królak*, Professor
Agnieszka Majczyna, PhD
Małek Katarzyna, PhD
AgnieszkaPollo, Assoc. Professor
Marcin Sokołowski, PhD
Aleksandra Solarz, PhD
Barbara, Szabelska*, PhD
Jacek Szabelski, PhD,
Teresa Tymieniecka*, Professor
Tadeusz Wibig*, Assoc. Professor
Janusz Zabierowski, Professor
Adam Zadrożny, PhD

Technical research staff

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Ariel Majcher, Msc
KrzysztofNikliborc , MSc Eng
Jerzy Orzechowski, MSc Eng
Zbigniew Plebaniak , MSc Eng
Paweł Pluciński, MSc
Wojciech Skowronek
Maciej Suchiński, MSc Eng
Jacek Karczmarczyk
Przemysław Tokarski, MSc Eng
Anna Zwolińska, MSc Eng

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NUCLEAR TECHNIQUES &EQUIPMENT DEPARTMENT

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Overview

The Department of Nuclear Techniques and Equipment has ~100 employees, including 2 professors, 5 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 that is managed by theHead of Department, 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, IEEE Transactions on Nuclear Science, Nuclear Fusion, Plasma Physics and Controlled Fusion, Radiation Measurements, and many others. Among others, in 2016 we published important results on:

- A new method for designing dual foil electron beam forming systems.
- Energy resolution and slow components in undoped CSI crystals.
- A digital approach to high count rate gamma-ray spectrometry.
- Detection of explosives by means of fast neutron activation analysis.
- Change in the sensitivity of PM-355 track detectors for protons after long – term storage.
- Estimation of plasma electron temperature based on soft X-rays in high-current plasma-focus discharges.
- Machine-learning identification of galaxies in the WISE x supercosmos all-sky catalogue.

In 2016 the Department's activity was focused on the development of accelerators for medicine, science and industry as well as detection systems based on scintillators and new generation photomultipliers. We also developed advanced detection systems for industry, research thermonuclear reactors, space-lab and for micro-dosimetry and air pollution. In 2016 the Department's activity was also related to the commercialization process for medical accelerators, a neutron activation analyser and X-ray radiography systems constructed in the Accelerators and Detectors (A&D) project. Among others, an agreement on the commercialization of the Polish Control System Cargo 'Canis' was signed between the National Centre for Nuclear Research (NCBJ) and the PID-Polska company. This is an important milestone in bringing to market a unique technology developed largely by our department.

Our research groups participated in the following National 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,
- RaM-ScaN - development of a Prompt Gamma Neutron Activation Analysis system for controlling the chemical composition of raw materials in cement production,
- POLAR - development of digital electronics for space-lab polarization measurements of Gamma Ray Bursts,
- 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 jet tokamak and Cherenkov-type detectors, designed for the FTU and Compass tokamaks,
- GBAR - construction of a 9-MV accelerator for the GBAR experiment at CERN, in particular integration of key accelerator elements including the accelerating structure,
- 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

PARTICLE ACCELERATION PHYSICS & TECHNOLOGY DIVISION

Head of Division: Sławomir Wronka PhD Eng

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Overview

The activities of the TJ1 department are focused on the development of new acceleration techniques and technologies, as well as on applications of particle accelerators. Its main expertise is concentrated on cavity optimisation, calculation of magnets, transfer lines, sources and targets, collimators and applicators. In particular, beam dynamics calculations and Monte Carlo simulations of accelerator heads and detectors are continuously performed for different projects.

The main activities of the TJ1 department in 2016 were related to the development of the CANIS system, measurements of a new IORT accelerator, starting-up of the Gamma Blockers for the ESS (European Spallation Source), participation in the GBAR experiment and in the ENS (Early Neutron Source) project .

The Medical Physics group's main activity was concentrated on upgrading the Jet Counter nanodosimetry facility with the ability to measure the radial dependence of the ionization cluster spectra distribution in the ionization track of carbon ions.

The TJ1 department is quite well equipped with experimental accelerator stands. Due to the availability of radiographic detectors, a number of radiographic tests have been performed with good results.

Good perspectives were achieved for 300keV cineradiography, with current timing of up to10^5 frames per second.

A new and efficient method for designing passive beam forming systems was developed by dr Adrich as part of his habilitation thesis. The new method overcomes the deficiencies of previously known methods and, despite its computational complexity, allows for rapid and extensive optimization of beam forming systems for a broad range of applications. In addition, the new method allows some challenging design problems to be adressed that were practically not solvable before.

For the CANIS demonstrator an innovative solution has been prepared[1], which is an intra-pulse energy switching. Successful implementation of this feature can speed-up the cargo-scanning process by a factor of two.

The aim of the 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 the topics discussed briefly above are described in detail in separate articles.

The TJ1 department offers a friendly surrounding for young people, for many years engineering- and masters-degree theses have been carried out in cooperation with and under the supervision of our experts.

Also, summer work experience placements are offered to students, typically from Warsaw University and Warsaw University of Technology.

Sławomir Wronka

[1] PAtent pending

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

HOM Couplers and Absorbers - NCBJ In-kind Contribution to European XFEL
E. Pławski, J. Sekutowicz, **W. Grabowski**, **K. Kosiński**, **J. Lorkiewicz**, **M. Wojciechowski**, Z. Gołębiewski
Superconductivity & Particle Accelerators (Poland, Kraków, 2016-12-06 - 2016-12-07)
IFJ PAN, Kraków No. (2016) p. 17

Development of the electron linac for GBAR@CERN experiment
M. Staszczak
SPAS 2016 (Superconductivity & Particle Accelerators) (Poland, Kraków, 2016-12-06 - 2016-12-07)

Heuristic optimisation algorithms in the design of the ESS cold linac BLM system
M. Jarosz
Superconductivity & Particle Accelerators (Poland, Kraków, 2016-12-06 - 2016-12-07)

Gamma Blocker System for the European Spallation Source
K. Szymczyk
Superconductivity and Particle Accelerators 2016 (Poland, Kraków, 2016-12-06 - 2016-12-07)

Radioembolizacja - nowy standard terapii celowanej wątroby w leczeniu mCRC
A. Wysocka-Rabin
Rak Jelita Grubego:diagnostyka i leczenie, standardy-terazniejszość i przyszłość (Poland, Serock, 2016-03-03 - 2016-03-05)

Applying nuclear physics to the treatment of cancer today and tomorrow
A. Wysocka-Rabin
Women in Science-Tradition of Maria Skłodowska-Curie (Poland, Łódź, 2016-09-29 - 2016-09-30)

Accelerator technology development at NCBJ
S. Wronka
Superconductivity & Particle Accelerators (Poland, Kraków, 2016-12-06 - 2016-12-07)

Nowe rozwiązania techniczne i technologiczne w dziedzinie źródeł promieniowania i detektorów obrazujących
S. Wronka, **W. Dziewiecki**, **M. Matusiak**
Krajowa Konferencja Badań Radiograficznych (Poland, Bolesławiec, 2016-09-05 - 2016-09-07)

Experience on Electron Linacs at NCBJ
P. Adrich
Design Characteristics of a Novel Linear Accelerator for Challenging Environments: Improving global access to radiation therapy (Switzerland, Genewa, 2016-11-07 - 2016-11-08)

Oral Presentation

Mathematical modeling of neutron generation in natural uranium target assembly QUINTA irradiated by deuterons with energies from 1 to 8 GeV
A. Polański
XXIII International Baldin Seminar on High Energy Physics Problems - Relativistic Nuclear Physics and Quantum Chromodynamics (Russia, Dubna, 2016-09-19 - 2016-09-24)

Nitride Betavoltaic - Exploring the Concept
S. Grzanka, P. Laskowski, L. Marona, G. Targowski, **B. Zaręba**, **K. Wincel**, **M. Klimasz**, **T. Lotz**, P. Perlin, T. Suski
International Workshop on Nitride Semiconductors (IWN 2016) (USA, Orlando, 2016-10-02 - 2016-10-07)

Polish contribution to Beam Dynamic preliminary accelerator systems analysis in the Early Neutron Source project
W. Grabowski, **K. Kosiński**, **M. Staszczak**, **A. Wysocka-Rabin**
Superconductivity & Particle Accelerators (Poland, Kraków, 2016-12-06 - 2016-12-07)

Towards a test of the weak equivalence principle of gravity using anti-hydrogen at CERN
D. Banerjee, **M. Staszczak**, **S. Wronka**
Conference on Precision Electromagnetic Measurements (Canada, Ottawa, 2016-07-10 - 2016-07-15)

Nanodosimetry - a tool for investigating particle track structure in nanoscale
M. Pietrzak, **A. Bancer**, **S. Pszona**
radioWARSAW meeting (Poland, Warsaw, 2016-05-19 - 2016-05-19)

New and efficient method for designing dual foil electron beam forming systems.
P. Adrich
Low energy electron beams for industrial and environmental applications - EuCARD-2 Workshop with Industry (Poland, Warszawa, 2016-12-08 - 2016-12-09)

Poster

Comparison of prompt and delayed photofission neutron detection techniques using different types of radiation detectors
P. Sibczyński, **Ł. Świderski**, **M. Moszyński**, **A. Syntfeld-Każuch**, **J. Iwanowska-Hanke**, **K. Grodzicki**, **M. Matusiak**, **T. Kosiński**, F. Carrel, M. Hamel, A. Sari, A. Grabowski, F. Laine, A. Iovene, C. Tintori
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Verification of the GaN Diode Design Aspects Influencing the Intensity of the Electron Energy Deposition
P. Sobkowicz, P. Laskowski, S. Grzanka, **B. Zaręba**, **K. Wincel**
International Workshop on Nitride Semiconductors (IWN 2016) (USA, Orlando, 2016-10-02 - 2016-10-07)

Origins of silver and production of coins and jewelry in early medieval Poland
E. Miśta, **A. Gójska**, W. Duczko, **A. Turos**, P. Kalbarczyk, J. Dudek, A. Kędzierski, Wyczółkowski, R. Czech, M. Widawski, **T. Kosiński**, J. Gaca
41st International Symposium on Archaeometry (ISA2016) (Greece, Kalamata, 2016-05-15 - 2016-05-21)

Origins of silver and production of coins and jewelry in early medieval Poland
E. Miśta, **A. Gójska**, W. Duczko, **A. Turos**, P. Kalbarczyk, J. Dudek, A. Kędzierski, Wyczółkowski, R. Czech, M. Widawski, **T. Kosiński**, J. Gaca
Inspiracje i funkcje sztuki pradziejowej i wczesnośredniowiecznej (Poland, Biskupin, 2016-06-27 - 2016-06-29)

X-ray Computed Tomography study of ancient objects
E. Miśta, **T. Kosiński**, W. Weker
6th Meeting X-ray and other techniques in investigations of the objects of cultural heritage, Krakow, 19-21 May 2016 (Poland, Kraków, 2016-05-19 - 2016-05-21)

High resolution radiographic detector
W. Dziewiecki, **M. Matusiak**, **S. Wronka**
XXXVIII-th IEEE-SPIE Joint Symposium Wilga 2016 (Poland, Wilga, 2016-05-29 - 2016-06-06)

In-kind contribution of Polish institutions to European X-ray free electron laser (Eu-XFEL) - status in. Dec. 2015
E. Pławski, J. Sekutowicz, **W. Grabowski**, **K. Kosiński**, **J. Lorkiewicz**, **M. Wojciechowski**,

Z. Gołębiewski, K. Meissner, **G. Wrochna**, M. Duda, E. Górnicki, M. Jeżabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Sienkiewicz, M. Stodulski, J. Świerblewski, M. Więcek, M. Chorowski, E. Rusiński, J. Fydrych, A. Iluk, K. Malcher, J. Poliński, P. Duda, J. Głowinkowski, P. Wilk, M. Winkowski, P. Grzegory, G. Michalski
European XFEL Users Meeting 2016 (Germany, Hamburg, 2016-01-27 - 2016-01-29)

LECTURES, COURSES AND EXTERNAL SEMINARS

Therapeutical beam shaping in linear accelerators of electrons[a]
A. Wysocka-Rabin
Bydgoszcz, Oncological Centre in Bydgoszcz, 2016-01-08

Beam shaping in hadrontherapy[a]
A. Wysocka-Rabin
Bydgoszcz, Oncological Centre in Bydgoszcz, 2016-01-08

Nanodosimetry or how to track single ionizing events and what they tell us[a]
M. Pietrzak
Warsaw, Faculty of Physics, University of Warsaw, 2016-05-12

Design of the X-ray tube to the first stage of the MC calculation[a]
A. Wasilewski
Kielce, Jan Kochanowski University, Faculty of Mathematics and Natural Sciences, Institute of physics, 2016-10-13

MC simulations of the X-ray tube for the experimental setup using low energy X-rays for radiobiological studies (the first stage of calculations)[a]
A. Wysocka-Rabin
Kielce, Jan Kochanowski University, Faculty of Mathematics and Natural Sciences, Institute of Physics , 2016-10-13

[a)] in Polish

INTERNAL SEMINARS

Expected level and sources of stray radiation outside patient plane for the IntraDose accelerator. Geant4 simulations.[a]
P. Adrich
Otwock-Świerk, National Centre for Nuclear Research, 2016-01-11

Control of the electron flux supplied to the cell layer[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-01-11

Requirements for the experimental setup using low energy X-rays for radiobiological studies[a]
A. Wysocka-Rabin
Świerk, NCBJ, 2016-01-11

Laboratory of Accelerating Structures and High Frequency Systems. The work carried out in the laboratory.[a]
M. Staszczak
Otwock, National Centre for Nuclear Research, 2016-01-18

Multi-stage Monte-Carlo calculations in FLUKA code. Normalization of the results of the second stage.[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-01-27

Test of neutron moderation[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-02-02

Analysis of 300kV likeage radiation through the slot collimator and covered shipping container. Two-step method of calculation.[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-02-03

Neutron moderation for geometry in version 1[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-02-09

NCBJ contribution to Early Neutron Source project realised in frame of EUROfusion consortium[a]
A. Wysocka-Rabin
Świerk, NCBJ, 2016-02-10

Ionizing radiation safety of the IntraDose accelerator in context of the requirements of the PN-EN 60601-2-1 standard - Geant4 simulations. The beamstopper problem. Comparison with the literature.[a]
P. Adrich
Otwock-Świerk, NCBJ, 2016-03-07

NCBJ cooperation with the European Spallation Source in Lund[a]
K. Szymczyk
Warsaw-Otwock, National Centre for Nuclear Research in Poland, 2016-03-10

Test of neutron moderation from 2.45MeV source for geometry optimal for 14MeV source[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-03-21

Optimizing the upper layer of the neutron moderator for geometry in version 1[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-03-21

Optimizing the side layers of the neutron moderator for geometry in version 1[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-03-21

Discharges inside the triode gun - causes and possible ways to solve the problem.[a]
M. Staszczak
Otwock, National Centre for Nuclear Research, 2016-04-13

Simulation codes[b]
M. Staszczak
Otwock, National Centre for Nuclear Research, 2016-04-26

High resolution radiographic digital detector based on multi channel plates[a]
W. Dziewiecki
Warsaw, Warsaw University of Technology, 2016-05-04

Next generation method for designing passive electron beam forming systems[a]
P. Adrich
Otwock-Świerk, National Centre for Nuclear Research, 2016-05-19

Optimizing the lead reflector of neutrons for optial geometry of polyethylene shield[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-05-25

Optimizing the upper layer of the neutron moderator for the geometry with 20cm thickness lead reflector[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-05-25

Visualization of the neutron fluence for the optimal geometry[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-05-25

Visualization of the thermal neutron fluence for the optimal geometry[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-05-31

Study of the energy distribution of neutrons registered in the detectors[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-06-06

NCBJ Contribution to the task:Accelerator Systems in the WPENS project[a]
A. Wysocka-Rabin
Świerk, NCBJ, 2016-06-22

Study of the energy distribution of neutrons registered in the detectors. Calculations for the experimental setup.[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-07-18

Optimizing of the thickness of tungsten as a neutron generator with a 30MeV electron beam[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-08-29

Tungsten as a neutron generator with a 30MeV electron beam[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-09-12

Optimizing of the thickness of tungsten as a neutron generator with a 30MeV electron beam. Neutron reflector added.[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-10-05

Predatory publishing – don\'t get caught by surprise[a]
P. Adrich
Otwock-Swierk, National Centre for Nuclear Research, 2016-10-20

Test of angular distribution of neutron flux[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-10-28

Test of manually entered angular distribution of neutron flux[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-11-15

Design of the X-ray tube to the first stage of the MC calculation and the second stage of the MC calculation[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-11-21

Test of angular distribution of the neutron flux generated at the ellipsoid target[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-11-29

Test calculations of the possibility of generating neutrons with the 40MeV deuterium beam irradiating the lithium target[a]
A. Wasilewski
Świerk, National Centre for Nuclear Research, 2016-12-05

Analysis of discharges in the short 6MeV accelerating structure, possible solutions of the problem[a]
M. Staszczak
Otwock, National Centre for Nuclear Research, 2016-12-14

[a)] in Polish
[b)] in English

DIDACTIC ACTIVITY

A. Wasilewski - Teaching methods for Monte-Carlo computing trainee mgr Joanna Czub of Jan Kochanowski University in Kielce.

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

S. Wronka - PhD Thesis of W.Dziewiecki: "High resolution digital radiographic detector based on multi-channel plates"

S. Wronka - Supervising of the PhD thesis:
"Digital Radiographic Detector based on MPC plates"

S. Wronka - Supervising the PhD student. Topic: Intra-pulse energy switchning in electron linear accelerator

S. Wronka - Two engineering theses - supervising.

A. Wysocka-Rabin - Lectures for medical doctors "Therapeutical beam shaping in linear accelerators of electrons", Beam shaping in hadrontherapy", Oncological Centre in Bydgoszcz

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

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

S. Pszona
Institute of Electrical and Electronics Engineers, Inc

S. Wronka
Member of Organizing Committee on Design Characteristics of a Novel Linear Accelerator for Challenging Environments: Improving global access to radiation therapy in Genewa, Switzerland
Polish Society of Medical Physics

A. Wysocka-Rabin
Polish Society of Medical Physics
PTCOG
member, European Society for Therapeutic Radiology and Oncology
Polish Society of Radiation Oncology
WiN Poland, Women in Nuclear
Polish Nuclear Society
member , National Centre for Nuclear Research

PERSONNEL

Research staff

Sławomir Wronka, PhD DSc Eng
Przemysław Adrich, PhD
Aleksandr Bancer, PhD
Wojciech Dziewicki, MSc Eng
Wojciech Grabowski, MSc
Michał Jarosz, MSc Eng
Marcin Klimasz, MSc Eng
Tymoteusz Kosiński, Eng
Michał Matusiak, MSc Eng
Marcin Pietrzak, MSc Eng
Eugeniusz Pławski, PhD Eng
Aleksander Polański, PhD
Stanisław Pszona, PhD
Marcin Staszczak, MSc Eng
Karol Szymczyk, MSc Eng
Adam Wasilewski, PhD
Krzysztof Wincel, MSc Eng
Marcin Wojciechowski, MSc Eng
Jolanta Wojtkowska, PhD
Anna Wysocka-Rabin, Assoc. Prof.
Barbara Zaręba, MSc

Technical, administrative staff

Józef Bogowicz
Adam Dudziński
Elżbieta Jaworska
Andrzej Łubian

RADIATION DETECTORS DIVISION

Head of Division: Łukasz Świderski PhD
Phone: +48 22 273 16 03
e-mail: l.swiderski@ncbj.gov.pl

Overview

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:

- a 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,
- a study of the CsI:Tl response to gamma-rays at temperatures close to the liquid nitrogen boiling point,
- characterization of large size (48 × 48 mm^2) Silicon Photomultiplier (SiPM) performance for timing applications with large scintillators,
- development of new photomultipliers with the screening grid at the anode for TOF PET block detectors,
- characterization of the temperature dependence of La-GPS scintillators, gamma-ray response,
- neutron induced damage of MPPC's as photodetectors for scintillation light readout,
- 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 Si(Li) semiconductor detectors by means of an acceptor doping compensation method.

The results of our studies were used in the realization of several projects, including:

- C-BORD, Neutron activation: we have been involved in the development of the Rapidly Relocatable Tagged Neutron Inspection System (RRTNIS) for the detection of illicit goods and dangerous materials inside containers transported through sea-ports.
- C-BORD, Photofission: methods for detection of fissile materials by means of photofission have been studied using Threshold Activation Detectors containing fluorine.
- RaM-ScaN: the aim of the project was to develop a Prompt Gamma Neutron Activation Analysis system for controlling the chemical composition of raw materials used in cement production. The project has reached the DEMO phase at the Gorazdze Cement Plant.
- TAWARA_RTM: we have been involved in the development of a multi-step platform for detection and identification of trace activities in water processed in Waterworks. The DEMO phase took place at Warsaw Waterworks Plant in Wieliszew between May and October 2016.

Most of the scientific achievements of the Division were summarized in 19 refereed publications, published mainly in Nuclear Instruments and Methods A, IEEE Transactions on Nuclear Science, Radiation Measurements and Acta Physica Polonica A. Besides that, our scientists presented 17 contributions at international conferences – including 5 presentations at the IEEE Nuclear Science Symposium and Medical Imaging Conference 2016 in Strasbourg, France and 2 invited talks during various Workshops.

The Division has also been involved in scientific collaborations with a number of international centres, 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, Heavy Ion Laboratory, Poland and companies such as Saint-Gobain, France, Scionix B.V., Holland, Siemens Healthcare, USA, Syskon, OTJ Polon Wroclaw and Lubrina, Poland, Hamamatsu Photonics K.K., Tokuyama and C-and-A., Japan, ADIT, USA.

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

Łukasz Świderski

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Experimental Methods for Scintillator Characterization with Reference to Light Yield Non-proportionality, Energy Resolution and Scintillation Decay Time
Ł. Świderski, **M. Moszyński**, **A. Syntfeld-Każuch**
ICC-IMR - JSPS 161/186 Committee Joint International Workshop - Crystals and Their Applications Into Radiation Devices (Japan, Sendai, 2016-01-07 - 2016-01-08)

Organic and inorganic scintillators for neutron detection
M. Moszyński
Summer School on Neutron Detectors and Related Applications: NDRA-2016 (Italy, Riva del Garda, Trento, 2016-06-29 - 2016-07-02)

Oral Presentation

Study of CsI:Tl scintillators with different concentration of Tl at the temperature range from +30°C to -70°C
Z. Mianowska, **M. Moszyński**, **P. Sibczyński**, **Ł. Świderski**, **A. Syntfeld-Każuch**, **T. Szczęśniak**, A. Gektin, S. Vasyukov, R.T. Williams, S. Gridin, X. Lu, M.R. Mayhugh
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

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, C. Carasco, **K. Grodzicki**, A. Iovene, M. Lunardon, **M. Moszyński**, G. Nebbia, B. Perot, F. Pino, G. Sannie, A. Sardet, **P. Sibczyński**, L. Stevanato, **Ł. Świderski**, C. Tintori, S. Moretto
CAARI 2016. 24th Conference on Application of Accelerators in Research and Industry (USA, Fort Worth, 2016-10-30 - 2016-11-04)

Set-up optimization for measurements of CsI:Tl scintillation properties[b]
Z. Mianowska
Mediolan, University of Milano-Bicocca, 2016-09-13

Projekt C-BORD: efektywna inspekcja kontenerów w punktach kontroli granicznej. Rola Służby Celnej w Gdyni.
B. Kosk, **Ł. Świderski**
VII Międzynarodowa Konferencja Naukowo-Techniczna NATCON 2016 (Poland, Gdańsk, 2016-06-20 - 2016-06-22)

Poster

CsI:Tl Scintillation Pulse Shapes Measured with a SiPM Photodetector in a Liquid Nitrogen Cryostat
Ł. Świderski, **M. Moszyński**, **W. Czarnacki**, **Z. Mianowska**, **P. Sibczyński**, **T. Sworobowicz**, **T. Szczęśniak**, **A. Syntfeld-Każuch**, W. Klamra, R.T. Williams, S. Gridin, X. Lu, M.R. Mayhugh, A. Gektin, S. Vasyukov, C. Piemonte, A. Ferri, A. Gola
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Effective Container Inspection at BORDer Control Points - a project overview
P. Sibczyński
Drugie Polsko-Francuskie Forum Nauki i Innowacji (Poland, Kraków, 2016-06-08 - 2016-06-08)

Performance of the prototype LaBr3 spectrometer developed for the JET Gamma-ray Camera Upgrade
D. Rigamonti, **G. Bołtruczyk**, **M. Gosk**, **S. Korolczuk**, **S. Mianowski**, **I. Zychor**
21st Topical Conference on High Temperature Plasma Diagnostics (HTPD 2016) (USA, Madison, 2016-06-05 - 2016-06-09)

$CeBr_3$ –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**, V. Braic, R. CostaPereira, T. Craciunescu, D. Croft, M. Curuia, A. Fernandes, V. Goloborod'ko, G. Gorini, V. Kiptily, I. Lengar, J. Naish, R. Naish, M. Nocente, K. Schoepf, B. Santos, S. Soare, M. Tardocchi, V. Yavorskij, V.L. Zoita
29th Symposium on Fusion Technology (SOFT 2016) (Czech Republic, Prague, 2016-09-05 - 2016-09-09)

TAWARA_RTM – The Detection System for Real Time Monitoring of Radioactive Contamination in Water Processed at Water Treatment Facilities
M. Lunardon, **T. Batsch**, **J. Iwanowska-Hanke**, **M. Moszyński**, **Ł. Świderski**
2016 IEEE Symposium on Radiation Measurements and Applications (SORMA) (USA, Berkeley, 2016-05-22 - 2016-05-26)

Comparison of SensL and Hamamatsu 4x4 channel SiPM arrays in gamma spectrometry with scintillators
M. Grodzicka, **T. Szczęśniak**, **M. Moszyński**
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Design of the Rapidly Relocatable Tagged Neutron Inspection System of the C-Bord project
A. Sardet, **M. Moszyński**, **P. Sibczyński**, **K. Grodzicki**, **Ł. Świderski**
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Timing Resolution of Monolithic Scintillators Coupled to Large SiPM Arrays
T. Szczęśniak, **M. Grodzicka**, **M. Moszyński**, **D. Wolski**, **M. Szawłowski**
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Comparison of prompt and delayed photofission neutron detection techniques using different types of radiation detectors
P. Sibczyński, **Ł. Świderski**, **M. Moszyński**, **A. Syntfeld-Każuch**, **J. Iwanowska-Hanke**, **K. Grodzicki**, **M. Matusiak**, **T. Kosiński**, F. Carrel, M. Hamel, A. Sari, A. Grabowski, F. Laine, A. Iovene, C. Tintori
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Conceptual design of the Radial Gamma Ray Spectrometers system for alpha particle and runaway electron measurements at ITER
M. Nocente, **J. Rzadkiewicz**, **I. Zychor**
26th IAEA Fusion Energy Conference (Japan, Kyoto, 2016-10-17 - 2016-10-22)

Dynamic Derivative Convolution Algorithm for Prompt Gamma Neutron Activation Spectra
M. Neuer, **T. Szczęśniak**, H. Zastawny, E. Jacobs, **M. Grodzicka**
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

LECTURES, COURSES AND EXTERNAL SEMINARS

Expermental techniques for characterization of basic properties od scintillators[a]
Ł. Świderski
Warsaw, University of Warsaw, Faculty of Physics, 2016-12-15

NCBJ contribution to EUROfusion activities[b]
J. Rzadkiewicz
Warsaw, IPPLM, 2016-12-01

[a)] in Polish
[b)] in English

DIDACTIC ACTIVITY

M. Moszyński - J. Iwanowska-Hanke
The comparative studies of neutron detectors in the crysis of He-3 supply

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

M. Moszyński
Member of Advisory Board on Application of Novel Scintillators for Research and Industry in Dublin, Ireland
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)
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

J. Rzadkiewicz
Session chairman on Italy – Poland 5th Workshop in Warszawa, Poland
Chairman of the Governing Board of the Centre for Scientific and Industrial New Energy Technologies
Governing Board of the European Union’s Joint Undertaking for ITER and the Development of Fusion Energy (Fusion for Energy)
Member of Scientific & Technical Advisory Committee (STAC) in EUROATOM Horizon 2020

Ł. Świderski
Member of IEEE Nuclear and Plasma Sciences Society

A. Syntfeld-Każuch
Member of IEEE Nuclear and Plasma Sciences SocietyPERSONNEL
Member-observer of HiLumi LHC Collaboration Board

PERSONNEL

Scientific Staff

Eugeniusz Belcarz, MSc Eng
Wiesław Czarnacki, PhD
Martyna Grodzicka-Kobyłka, PhD Eng
Joanna Iwanowska-Hanke, MSc
Zuzanna Mianowska, MSc
Sławomir Mianowski, MSc
Marek Moszyński, Professor
Jacek Rzadkiewicz, PhD
Paweł Sibczyński, MSc
Agnieszka Syntfeld-Każuch, PhD
Marek Szawłowski, MSc Eng
Tomasz Szczęśniak, PhD
Łukasz Świderski, PhD
Dariusz Wolski, MSc Eng
Maciej Kapusta, PhD

Technical and administrative staff

Andrzej Dziedzic
Krzysztof Kostrzewa
Monika Kos, MSc
Tadeusz Sworobowicz
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ELECTRONICS AND DETECTION SYSTEMS DIVISION

Head of Division: Michał Gierlik, PhD

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The year 2016 was bustling with activity and while the teams felt the burden of additional tasks, the results achieved leave a feeling of deep satisfaction. Below are short descriptions of our main activities, categorized by subdivisions and the projects they belong to.

Laboratory of Spectrometry and Nuclear Electronics (Dr Michał Gierlik)

- Dr. Michał Gierlik and Piotr Mazerewicz MSc Eng, *The R&D contract with KGHM "Polska Miedź" S. A.*

The cooperation between NCBJ and our client from Lubin, KGHM "Polska Miedź" S.A. experienced a long pause in 2016, after rapid changes in the company management board. Eventually, in December we signed two contracts that mark progress in the industrial applications of Neutron Activation Analysis and X-Ray Fluorescence for appraising the quality and composition of copper ore at various stages of mining. It is noteworthy that both branches of this project have their roots in the Accelerators and Detectors project and contribute to the commercialization results of its results.

- 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 $CeBr_3$ 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. New electronics to be operated at D-T JET campaigns was designed and produced at NCBJ, especially an active voltage divider AVD@NCBJ – the Scionix company placed an order for this divider, completed in December 2016. Tests with dedicated new detector setups were performed at both NCBJ and JET, under laboratory conditions. The results obtained prove the correct and effective operation of a detector for the upgraded Gamma-ray Camera, consisting of MPPC, MTCD@NCBJ, TIA and a scintillator in measurements at rates up to ~1 Mcps. In 2016 we delivered to JET for the Gamma-ray Spectrometer a detector based on a 3″×3″ $CeBr_3$ scintillator coupled to a photomultiplier tube, and the results of tests have shown that this new detector equipped with the active voltage divider is well suited for measurements at rates up to ~1 Mcps.

- Dr. Jarosław Szewiński, LLRF for European Spallation Source

After almost 2 years of negotiations with ESS, finally on 8.11.2016 an agreement for participation in the LLRF system development was signed by the ESS. NCBJ participates in this topic as leader of the PEG (Polish Electronics Group), which is a consortium of NCBJ, Warsaw University of Technology and Łódź University of Technology. Within this contract, PEG will deliver 120 LLRF systems for ESS. These systems will made up of both COTS and custom design components. NCBJ will be responsible for the design of the "RTM Carrier", a custom PCB board and assembly and testing and shipment of LLRF systems to Lund. This project is planned for 5 years, and should finish at the end of 2021.

- Dr. Jarosław Szewiński, *Early Neutron Source*

In 2017 the TJ4 Division participated in the EUROfusion WPENS – Early Neutron Source project, also called IFMIF/DONES (DEMO Oriented Neutron Source). In the actual phase, the project was focused on the preparation of technical documentation for construction of thew facility, which was based mostly on the previous project approach called EVEDA. TJ4 members have been involved in the following tasks in this project:

- Project Integration: preparation of the Plant Integration Document
- Test Systems
  - Report on transport and dismantling of radioactive materials
  - Contribution to Start-Up Monitoring Module (STUMM) design
  - Test Systems Ancillaries – Design of the Test Systems control systems architecture
- Accelerator Systems: HEBT and DUMP diagnostics – review and comparison of possible beam loss monitors for DONES
- NCBJ grants for young researchers
  - Łukasz Kaźmierczak MSc, Design and implementation of a math library for analysis of gamma spectra and its practical use in the Tukan DSP software

The aim of the project is to build a math library for analysis of gamma spectra and a graphical user interface for the Tukan DSP software. One of the most important achievements is the implementation of an algorithm responsible for the search for peaks in the spectrum of gamma rays. The implemented function is used in matching Gaussian double peaks and will be available to the user as a tool for automatically finding a peak.

- Tomasz Krakowski MSc, Classification of VIPERS galaxies with unsupervised learning algorithms

Classification of galaxies in VIPERS gave us division of the data into twelves groups. The method used in this work allowed for a more subtle division of data than that achieved with the usual technique. To validate the group division given by the FisherEM algorithm we decided to conduct a series of tests with commonly used astronomy id parameters such as: “D4000”, “NUV-r – r-K”, “U-V”, “OII FLUX”, “OII EW”, “SFR”, “log ($M_{star}/M_{\odot}$)”. In the case of these parameters the separation of different types of galaxies isvisible.

- Astrophysics related projects
    - Dr. Tadeusz Batsch, SWISS project and POLAR experiment

On September 15th 2016 theChinese rocket Long March 2F was launched successfully, placing the Chinese space lab TG2, together with the POLAR detector in orbit. The event was widely covered by Chinese, Swiss and Polish media. Since the launch the instrument has run stably bringing useful data to Earth - based computing centre. Up to now it has registered several important observations. Data are available for all consortium members.

- Tomasz Krakowski MSc, Machine-learning identification of galaxies in the WISExSuperCOSMOS all-sky catalogue

The two currently largest all-sky photometric datasets, WISE and SuperCOSMOS, have been recently cross-matched to construct a novel photometric redshift catalogue. The aim of the project was the automatic identification of galaxies in these catalogues through an alternative approach of machine learning. The new approach yielded over 15 million galaxies.

- Tomasz Krakowski MSc, Spectrometry System for Nuclear Radiation

Work was mainly focused on performance improvements of the digital analyser Tukan DSP release candidate. A new circuit board was introduced with an improved power supply and a Wi-Fi communication module.

- Arkadiusz Chłopik MSc Eng, *The CANIS antidewing system*

The Interlaced Energy Scanning System (CANIS) demonstrator was intended for indoor use. In typical applications, however, it will be installed outside and exposed to atmospheric conditions. The device is waterproof, but not airconditioned, so there was a necessity to protect its sensitive electronics from dewing. An antidewing system was designed and a prototype was built and tested.

Laboratory of Environment Preservation Physics (Dr. Janusz Licki)

The hybrid process of the electron beam flue gas treatment process combined with a seawater scrubber enhanced with $NaClO_2$ solution and Michele’s buffer was applied to purification of exhaust gases with high NO_x concentration, above 1000 ppmv. The second study of this process was carried out at the laboratory plant in the Institute of Nuclear Chemistry and Technology in Warsaw. Ion-chromatographic analyses of washer effluents were performed to obtain information about by products formed in the process.

Laboratory of X-ray Radiation Physics (Piotr Mazerewicz Msc Eng)

Non-destructive XRF elemental analysis using a polycapillary.

A polycapillary is an array of small hollow glass tubes that is able to focus X-ray radiation. Such a device can measure X-ray fluorescence response from small sample areas. The Laboratory of X-ray Radiation Physics has investigated the physical properties of a polycapillary and its possible industrial applications.

Michał Gierlik

REPORTS

GSU D28 Report on neutron-photon transport calculations (IV). Evaluation of detector response to neutron and gammaradiations.
R. Kwiatkowski, **A. Urban**, **A. Brosławski**, **S. Korolczuk**, **I. Zychor**
Świerk

Origins and production of silver objects in Early Medieval Poland
E. Miśta, ... , **A. Turos**, **A. Gójska**, **M. Dorosz**, ... et al.
Annual Report NCBJ 2015, Otwock-Świerk

ENS-4.6.0.0-T10-05-N1 IPPLM contribution to TSA update of functions, requirements and interfaces, Document Id.: ENS-4.6.0.0-T10-05
J. Szewiński, **I. Petrenko**
Eurofusion, https://idm.euro-fusion.org/, Report IDM Ref. No. 2MTTJ7 (in press)

ENS-6.6.3.0-T7-02-N1 IPPLM Contribution to Conceptual Design Report, Subtask ENS-6.6.3.0-T7-02, Document Id.: ENS-6.6.3.0-T7-02,
J. Szewiński, **I. Petrenko**
EuroFusion, https://idm.euro-fusion.org/, Report IDM Ref. No.: 2MUN2A (in press)

IPPLM contribution to preliminary engineering design of irradiated materials and dismantling, project ENS, subtask ENS-4.1.2.0-T1-02, Document Id.:ENS-4.1.2.0-T1-02N1
J. Szewiński, **I. Petrenko**, **K. Szewczak**
EuroFusion, https://idm.euro-fusion.org/, Report IDM Ref. No.:2MSRJJ (in press)

Project Integration Document (PID), project ENS, Document Id. ENS-1.1.2.4-T4-02-R1
J. Szewiński, **I. Petrenko**, A. García, M. Sholtz, M. Ciotti
Eurofusion,https://idm.euro-fusion.org/, Report IDM Ref. No.: 2N45NL (in press)

Subtask ENS-4.4.1.1-T10-03 Concept of STUMM, pre-selection of instrumentation : Review of available sensors and commercial availability
M. Gierlik, **R. Kwiatkowski**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**, **I. Zychor**
Madrid (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Napromieniowanie spalin wiązka elektronów z akceleratora dla jednoczesnej redukcji emisji $SO_{2,\ NOx}$ i WWA z kotłów opalanych węglem
J. Licki, A.G. Chmielewski, Z. Zimek
XIII Konferencja Naukowa Pol-Emis 2016. Powietrze Atmosferyczne. JAKOŚĆ-ZAGROŻENIA-OCHRONA (Poland, Szklarska Poręba, 2016-06-01 - 2016-06-04)
Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2016 No. (2016) p. 212-222

Oral Presentation

A new suggestion on a substitute of colour-colour selection
T. Krakowski, **K. Małek**, M. Scodeggio, T.T. Takeuchi
The 13th VIPERS meeting (Italy, Triest, 2016-04-11 - 2016-04-15)

Update on unsupervised galaxy classification
K. Małek, M. Siudek, **T. Krakowski**, M. Scodeggio, T.T. Takeuchi
XIV VIPERS Science Meeting (France, Marseille, 2016-10-10 - 2016-10-14)

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, C. Carasco, **K. Grodzicki**, A. Iovene, M. Lunardon, **M. Moszyński**, G. Nebbia, B. Perot, F. Pino, G. Sannie, A. Sardet, **P. Sibczyński**, L. Stevanato, **Ł. Świderski**, C. Tintori, S. Moretto
CAARI 2016. 24th Conference on Application of Accelerators in Research and Industry (USA, Fort Worth, 2016-10-30 - 2016-11-04)

Mobilne laboratorium do analizy stanu zanieczyszczenia powietrza pyłem PM_{10}, $PM_{2,5}$ i PM_1 w wybranych lokalizacjach
J. Licki, **M. Lasiewicz**, **M.T. Kowalski**
XIII Konferencja Naukowa Pol-Emis 2016. Powietrze Atmosferyczne. JAKOŚĆ-ZAGROŻENIA-OCHRONA (Poland, Szklarska Poręba, 2016-06-01 - 2016-06-04)
Oficyna Wydawnicza Politechniki Wrocławskiej (Wrocław) No. (2016) p. 223

Polish Activities in Gamma-ray Diagnostics Upgrade at JET
I. Zychor
5th Italy – Poland Workshop (Poland, Otwock-Świerk, 2016-07-14 - 2016-07-15)

Poster

TAWARA_RTM – The Detection System for Real Time Monitoring of Radioactive Contamination in Water Processed at Water Treatment Facilities
M. Lunardon, **T. Batsch**, **J. Iwanowska-Hanke**, **M. Moszyński**, **Ł. Świderski**
2016 IEEE Symposium on Radiation Measurements and Applications (SORMA) (USA, Berkeley, 2016-05-22 - 2016-05-26)

STUMM Test module for a high intensity neutron stripping
W. Wiacek, A. Igielski, B. Gabanska, **M. Gierlik**, **R. Kwiatkowski**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**, **I. Zychor**
Zakopane Conference on Nuclear Physics (Poland, Zakopane, 2016-08-28 - 2016-09-04)

Technology secrets of precious metal artifacts from Nidajno bog site in Poland
A. Gójska, **E. Miśta**, A. RzeszotarskaNowakiewicz, T. Nowakiewicz, P. Kalbarczyk, J. Dudek
41st International Symposium on Archaeometry (ISA2016) (Greece, Kalamata, 2016-05-15 - 2016-05-21)

Design of the Rapidly Relocatable Tagged Neutron Inspection System of the C-Bord project
A. Sardet, **M. Moszyński**, **P. Sibczyński**, **K. Grodzicki**, **Ł. Świderski**
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Origins of silver and production of coins and jewelry in early medieval Poland
E. Miśta, A. Gójska, W. Duczko, **A. Turos**, P. Kalbarczyk, J. Dudek, A. Kędzierski, Wyczółkowski, R. Czech, M. Widawski, **T. Kosiński**, J. Gaca
41st International Symposium on Archaeometry (ISA2016) (Greece, Kalamata, 2016-05-15 - 2016-05-21)

Comparison of prompt and delayed photofission neutron detection techniques using different types of radiation detectors
P. Sibczyński, **Ł. Świderski**, **M. Moszyński**, **A. Syntfeld-Każuch**, **J. Iwanowska-Hanke**, **K. Grodzicki**, **M. Matusiak**, **T. Kosiński**, F. Carrel, M. Hamel, A. Sari, A. Grabowski, F. Laine, A. Iovene, C. Tintori
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Origins of silver and production of coins and jewelry in early medieval Poland
E. Miśta, **A. Gójska**, W. Duczko, **A. Turos**, P. Kalbarczyk, J. Dudek, A. Kędzierski, Wyczółkowski, R. Czech, M. Widawski, **T. Kosiński**, J. Gaca
Inspiracje i funkcje sztuki pradziejowej i wczesnośredniowiecznej (Poland, Biskupin, 2016-06-27 - 2016-06-29)

Development of a digital method for neutron-gamma discrimination based on matched filtering
S. Korolczuk, M. Linczuk, **I. Zychor**
4th International Conference Frontiers in Diagnostic Technologies (Italy, Frascati, 2016-03-30 - 2016-04-01)

Development of MPPC-based detectors for high count rate DT campaigns at JET
A. Brosławski, **G. Bołtruczyk**, **M. Gosk**, **S. Korolczuk**, **R. Kwiatkowski**, **A. Urban**, **I. Zychor**
29th Symposium on Fusion Technology (SOFT 2016) (Czech Republic, Prague, 2016-09-05 - 2016-09-09)

Conceptual design of the Radial Gamma Ray Spectrometers system for alpha particle and runaway electron measurements at ITER
M. Nocente, **J. Rzadkiewicz**, **I. Zychor**
26th IAEA Fusion Energy Conference (Japan, Kyoto, 2016-10-17 - 2016-10-22)

Gamma-ray spectroscopy of fusion plasmas at MHz counting rates with a compact LaBr3 detector and silicon photomultipliers
M. Nocente, **G. Bołtruczyk**, **A. Brosławski**, **M. Gosk**, **S. Korolczuk**, **I. Zychor**
21st Topical Conference on High Temperature Plasma Diagnostics (HTPD 2016) (USA, Madison, 2016-06-05 - 2016-06-09)

Performance of the prototype LaBr3 spectrometer developed for the JET Gamma-ray Camera Upgrade
D. Rigamonti, **G. Bołtruczyk**, **M. Gosk**, **S. Korolczuk**, **S. Mianowski**, **I. Zychor**
21st Topical Conference on High Temperature Plasma Diagnostics (HTPD 2016) (USA, Madison, 2016-06-05 - 2016-06-09)

$CeBr_3$ –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**, V. Braic, R. CostaPereira, T. Craciunescu, D. Croft, M. Curuia, A. Fernandes, V. Goloborod'ko, G. Gorini, V. Kiptily, I. Lengar, J. Naish, R. Naish, M. Nocente, K. Schoepf, B. Santos, S. Soare, M. Tardocchi, V. Yavorskij, V.L. Zoita
29th Symposium on Fusion Technology (SOFT 2016) (Czech Republic, Prague, 2016-09-05 - 2016-09-09)

LECTURES, COURSES AND EXTERNAL SEMINARS

Argentum Project 2014-2017[a]
A. Gójska
Warsaw, The Institute of Archaeology and Ethnology PAN, 2016-03-03

Simultaneous reduction of SO_2, NO_x and PAHs emission from coal-fired boiler by electron beam irradiation[a]
J. Licki
Warsaw, Institute of Power Engineering, Thermal Processes Department, 2016-11-09

[a)] in Polish

INTERNAL SEMINARS

EUROFusion project in 2016[a]
I. Zychor
Świerk, National Centre for Nuclear Research (NCBJ), 2016-12-09

[a)] in Polish

DIDACTIC ACTIVITY

I. Zychor - external supervisor for diploma student Valeria Perseo from University in Milano, title of work "Development of gamma ray spectroscopy camera for fusion plasmas"

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

A. Gójska
Polish Physical Society
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
Member of Organizing Committee on 5th Italy – Poland Workshop in Otwock-Świerk, Poland
PhD Proceedings Admission Committee Chairperson (since 2016), National Centre for Nuclear Research (NCBJ) Scientific Council

PERSONNEL

Scientific staff

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Stanisław Borsuk, MSc Eng
Andrzej Brosławski, MSc
Arkadiusz Chłopik, MSc Eng
Michał Gierlik, PhD
Marcin Gosk, MSc Eng
Krystian Grodzicki, MSc Eng
Zbigniew Guzik, Assoc. Prof.
Łukasz Kaźmierczak, MSc
Łukasz Komorowski, Eng
Stefan Korolczuk, MSc Eng
Marek Kowalski, MSc
Tomasz Krakowski, MSc
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Jakub Szymanowski, Eng
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PLASMA STUDIES DIVISION

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Overview

In 2016 the activities of the Plasma Studies Division was concentrated on two tasks, which were the continuation of previous research: 1) Studies of fast electrons, ions, neutrons, and X-ray emissions within different research facilities of the PF-, RPI-, ICF- and Tokamak-type (by means of different diagnostic techniques); 2) Investigation of high-temperature plasma streams and their interaction with solid targets.

Within the framework of a scientific collaboration between NCBJ (Otwock-Swierk), IFPiLM (Warsaw) and CVUT (Prague) several new experiments at the PF-1000U facility were performed. The main results can be summarized as follows:

- The insertion of an Al-wire did not prevent the formation of a pinch column;
- Fusion-produced neutrons (from discharges with the Al-wire) were emitted mainly during the transformation of the pinch column, when the wire corona was not interrupted;
- In discharges when a nitrogen admixture to the working gas (deuterium) was added, distinct current filaments of 1-2 mm in diameter were observed (mainly during the implosion and the pinch phase), and it was estimated that the electron density amounted to (3-7) x 10^{18} cm^{-3};
- Detailed interferometric measurements and X-ray diagnostics of pinched helium-plasma in PF-discharges with the Al-wire on the axis were performed and helical-, toroidal- and plasmoidal-structures were observed.

In 2016 studies of fast runaway electrons, carried out within the framework of the EUROfusion Consortium, were continued at the COMPASS tokamak (in the IPP ASCR, Prague). A new Cherenkov three-channel probe (with electron-energy thresholds equal to 58 keV, 145 keV and 221 keV, respectively) was applied during the 2016 winter campaign. It was shown that the first fast-electron peak usually appeared during the current ramp-up phase (even before the hard X-ray (HXR) pulse), and some electron signals also appeared during the emission of subsequent HXR peaks. A correlation of the Cherenkov signals with MHD activity was investigated. It was shown that the Cherenkov signals might corroborate the appearance of post-disruptive runaway electron beams in circular-plasma discharges with a massive Ar-puff.

Solid-state nuclear track detectors (SSNTDs) were applied in 2016 to an investigation of the acceleration of protons in plasmas, which were produced from thin targets irradiated by 45-femtosecond laser pulses of energy equal to 400 mJ at the PULSAR facility at the IPPLM. The application of such track detectors allowed energy spectra of the emitted particles to be measured and the appearance of fast protons of energy up to 2.1 MeV to be confirmed.

Studies of high-temperature plasma streams and their interaction with various targets were carried out during different experiments performed in 2016. Investigation of plasma produced during discharges in a so-called Gas-Controlled Impulse Plasma Deposition (GCIPD) facility, as used for the deposition of TiN layers, was carried out by means of the optical emission spectroscopy (OES) technique. Identification of many spectral lines of Ti- and N-ions was performed. Many efforts were devoted to research on soft X rays emitted from high-current PF discharges and to estimations of the plasma electron temperature. For PF-1000U discharges with gas puffing detailed studies of the soft X ray emission were performed with two couples of PIN diodes observing different regions of the pinch column. It was found that T_e could reach 210-550 eV near the electrode ends, and 110-115 eV at larger distances. Some filamentary plasma structures and several SXR peaks, which might correspond to "hot-spots", were recorded for deuterium-discharges performed with a small admixture of neon. Spectroscopic measurements of long deuterium- and helium-plasma jets, which might be used for astrophysical studies in the laboratory, were performed at the PF-1000U facility in collaboration with researchers from the IFPiLM and the Kurchatov Institute (Moscow).

Jarosław Żebrowski

REPORTS

GSU D28 Report on neutron-photon transport calculations (IV). Evaluation of detector response to neutron and gammaradiations.
R. Kwiatkowski, **A. Urban**, **A. Brosławski**, **S. Korolczuk**, **I. Zychor**
Świerk

Subtask ENS-4.4.1.1-T10-03 Concept of STUMM, pre-selection of instrumentation : Review of available sensors and commercial availability
M. Gierlik, **R. Kwiatkowski**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**, **I. Zychor**
Madrid (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Status and prospects of Cherenkov-type detectors for fast electron studies
M. Rabiński
Italy –Poland 5th Workshop Jointly organized by IPPLM and NCBJ (Poland, Otwock-Świerk, 2016-07-14 - 2016-07-15)

Czarnobyl - fakty i mity
M. Rabiński
IX Festiwal Filozofii Filozofia i technika (Poland, Olsztyn, 2016-09-07 - 2016-09-09)

Synteza termojądrowa
M. Rabiński
Akademickie Forum Energii Jądrowej (Poland, Kraków, 2016-05-19 - 2016-05-20)

Highlights of recent high-temperature plasma studies at the NCBJ, Poland
M.J. Sadowski, **E. Składnik-Sadowska**, **R. Kwiatkowski**, **A. Malinowska**, **K. Malinowski**, **K. Nowakowska-Langier**, **A. Szydłowski**, **J. Żebrowski**, **K. Czaus**, **W. Surała**, **D. Załoga**, M. Kubkowska, M. Paduch, R. Miklaszewski, E. Zielinska, P. Kubes, D. Margarone, J. Krasa, I. Garkusha, V. Makhlay, M. Ladygina
Annual Meeting of International Centre for Dense Magnetized Plasmas (ICDMP-2016) (Poland, Warsaw, 2016-10-14 - 2016-10-15)

Detektory typu Czerenkowa w badaniach tokamaków
J. Żebrowski, **L. Jakubowski**, **M. Rabiński**, **M.J. Sadowski**, **M.J. Jakubowski**, **K. Malinowski**, **R. Mirowski**, **R. Kwiatkowski**
Sympozjum Narodowego Centrum Badań Jądrowych NCBJ-2016 (Poland, Otwock-Swierk, 2016-10-05 - 2016-10-05)

Comments on recent studies of high-temperature plasmas at the NCBJ in Poland
M.J. Sadowski, **J. Żebrowski**
ICPPCF-2016 International Conference & School on Plasma Physics and Controlled Fusion (Ukraine, Kharkov, 2016-09-12 - 2016-09-15)

Research on PF-1000 during last year
P. Kubes, D. Klir, J. Cikhardt, J. Kravarik, K. Rezac, B. Cikhardtova, M. Paduch, E. Zielinska, **M.J. Sadowski**, **D. Załoga**, K. Tomaszewski
Annual Meeting of International Centre for Dense Magnetized Plasmas (ICDMP-2016) (Poland, Warsaw, 2016-10-14 - 2016-10-15)

Laboratory simulation of astrophysical jets on PF-3, PF-1000 and KPF-4
V. Krauz, V. Myalton, V. Vinogradov, E. Velikhov, S. Ananyev, S. Dan'ko, Yu. Kalinin, A. Kharrasov, Yu. Vinogradova, K. Mitrofanov, M. Paduch, R. Miklaszewski, E. Zielinska, **E. Składnik-Sadowska**, **R. Kwiatkowski**, **M.J. Sadowski**, **D. Załoga**, K. Tomaszewski, D. Vojtenko
Annual Meeting of International Centre for Dense Magnetized Plasmas (ICDMP-2016) (Poland, Warsaw, 2016-10-14 - 2016-10-15)

Investigation of x-ray emission from high-current discharges of the PF type
E. Składnik-Sadowska, **M.J. Sadowski**, **K. Malinowski**, **W. Surała**, **D. Załoga**, M. Paduch, E. Zielińska, K. Tomaszewski
ICPPCF-2016 International Conference & School on Plasma Physics and Controlled Fusion (Ukraine, Kharkov, 2016-09-12 - 2016-09-15)

Overview of Cherenkov proposals
M. Rabiński
19th IBA Meeting & 8th COMPASS Programmatic Conference (Czech Republic, Prague, 2016-09-21 - 2016-09-22)

Oral Presentation

Simulations of the GEM detector parameters
K. Malinowski, M. Chernyshova, T. Czarski, E. Kowalska-Strzęciwilk
XXXVIII-th IEEE-SPIE Joint Symposium on Photonics, Web Engineering, Electronics for Astronomy and High Energy Physics Experiment, Wilga 2016 (Poland, Wilga, 2016-05-30 - 2016-06-06)

Development of the GEM-based SXR tomography:current status
M. Chernyshova, T. Czarski, **K. Malinowski**, E. Kowalska-Strzęciwilk, S. Jabłoński, B. Bieńkowska, R. Prokopowicz, A. Ziółkowski, S. Jednoróg, W. Figacz, K. Poźniak, G. Kasprowicz, W. Zabołotny, A. Wojeński, P. Zienkiewicz, R. Krawczyk, P. Kolasiński, M. Polasik, K. Słabkowska, Ł. Syrocki, D. Mazon, F. Faisse, J.M. Verger, C. Coston, A. Jardin, P. Malard, S. Larroque, D. Vezinet, S. Eder, A. Herrmann
Italy –Poland 5th Workshop Jointly organized by IPPLM and NCBJ (Poland, Otwock-Świerk, 2016-07-14 - 2016-07-15)

Study of soft X-rays emission from PF-1000U discharges performed during the recent experimental campaign
D. Załoga, **E. Składnik-Sadowska**, **M.J. Sadowski**, **K. Malinowski**, M. Paduch, **W. Surała**, E. Zielińska, K. Tomaszewski
27th Symposium on Plasma Physics and Technology (SPPT-2016) (Czech Republic, Prague, 2016-06-20 - 2016-06-23)

Evolution of environmental pollution in the Chernobyl area and in Poland during 30 years after the accident
K. Isajenko, S. Kireev, K. Kuszneruk, J. Pluta, **M. Rabiński**, M. Szurmańska
European Nuclear Conference ENC-2016 (Poland, Warsaw, 2016-10-09 - 2016-10-13)

Poster

Research on interaction of pulsed plasma-ion streams with different energy fluxes with SiC and CFC samples
R. Kwiatkowski, **K. Nowakowska-Langier**, **E. Składnik-Sadowska**, **M.J. Sadowski**, **D. Załoga**, M.S. Ladygina
43rd EPS Conference on Plasma Physics (Belgium, Leuven, 2016-07-04 - 2016-07-07)

Change in the sensitivity of solid state nuclear track detectors for ions emitted from plasma
A. Malinowska, **M. Jaskóła**, **A. Szydłowski**
18th International Conference on the Physics of Highly Charged Ions (Poland, Kielce, 2016-09-11 - 2016-09-16)

$CeBr_3$ –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**, V. Braic, R. CostaPereira, T. Craciunescu, D. Croft, M. Curuia, A. Fernandes, V. Goloborod'ko, G. Gorini, V. Kiptily, I. Lengar, J. Naish, R. Naish, M. Nocente, K. Schoepf, B. Santos, S. Soare, M. Tardocchi, V. Yavorskij, V.L. Zoita
29th Symposium on Fusion Technology (SOFT 2016) (Czech Republic, Prague, 2016-09-05 - 2016-09-09)

Lead layer photocathodes for XFEL-type superconducting RF electron injectors - coating and processing at NCBJ Świerk
J. Lorkiewicz, **R. Nietubyć**, J. Sekutowicz, **A. Kosińska**, D. Kostin, **M. Barlak**, R. Barday, R. Xiang, J. Smedley, P. Kneisel, **R. Mirowski**, **J. Witkowski**
European XFEL Users Meeting 2016 (Germany, Hamburg, 2016-01-27 - 2016-01-29)

Development of MPPC-based detectors for high count rate DT campaigns at JET
A. Brosławski, **G. Bołtruczyk**, **M. Gosk**, **S. Korolczuk**, **R. Kwiatkowski**, **A. Urban**, **I. Zychor**
29th Symposium on Fusion Technology (SOFT 2016) (Czech Republic, Prague, 2016-09-05 - 2016-09-09)

STUMM Test module for a high intensity neutron stripping
W. Wiacek, A. Igielski, B. Gabanska, **M. Gierlik**, **R. Kwiatkowski**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**, **I. Zychor**
Zakopane Conference on Nuclear Physics (Poland, Zakopane, 2016-08-28 - 2016-09-04)

Chernobyl Exclusion Zone as an international training center
S. Akulinin, K. Isajenko, S. Kireev, P. Mielczarek, J. Pluta, **M. Rabiński**, Yu. Reikhtman
European Nuclear Conference ENC-2016 (Poland, Warsaw, 2016-10-09 - 2016-10-13)

LECTURES, COURSES AND EXTERNAL SEMINARS

Zone of Allienation - present status[a]
M. Rabiński
Białystok, University of Bialystok, Faculty of Physics, 2016-04-21

Chernobyl 30 years later; reasons od disaster and licquidation of effects[a]
M. Rabiński
Warsaw, Warsaw University of Life Sciences (SGGW), 2016-05-17

Student training in Chernobyl Zone of Allienation[a]
M. Rabiński
Warsaw, 25th International Educational Fair PERSPEKTYWY 2016, 2016-02-27

Chernobyl - facts and miths[a]
M. Rabiński
Olsztyn, University of Warmia and Mazury, 2016-04-22

Chernobyl - 30 years after the disaster[a]
M. Rabiński
Cracow, Center of Didactics, AGH University of Science and Technology, 2016-04-25

Drink Lugol\'s iodine, or Chernobyl 30 years later[a]
M. Rabiński
Warsaw, University of Warsaw, Biological and Chemical Research Centre, 2016-04-27

Does we need nuclear energy - safety, economy, ecology and people\\\\\\\'s interests? Priority dilemma[a]
M. Rabiński
Olsztyn, Center for Regional Development, 2016-09-07

a) in Polish

INTERNAL SEMINARS

Studies of hot plasma and prospects of thermonuclear energetics[a]
M.J. Sadowski
Otwock-Swierk, National Centre for Nuclear Research (NCBJ), 2016-02-18

Research on microstructure of a dense plasma column in discharges of the Plasma-Focus type[a]
M.J. Sadowski
Otwock-Swierk, National Centre for Nuclear Research (NCBJ), 2016-04-14

a) in Polish

DIDACTIC ACTIVITY

M. Rabiński - E. Wilińska - Analysis of the radioactive waste management system in the Chernobyl Exclusion Zone

M. Rabiński - K. Kuszneruk - Evolution of environmental pollution in the Chernobyl area and in Poland after the disaster in 1986

M. Rabiński - M. Szurmańska - Evolution of environmental pollution in the Chernobyl area and in Poland after the disaster in 1986

M.J. Sadowski - Superviser of a Ph.D. thesis of Wladyslaw Surala, which was entitled "Studies of electron beams and x-ray radiation in facilities of the Plasma-Focus type" and protected on Dec. 6, 2016.

M.J. Sadowski - Superviser of Ph.D. studies of M.Sc. Dobromil Zaloga (Vth year)

J. Żebrowski - Auxiliary promoter of Władysław Surała PhD thesis: „Studies on electron beams and X-ray radiation in Plasma-Focus type facilities"

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

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
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

E. Składnik-Sadowska
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Overview

The Division of Nuclear Equipment - HITEC carries out research and development, design, manufacture, installation and commissioning, sales and after sales support of advanced technical devices, including equipment producing ionizing radiation for medicine and industry.

The scope of our 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 for external recipients,
- Carrying out maintenance services,
- Cooperation with other scientific departments of NCBJ and other research institutions in Poland and abroad.

In 2016 HITEC focused on performing research and development activities related to the development of the intraoperative radiotherapy system within the INTRA-DOSE project. The IntraLine-IOERT accelerator is suitable for use in sterile conditions, and serves to irradiate tissues and organs with a spatially homogeneous and time-stable beam of electrons of high energy and intensity, administered directly to an open operating field. The exceptional mobility of the IntraLine-IOERT accelerator head makes it possible to deliver the therapeutic beam rapidly and comfortably directly to the area at risk. With the integrally built-in trolley the surgeon can move the IntraLine-IOERT accelerator to a standard operating table just for the time of irradiation. HITEC has begun work on the commercialization of the IntraLine-IOERT system.

Within the framework of international scientific cooperation in 2016, HITEC successfully completed the manufacture of the PI-Mode Structure (PIMS) accelerating cavities for LINAC4 as the continuation of the Collaboration Agreement with CERN aimed at upgrading the performance of the Large Hadron Collider (LHC).

HITEC's task included the initial and final machining of all elements of the 12 accelerator structures, their vacuum-tight soldering, coordination and technical control over electron welding of the cavities performed by the Forschungszentrum Julich, and the carrying out and documenting of a number of detailed qualitative tests.

Finally, on November 11, 2016, LINAC4 reached the projected proton energy of 160 MeV.

Within another agreement with CERN HITEC carried out work related to the GBAR experiment aimed at measuring the gravitational behaviour of antimatter. The work consisted of the development of the beam transport design, temperature stabilization system, gas and pneumatic installations and the construction of an electron accelerator. The electrical documentation, assumptions and installation methodology, and documentation of the safety instructions prevailing at CERN were developed.

In 2016 HITEC, together with other NCBJ scientific departments, began 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 main site.

Finally, in 2016 HITEC supplied radiographic accelerators and other goods and services to customers in Poland and abroad.

Edyta Dymowska-Grajda

DEPARTMENT OF COMPLEX SYSTEM

Head of division: Professor Wojciech Wiślicki
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Overview

Department of Complex Systems (DUZ) is mainly devoted to the computing-intensive research and systems with large number of degrees of freedom.

Department consists of two subdepartments, UZ1 and UZ3, and operates the large-scale computing infrastructure Computing Centre Świerk (CIS). The UZ1 is responsible for the information technologies development and support, IT services and running CIS. The UZ3 is responsible for R&D in nuclear technologies and environment analyses. In total, DUZ employs 63 people, about 30% of them being scientists and 60% are the technical, engineering and research support.

The computing infrastructure of CIS consists of the 1 petaflop CPU and GPU cluster and 17 petabyte disk storage. It is connected to the outside world by a redundant 10 Gbps link. Part of the processors are cooled using warm water and thus ensuring high power efficiency and environment friendliness. The cluster is connected to three independent power lines and, in addition, has its own Diesel generator, thus ensuring support of service machines in case of power cuts. The centre is located in a well-secured building with electronic security and fire control.

The staff pursues many projects in basic and applied science and engineering and is involved in a number of collaborations worldwide. In fundamantal science, the are: the grid-computing support for CERN experiments in particle physics, LHCb and CMS at the Large Hadron Collider (Tier-2 level), astrophysics projects in extragallactic astronomy and high-energy astrophysics, computational molecular chemistry in the domain of radiopharmaceuticals (a unique competence in Poland), medical diagnostics using PET (signal and image reconstruction and data processing), medical diagnostics using machine learning methods for textual information, managment of radioactive and chemical hazards in atmosphere, soil and water (chemicals and suspensions), security analyses and design of new nuclear reactors (collaborations with many nuclear centres, including Euroatom projects), energy distribution in power networks (government supported National Centre of Energy Analysis), IT technologies (engineering of file systems, grid middleware DIRAC, cybersecurity), film rendering for entertaiment movies (sponsorship program with Polish National Film Institute), processing of geo-location data from lidar, computational fluid dynamics applied to real systems (e.g. helicopters and nuclear reactors).

In 2016, employees of CIS published 290 papers from so called philadelphian list, about half of them in journals with impact factor above 5.

Wojciech Wiślicki

LABORATORY OF NUCLEAR ENERGY AND ENVIRONMENTAL STUDIES

Head of Division	Mariusz Dąbrowski, Professor
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e-mail:	Mariusz.Dabrowski@ncbj.gov.pl

Overview

Main scientific and technical achievements.

The main activities of the Neutronics and New Technologies Section were:

1. Neutron-physics analysis of research and power reactors:

- Burnup calculations for 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.
- Criticality safety study of pebble bed high temperature reactors based on the Chinese HTR-10 reactor.
- Neutron-physics safety analysis of a PWR core with new cladding material using the MCNP code.
    - Code comparison for depletion of gadolinium-bearing fuel rods in boiling water reactor assemblies – OECD benchmark.
    - Modelling of AP1000 fuel assemblies using the SCALE/NEWT code.

2. Development of Gas Cooled Reactor Technology and nuclear cogeneration:

- participation in the ESNII PLUS project. ALLEGRO is being developed as one of four fast reactor demonstrators under this EU programme. Common and coordinated activities were created by “The Project Coordination Team" from Poland, Slovakia, Hungary, the Czech Republic and France. The strategy document "ALLEGRO Roadmap" was published as a result of this cooperation.
- participation in two benchmarks related to criticality study and burnup calculations for the pin and assembly the ALLEGRO reactor core.

3. Education:

- training course with the Maria research reactor simulator for students in Nuclear Energy Postgraduate Studies from the Warsaw University of Technology.
- Scientific supervision of bachelor’s and master’s 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:

Activities in the field of safety assessment, code development and validation:

1. Severe accidents – molten core retention and propagation in the framework of the EU Horizon 2020 Euratom Project ”In-Vessel Melt Retention – IVMR”; conducted analyses: (i) studying the effects of turbulence on mixing and heat exchange between layers (ii) analytical evaluation and analysis of external boiling and convection, (iii) strength calculations of a structure element of the reactor pressure vessel;

2. Analysis of the possibilities of the system code CATHARE-3 in predicting the phenomenon of ”dryout” – drying fuel elements; work done includes : (i) comparison of results of the CATHAR-3 code with four series of adiabatic experiments and three sets of experiments with heat exchange, (ii) identification of phenomena that have the greatest impact on the measured values with their respective physical models, (iii) modification of the modelled phenomena in CATHARE-3 and their physical models;

3. Thermal-hydraulic analyses of selected components of the primary cooling system of the EPR reactor;

4. Development of the new code ”DARIA”: (i) the simulation engine balancing mass and energy in two-phase flow with heat exchange taking into account the three fields flow, (ii) prediction of dryout phenomena;

5. Thermal-hydraulic analyses of the cooling system of a gas-cooled fast reactor – steady state and selected ”protected” accidents;

6. Program supporting refuelling planning of the MARIA reactor with utilization of the REBUS code, and nuclear data libraries supporting required analyses;

In the field of the fuel cycle the following tasks were conducted:

1. Actinide burning and determination of the energy spectrum of neutrons in the ”KWINTA” assembly,
2. Analysis of the use of minority actinides as detectors of neutron fluence
3. Behaviour of fuel during operation (analysis of the process of recrystallization and grain poligonization of uranium dioxide during irradiation with neutrons, capabilities of immobilization of helium in the fuel UO2);
4. Dynamic modelling of the fuel cycle of a molten salts power reactor (MSR);
5. Study of the neutron field in spallation targets for optimal transmutation of radioactive waste.

The work of the **Centre of Hazard Analyses MANHAZ** (previously the Probabilistic Safety Analysis Team) was mainly concentrated on the analysis of environmental issues and risk analyses.

The most important activities were:

1. Development of computing tools for the safety analysis and optimization of the exploitation of light water reactors:
   - In the framework of the EU project ASAMPSA_E (Advanced PSA-Extended) preparation of several guidance documents on Probabilistic Safety Assessment, related to methods and models for including external human and natural hazards into analyses.
   - Expertise for the National Atomic Energy Agency on the methodologies of performing PSA-Level 2 and spent fuel damage analyses.
2. High fidelity models for energetic reactors suited to high performance computing:
   - Performing CFD prediction and uncertainty quantification of the GEMIX (Generic Mixing eXperiment) mixing layer test.
3. Development of tools for the analysis of the impact of nuclear installations on the environment:
   - Participation in UDINEE (Urban Dispersion International Evaluation Exercise) project aiming at the evaluation of atmospheric dispersion models in order to improve Decision Support Systems following radiological dispersion device events in an urban environment.
   - Development of the prototype version of the computerized system for risk assessment of a major accident in an industrial installation with potential off-site hazards – within the national project EVARIS.
   - Contribution to the safety and reliability analysis for the planned installation DONES (Demo Oriented Early Neutron Source) within the Eurofusion framework programme.

Mariusz Dąbrowski

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Scaling and correlations in electromagnetic cascades produced by gamma quanta in dense amorphous media
B. Słowiński, P. Duda, **J. Bzdak**, **D. Mączka**
XXIII International Baldin Seminar on High Energy Physics Problems - Relativistic Nuclear Physics and Quantum Chromodynamics (Russia, Dubna, 2016-09-19 - 2016-09-24)
In: XXIII International Baldin Seminar on High Energy Physics Problems. Book of abstracts. Dubna, Russia, September 19-24, 2016, p.127. No. (2016)

Heat exchange modelling in uranium fuel assembly – operating pressure case.
M. Wielgosz, **T. Kwiatkowski**, **P. Prusiński**, **D. Zgorzelski**
European Nuclear Conference ENC-2016 (Poland, Warsaw, 2016-10-09 - 2016-10-13)

Detailed Thermal-Mechanical Modelling of Cylindrical Core Support Plate During Severe Accident in PWR
M. Skrzypek, **E. Skrzypek**
25th International Conference Nuclear Energy for New Europe-NENE2016 (Slovenia, Portoroz, 2016-09-05 - 2016-09-08)

Measurement problems of 241 americium burn-up efficiency -preliminary experimental result of spectral index for Americium 241in the place of their location.
M. Szuta, **S. Kilim**, **E. Strugalska-Gola**, **M. Bielewicz**, S. Tyutyunnikov
Sixth Meeting of the Expert Group on Reactor Physics and Advanced Nuclear System (EGRPANS) of Working Party on Scientific Issues of Reactor Systems (WPRS) (France, Paryż, 2016-02-16 - 2016-02-18)

Modelling of the severe accident in-vessel progressionissues -focusing effect and core support plate damage for high power PWR.
M. Skrzypek, **E. Skrzypek**
European Nuclear Conference (Poland, Warszawa, 2016-10-09 - 2016-10-13)

Analytical and Experimental Analysis of Fission Gas Immobilisation and its Release from the Irradiated UO2 fuel as a Basis for an Experimental Program.
M. Szuta, **L. Dąbrowski**
12th Meeting and Workshop of the Working Party on Multiscale Modelling of Fuels and Sructural Materials (M2F), OECD NEA Headquarters, (France, Paryż, 2016-05-17 - 2016-05-19)

Low temperature cogeneration – using waste heat from research reactor as a source for heat pump
A. Przybyszewska
Technical Meeting on the User–Vendor Interface in Cogeneration for Electricity Production and Seawater Desalination International Atomic Energy Agency (Austria, Wiedeń, 2016-03-14 - 2016-03-16)

Comparison of two fast neutron measurement methods based on Np-237 fission to capture ratio measurement (spectral index) and a reverse dark current measurement of planar silicon detector
M. Szuta, **S. Kilim**, **E. Strugalska-Gola**, **M. Bielewicz**, N.I. Zamyatin, A. Shafronovskaya, S. Tyutyunnikov
XXIII International Baldin Seminar on High Energy Physics Problems- Relativistic Nuclear Physics and Quantum Chromodynamics (Russia, Dubna, 2016-09-19 - 2016-09-24)

Investigation of properties of the Np-237, Pu-239 and Am-241 nuclei in the neutron field of the Quinta facility at the JINR PHASOTRON
V.I. Stegailov, **S. Kilim**, **E. Strugalska-Gola**, **M. Szuta**, **M. Bielewicz**
NUCLEUS 2016- 66-th International Confetrence on Nuclear Spectroscopy and Nucleus Structure Problems (Russia, Sarov, 2016-10-11 - 2016-10-14)

Application of minor actinides as neutron fluency and average neutron energy detectors in the place of their location
M. Szuta, **S. Kilim**, **E. Strugalska-Gola**, **M. Bielewicz**, S. Tyutyunnikov

International Conference on Nuclear Data for Science and Technology- ND 2016 (Belgium, Bruges, 2016-09-11 - 2016-09-16)
European Physical Journal Web of Conferences (2016)

Singularities and cyclic universes
M.P. Dąbrowski
3rd Polish Society on Relativity Meeting (Poland, Kraków, 2016-09-26 - 2016-09-30)
Acta Phys. Pol. B (2017)

Współpraca inrzynierów u naukowców na przykładzie pomiaru temperatury.
M. Bielewicz
Slow Control 2016 (Poland, Warszawa, 2016-11-18 - 2016-11-18)

The investigation of electromagnetic cascades produced by electrons and gamma quanta in heavy amorphous media: the state of the art and prospects
B. Słowiński
XI-th International Conference (Poland, Kazimierz Dolny, 2016-06-13 - 2016-06-16)
Book of abstracts. ION Implantation and other applications of ions and electrons. ION 2016. Kazimierz Dolny, Poland. June 13-16, 2016 (2016) 33

Quasi-two-body pion-nucleus collisions at the GeV energy region as an intranuclear space probe
B. Słowiński, A. Pacan, A. Malakhov, R. Korzeniewski
XXIII International Baldin Seminar on High Energy Physics Problems - Relativistic Nuclear Physics and Quantum Chromodynamics (Russia, Dubna, 2016-09-19 - 2016-09-24)
Book of abstracts. XXIII International Baldin Seminar on High Energy Physics Problems. Dubna, Russia, September 19-24, 2016, p.127. No. (2016)

Oral Presentation

Safety principles and codes: contribution to general safety
M. Borysiewicz, **O. Dorosh**, **E. Kowalik**, **T. Kwiatkowski**, **S. Potempski**, **P. Prusiński**
WPENS 2nd Technical Meeting (Spain, Madrid, 2016-10-05 - 2016-10-07)

Accident Analysis Report: IPPLM/NCBJ contribution to Accident Analysis Report 2015
M. Borysiewicz, **S. Potempski**
WPENS Technical Meeting #1 (Germany, Garching, 2016-04-04 - 2016-04-06)

Contribution to FMECAand PIE Studies
M. Borysiewicz, **S. Potempski**
WPENS 2nd Technical Meeting (Spain, Madrid, 2016-10-05 - 2016-10-07)

Approximate Bayesian Computation Methods in the identification of atmospheric contamination sources for DAPPLE experiment
P. Kopka, **A. Wawrzyńczak-Szaban**, **M. Borysiewicz**
3rd Bayesian Young Statisticians Meeting 2016 (Italy, Florencja, 2016-06-19 - 2016-06-20)
Springer Proceedings in Mathematics & Statistics No. (2016)

Contribution to Accident Analysis
M. Borysiewicz, **S. Potempski**
WPENS 2nd Technical Meeting (Spain, Madrid, 2016-10-05 - 2016-10-07)

Numerical simulation of stably stratified atmospheric flow around isolated complex-shaped tall building
M. Korycki, L. Łobocki, A. Wyszogrodzki
Workshop on numerical and computational methods for simulation of all-scale geophysical flows (United Kingdom, Reading, 2016-10-03 - 2016-10-06)

Fast neutron spectrum measurement in the QUINTA assembly of E+T RAW collaboration
M. Bielewicz, **E. Strugalska-Gola**, **S. Kilim**, **M. Szuta**, **A. Wojciechowski**, S. Tyutyunnikov
ISINN-24, 24-th International Seminar on Interaction of Neutrons with Nuclei: Fundamental

Interactions&Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics (Russia, Dubna , 2016-05-23 - 2016-05-27)

Contribution to non-radiological safety
M. Borysiewicz, **O. Dorosh**, **S. Potempski**
WPENS 2nd Technical Meeting (Spain, Madrid, 2016-10-05 - 2016-10-07)

Cost-benefit analsyis of design changes proposal and design change request
M. Borysiewicz, **A. Kaszko**, **S. Potempski**
WPENS 2nd Technical Meeting (Spain, Madrid, 2016-10-05 - 2016-10-07)

Comparison of neutron induced fission and capture in Np-237and Pu-239 irradiated in QUINTA assembly with 660 MeV proton beam
S. Kilim, **M. Szuta**, **E. Strugalska-Gola**, **M. Bielewicz**, S. Tyutyunnikov, V. Stigailov
XXIII International Baldin Seminar on High Energy Physics Problems - Relativistic Nuclear Physics and Quantum Chromodynamics (Russia, Dubna, 2016-09-19 - 2016-09-24)

Identification of main source of uncertainties in the EVEDA phase RAMI studies
M. Borysiewicz, **A. Kaszko**, **S. Potempski**
WPENS 2nd Technical Meeting (Spain, Madrid, 2016-10-05 - 2016-10-07)

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**, **A. Wojciechowski**, S. Tyutyunnikov
XXIII International Baldin Seminar on High Energy Physics Problems- Relativistic Nuclear Physics and Quantum Chromodynamics (Russia, Dubna, 2016-09-19 - 2016-09-24)

Time Domain F-stat analysis for RDC
A. Królak, M. Bejger, **O. Dorosh**
LSC-Virgo March 2016 Meeting (USA, Pasadena, 2016-03-14 - 2016-03-14)

Update on the TD F-stat all-skyfollowup stage
M. Bejger, P. Ciecieląg, **O. Dorosh**, **A. Królak**, M. Sieniawska
LVC Meeting September 2016 (United Kingdom, Glasgow, 2016-08-29 - 2016-09-01)

Main Results from the European NC2I-R Project on Nuclear Cogeneration with High Temperature Reactors
M. Fütterer, **T. Jackowski**, **A. Przybyszewska**, **G. Wrochna**
HTR 2016 - International Topical Meeting on High Temperature Reactor Technology (USA, Las Vegas, 2016-11-07 - 2016-11-10)

(n,xn) Cross section measurements for Y-89 foils used as detectors for high energy neutron measurements in deeply subcritical assembly Quinta
M. Bielewicz, **E. Strugalska-Gola**, **S. Kilim**, **M. Szuta**, **A. Wojciechowski**, S. Tyutyunnikov
International Conference on Nuclear Data for Science and Technology- ND 2016 (Belgium, Bruges, 2016-09-11 - 2016-09-16)
European Physical Journal Web of Conferences (2016)

Progress in implementation of some RODOS modules in Poland
R. Dąbrowski, I. Matujewicz, **S. Potempski**, **H. Wojciechowicz**
RODOS Users Group Meeting 2016 (Spain, Madrid, 2016-06-21 - 2016-06-22)

Neutronic Characteristics of PWR Core with Accident Tolerant Fuel
A. Boettcher, **Z. Marcinkowska**
European Nuclear Conference (Poland, Warszawa, 2016-10-09 - 2016-10-13)
European Nuclear Society, Brussels, Belgium No. (2016) p. 19-24

Poster

Atmospheric stability impact on flow structures around a tall complex-shaped building
M. Korycki, L. Łobocki, A. Wyszogrodzki
8th European Postgraduate Fluid Dynamics Conference (Poland, Warsaw, 2016-07-06 - 2016-07-09)
In Vessel Corium Propagation Sensitivity Study Of Reactor Pressure Vessel Rupture Time With PROCOR Platform
M. Skrzypek, **E. Skrzypek**, L. Saas, R. LeTellier
European Nuclear Conference (Poland, Warszawa, 2016-10-09 - 2016-10-13)

Innovations in nuclear technology and licensing
A. Przybyszewska, A. Putowska, I. Banic, A. Mazur
INTERCONTINENTAL NUCLEAR INSTITUTE - final meeting (USA, Lowwel, MA, 2016-06-27 - 2016-07-22)

The neutronic safety analysis of HTR-10 reactor using model with regular distribution of pebbles in the core in SCALE/KENO-VI code
Ł. Koszuk, **M. Klisińska**
European Nuclear Conference (Poland, Warszawa, 2016-10-09 - 2016-10-13)

LECTURES, COURSES AND EXTERNAL SEMINARS

The nuclear power plant as a Russian matrioshka - the safety of generation III reactors[a]
M. Klisińska
Poznan, Poznan, University of Technology, 2016-03-16

The nuclear power plant as a Russian matrioshka - the safety of generation III reactors[a]
Ł. Koszuk
Poznań, Poznan University of Technology, 2016-03-16

On the nature and discovery of gravitational waves[a]
M.P. Dąbrowski
Świerk, Narodowe Centrum Badań Jądrowych, 2016-03-22

Gravitational waves - what are they and how were they discovered[b]
M.P. Dąbrowski
Szczecin, Instytut Fizyki, Uniwersytet Szczeciński, 2016-03-23

Renaissance of nuclear power[a]
Ł. Koszuk
Białystok, Faculty of Physics, University of Białystok, 2016-04-21

Reactor physics - introduction[a]
Ł. Koszuk
Poznań, Poznan University of Technology, 2016-05-23

Inhomogeneous pressure conformally flat cosmologies and observations[b]
M.P. Dąbrowski
Brighton, Astronomy Centre, University of Sussex, Falmer, Brighton, UK, 2016-02-08

Inhomogeneous pressure conformally flat cosmologies and observations[b]
M.P. Dąbrowski
Portsmouth, Institute of Cosmology and Gravitation, University of Portsmouth, UK , 2016-02-10

Two phase flow simulation[a]
K. Samul
Warszawa, Warsaw University of Technology at Faculty of Power and Aeronautical Engineering, 2016-01-13

New technologies of IV generation reactors[a]
A. Przybyszewska
Łódź, Lodz University of Technology, 2016-06-17

[a)] in Polish
[b)] in English

INTERNAL SEMINARS

Feasibility study of nuclear waste incineration in Dubna - last three year work summary[a]
S. Kilim
Swierk, National Centre for Nuclear Research, 2016-01-19

Validation of sub channel level CFD approaches for bare rod bundles[a]
T. Kwiatkowski
Świerk, National Centre for Nuclear Research, 2016-02-16

EU decision support system for nuclear emergency RODOS[a]
S. Potempski
Otwock-Swierk, National Centre for Nuclear Research, 2016-03-01

Can we trust in CFD results? Few words on GEMIX benchmark[a]
P. Prusiński
Otwock-Świerk, NCBJ, 2016-03-08

About nature of the gravitational waves (supplement)[a]
O. Dorosh
Świerk, NCBJ, 2016-03-22

Hyperfine interactions and magnetoelectric properties of $(BiFeO_3)_x$-$(BaTiO_3)_{1-x}$[b]
K. Kowal
Lublin, Lublin University of Technology, 2016-04-18

EULAG model in UDINEE project - urban scale pollutant transport and dispersion[a]
M. Korycki
Otwock-Świerk, National Centre for Nuclear Research, 2016-04-19

Nuclear reactor simulators - examples of solutions[a]
J. Malesa
Otwock - Swierk, National Centre for Nuclear Research, 2016-04-26

Neutron-physics analysis of accident toleran fuel with new cladding materials based on EPR geometry.[a]
A. Boettcher
Otwock-Świerk, NCBJ, 2016-05-10

Sites and the public reception of nuclear power in the North of Poland[a]
M.P. Dąbrowski
Świerk, National Centre for Nuclear Research, 2016-05-17

Study of high energy spallation neutron field in the QUINTA assembly with Y-89 samples[a]
E. Strugalska-Gola
Swierk, National Centre for Nuclear Research, 2016-05-24

Information about fellowship INI[a]
A. Przybyszewska
Otwock, NCBJ, 2016-08-30

Evaluation of dryout prediction capabilities of CATHARE-3[b]
M. Spirzewski
Saclay, The French Alternative Energies and Atomic Energy Commission (CEA), 2016-10-21

[a)] in Polish
[b)] in English

DIDACTIC ACTIVITY

M.P. Dąbrowski - Albin Nilsson (M.Sc.) - a Ph.D. student of NCBJ enrolled in 2016 - cosmology

M.P. Dąbrowski - Artur Miroszewski (M.Sc.) - a Ph.D. student of NCBJ enrolled in 2016 - cosmology

M.P. Dąbrowski - Jakub Sierchuła - a Ph.D. student of NCBJ enrolled in 2016 - dual fluid reactor concept

M.P. Dąbrowski - University of Szczecin: classical and relativistic mechamics, mathematical methods of physics, statistical physics

Ł. Koszuk - The training course with the Simulator of Maria research reactor for students of Nuclear Energy Postgraduate Studies from Warsaw University of Technology, 10th June, 2016.

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.

S. Potempski - Industrial installations for safety and mitigation of the consequences of industrial accidents,
Main School of Fire Services, postgraduate studies

S. Potempski - Numerical methods for HPC, Lodz University, Faculty of Physics and Applied Informatics

P. Prusiński - Lecture on: Parallel computing for nuclear reactor safety - Computational Fluid Dynamics in a frame of PhD Seminars at NCBJ.

G. Siess - Certified Manager of Risk Management - Module 3 "Methods and techniques of risk analysis"

B. Słowiński - One semester (30h.) lectures "Physics foundation of nuclear power" for MSc students, Faculty of Physics, Warsaw University of Technology

B. Słowiński - One semester lectures (30h) "Global development of energetics" for MSc students, Faculty of Production Technology, Warsaw University of Life Sciences.

B. Słowiński - One semester lectures (30h) for undergraduates of the Faculty of Physics, Warsaw University of Technology "Radiation modification of materials"

B. Słowiński - Scientific leader for M.Sc. student V.Kozak. The subject of the work: "Scaling of the space structure of electromagnetic cascades induced by gamma quanta in heavy amorphouse media". Faculty of Physics, Warsaw Universitu of Technology, Poland.

B. Słowiński - scientific leader for Ph.D. student A.Pacan. The subject of the Ph.D.thesis: Physics processes in spallation reactor targets driven by electrons and protons beams. Faculty of Physics, Warsaw University of Technology, Poland

B. Słowiński - Sebastian Trzcianowski.The use of high-temperature heat in industry and economy. University of Live Science, Warsaw, 2016.

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

K. Andrzejewski
Nukleonika, Institute of Nuclear Chemistry and Technology

M. Bielewicz
Member of Advisory Board on Slow Control 2016 in Warszawa, Poland
Polish Astronomical Society
M. Borysiewicz
Member of the European Safety, Reliability and Data Association (ESReDA)

M.P. Dąbrowski
Session chairman on Varying constants and Fundamental Cosmology - Varcosmofun 16 in Szczecin, Poland
Session chairman on II Sympozjum Sekcji Fizyki Oddziaływań Fundamentalnych PTF Collider Physics in Katowice, Poland
Session chairman on Cosmology: from Philosophy to Mathematics and Back in Kraków, Poland
Member of Organizing Committee on Varying constants and Fundamental Cosmology - Varcosmofun 16 in Szczecin, Poland
Polish Physical Society

Ł. Koszuk
ATOMIC FORUM Foundation, President
Polish Nuclear Society, member
Forum Atomowe, Atomic Forum, ATOMIC FORUM Foundation

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
COST - Eueopean Cooperation in Science and Technology, member
Committee on Space Research (COSPAR), member

PERSONNEL

Research scientists

Krzysztof Andrzejewski, PhD
Marcin Bielewicz, PhD
Agnieszka Boettcher, MSc
Mieczysław Borysiewicz, PhD
Mariusz Dąbrowski, Professor
Ludwik Dąbrowski, Assoc. Prof
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
Ewa Kowalik-Pilarska, MSc Eng
Tomasz Kwiatkowski, MSc Eng
Tomasz Kozłowski, PhD Assoc. Prof.
Mariusz Łuszcz, MSc Eng
Tomasz Machtyl, MSc
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, Professor
Michał Spirzewski, MSc Eng
Elżbieta Strugalska-Gola, PhD
Marcin Szuta, PhD Eng. Assoc. Prof.
Anna Wawrzyńczak-Szaban, PhD
Henryk Wojciechowicz, MSc
Andrzej Wojciechowski, PhD
Małgorzata Wróblewska, MSc Eng

PhD Students

Artur Miroszewski, MSc
Albin Nilsson, MSc
Jakub Sierchuła, MSc Eng

Administrative Staff

Jolanta Przyłuska

LABORATORY FOR INFORMATION TECHNOLOGIES

Head of the Laboratory: Adam Padée, PhD Eng

Phone: 22 273 16 85

e-mail: adam.padee@ncbj.gov.pl

Overview

Laboratory for Information Technologies (UZ1) is focused mainly on High Performance Computing tasks. It is operating Swierk Computing Centre supercomputer, which has over 1 PFLOPS computing power and 18PB of disk storage. The machine is used to support scientific research done in the other laboratories of NCBJ, but also for UZ1's own research and for commercial purposes. The main consumer though is science, with notable examples of radiopharmaceuticals design (22% of cluster utilization), nuclear and industrial safety (36%) and high energy physics (31%). The commercial applications include Computational Fluid Dynamics simulations for aviation industry, rendering of visual effects for filmmakers and power distribution simulations for energy market.

The research conducted at UZ1 was focused on machine learning and algorithms supporting medical diagnostics. The biggest research topic at UZ1 was involvement in J-PET collaboration, aimed at creation of new generation of PET (Positron Emission Tomography) scanner. In 2016 NCBJ's contribution to the project regarded three main areas. First was determination of characteristics of J-PET scanner according to NEMA (National Electrical Manufact. Association) standards. The results of the analysis were presented in [P. Kowalski et al, (2016) „Scatter Fraction of the J-PET Tomography Scanner", Acta Physica Polonica B, vol. 47, pp. 549]. Second area of research was construction of theoretical model for estimation of temporal resolution of the scanner. Algorithm was based on statistical description of the process of signal formation on photomultiplier's output. The model was thoroughly tested and experiments shown that the error of estimation does not exceed couple of percent. Preliminary results were presented on IEEE NSS/MIC conference [L. Raczyński et al, (2016) „Statistical Analysis of Time Resolution of the J-PET Scanner", in Proc. IEEE Nuclear Science Symposium and Medical Imaging Conference NSS/MIC, Strasbourg, 29.10-06.11]. The article with detailed mathematical description of the model and the results gathered for different configurations of J-PET detector was published in [L. Raczyński et al, (2017) „Calculation of time resolution of the J-PET tomograph using the Kernel Density Estimation", Phys. Med. Biol. Vol. 62 (2017) pp. 5076–5097]. Third area of research in J-PET collaboration, that was started in 2016 in UZ1, was analysis of image reconstruction methods in PET, with special emphasis on utilization of TOF (Time of Flight) parameter. State-of-the-art research on advanced TOF-PET technologies show that for some scintillators temporal resolution of TOF parameter can be as low as 100 ps, while scanners commercially available on the market currently reach 400 ps. This is a strong indicator that new generation of scanners will require new image reconstruction algorithms to fully exploit their technical capabilities.

In 2016 there was also continuation of collaboration between NCBJ and Bielański Hospital in Warsaw, which was concentrated on analysis of anonymized data from HIS (Hospital Information System). The analysis is focused on two goals: probability of hospital readmission (return of patient within specified time interval) and finding similarities in patients' symptoms using graph theory methods. The analysis, apart from well-defined input data like ICD-10 codes or numerical results of medical tests takes into account also unstructured textual data, like doctors' notes. The data is analyzed using machine learning methods and High Performance Computing (HPC) algorithms. Currently the first results of the analyses are being prepared for publication.

Adam Padee

REPORTS

ICFA SCIC Network Monitoring Report
S. McKee, ... , **H. Giemza**, ... et al.
CERN, Genewa

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Jagiellonian Positron Emission Tomograph - TOF-PET based on Plastic Scintillators
L. Raczyński
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

Oral Presentation

Review of recent direct gluon polarization measurements
K. Klimaszewski
22nd International Spin Symposium (USA, Urbana-Champaign, 2016-09-25 - 2016-09-30)

Recent discrete symmetries tests at LHCb
K. Klimaszewski
DISCRETE 2016: Fifth Symposium on Prospects in the Physics of Discrete Symmetries (Poland, Warszawa, 2016-11-28 - 2016-12-03)

Monitoring of Dynamic Movements Using Acceleration Measurements
K. Neneman, **A. Łuczyk**, W. Pleskacz
23rd International Conference on Mixed Design of Integrated Circuits and Systems (MIXDES) (Poland, Łódź, 2016-06-23 - 2016-06-25)

Principal Components Representation of Accelerations in Dynamic Human Movements
K. Neneman, **A. Łuczyk**
XXXVIII-th IEEE-SPIE Joint Symposium Wilga 2016 (Poland, Wilga, 2016-05-29 - 2016-06-06)

Poster

Statistical Analysis of Time Resolution of the J-PET Scanner
L. Raczyński, **W. Wiślicki**, **P. Kowalski**, **W. Krzemień**, D. Alfs, T. Bednarski, P. Białas, C. Curceanu, E. Czerwiński, K. Dulski, A. Gajos, B. Głowacz, M. Gorgol, B. Hiesmayr, B. Jasinska, D. Kaminska, G. Korcyl, T. Kozik, N. Krawczyk, E. Kubicz, M. Mohammed, M. Pawlik-Niedzwiecka, S. Niedzwiecki, M. Palka, Z. Rudy, O. Rundel, N.G. Sharma, M. Silarski, J. Smyrski, A. Strzelecki, A. Wieczorek, B. Zgardzińska, M. Zieliński, P. Moskal
2016 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) (France, Strasbourg, 2016-10-29 - 2016-11-06)

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

A. Łuczyk
Program Committee Member of IEEE International Symposium on Design and Diagnostics of Electronic Circuits and Systems

PERSONNEL

Tomasz Fruboes, PhD
Henryk Giemza, MSc Eng
Tobiasz Jarosiewicz, MSc
Konrad Klimaszewski, PhD
Paweł Kowalski, MSc Eng
Sylwester Kozioł, MSc Eng
Krzysztof Kuźmicki, Eng
Arkadiusz Łuczyk, PhD
Piotr Małetka
Rafał Masełek, Eng
Rafał Moździonek, Eng
Krzysztof Nawrocki, PhD
Adam Padee, PhD
Lech Raczyński, PhD
Roman Shopa, PhD
Paweł Skrzypczak, MSc Eng
Piotr Wasiuk
Artur Wodyński, PhD
Michał Wójcik, Eng

EDUCATION AND TRAINING DIVISION

Head of Division: Professor Ludwik Dobrzyński

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Overview

The year 2016 was very busy for the Department of Education and Training.

Firstly, the location of the Department has changed. This forced us to carry out a substantial reorganisation of our exhibitions. In spite of many problems connected with the move, the transfer to the new location in the building of the Science and Technology Park was successful. The new lecture halls are equipped with good video and audio systems.

The Department hosted 7200 visitors from high schools, universities, and industrial and scientific institutions from many towns and villages. In addition, our group popularised elements of nuclear science in the villages of Gniewino and Choczewo, where the construction of a nuclear power plant is planned.

Among the visitors one may list students from the Medical Universities of Bialystok and Gdansk, Warsaw and Gdansk Technical Universities, the Academy of Mining from Cracow, the Maria Curie University from Lublin etc.. The Department also hosted film makers, participants in the European Nuclear Conference, firemen, military personnel, not to mention organised groups of senior citizens.

Department organised regular Radiological Protection courses and a special course for future nuclear reactor operators.

Although outreach activities are of the greatest priority, some of our employees are active scientists in the field of high-energy physics, and the influence of low dose radiation on organisms - modelling of the transformations of irradiated cells in particular.

At present, the Department participates in two EU Projects: BRILLIANT (Baltic Region Initiative for Long Lasting Innovative Nuclear Technologies) and VINCO (Visegrad Initiative for Nuclear Cooperation). A semi-popular brochure “Paving the Way to Gen IV Nuclear Reactors” was prepared and published as part of our obligations within this latter project.

As usual, the Department was very active during the Science Picnic and the Science Festival, both held in Warsaw.

It also organised (in collaboration with the Institute of Physics and the Polish Academy of Sciences) the annual high-school student competition “The Paths of Physics”. This was the 12th edition of this competition.

L. Dobrzyński served as an expert in the preparation of the IAEA report on the Fukushima event and 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

Myths and Reality of the Impact of Ionizing Radoation on Living Organisms
L. Dobrzyński, L. Dobrzynski
3rd Central & European Nuclear Power Congress 2016 (Poland, Warszawa, 2016-11-28 - 2016-11-29)

Katastrofy w przemyśle jądrowym
L. Dobrzyński, L. Dobrzynski
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)

Konsekwencje zdrowotne awarii w Czarnobylu i Fukushimie
L. Dobrzyński
Ochrona Radiologiczna w Weterynarii (Poland, Łomża, 2016-04-24 - 2016-04-25)

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

PERSONNEL

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
Władysław Szymczyk, PhD (3/5)
Krzysztof Masłowski, MSc
Katarzyna Deja, PhD
Artur Skwarek, MSc
Joanna Reszczyńska MSc, PhD student

RADIOISOTOPE CENTRE POLATOM

Director of Centre: Dariusz Socha, PhD Eng
Phone: +48 22 273 17 00/ 273 17 01
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Overview

The Radioisotope Centre POLATOM is a self-contained unit of the National Centre for Nuclear Research which is 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 1950's. 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 launching of Maria, another research reactor with which POLATOM's activities have been inextricably connected until today.

Currently, POLATOM combines basic scientific statutory objectives with, successfuly commercialisation of its own potential and research achievements. In the scientific arena it is a leading centre in Poland that conducts interdisciplinary research in the field of 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. Its research and development 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 result of our own work.

In recent years POLATOM has launched the manufacture of several innovative products, among them a ^{99m}Tc-Tektrotyd - a radiopharmaceutical kit for diagnostic imaging of tumours expressing somatostatin receptors useful in oncology, Tchimmuna - radiopharmaceutical kit for the 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. The 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 9001:2009 Certificate of Compliance 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 the Calibration Laboratory on compliance with PN-EN/ISO 17025:2005.

Dariusz Socha

REPORTS

Feasibility of production of metal reference standards for radioactive waste measurements.
F. Tzika, ... , **Z. Tymiński**, **A. Listkowska**, ... et al.
European Commission, Joint Research Centre, Directorate for Nuclear Safety and Security, Retieseweg 111, B-2440 Geel, Belgium

Estimation of radiological protection on the territory of Nuclear Centre Świerk and its vicinity (2015).
B. Filipiak, ... , **Z. Haratym**, **J. Ośko**, **T. Pliszczyński**, **B. Snopek**, **B. Boimski**, **S. Domański**, **M. Dymecka**, **R. Ejsmont**, **M. Feczko**, **A. Garboliński**, **B. Karpińska**, **A. Pawełczuk**, **B. Piotrkowicz**, **K. Rzemek**, **R. Sosnowiec**, **W. Śniegoń**, **M. Prusińska**, **M. Umaniec**, **K. Wiśniewska**, **K. Wojdowska**, **J. Wojnarowicz**, **Z. Worch**, **D. Zielińska**, ... et al.
National Centre for Nuclear Research

Preliminary results of determination of trifluoroacetic acid in DOTA-TOC samples
R. Lipka
National Centre for Nuclear Research RC Polatom

Verification and Validation of the method for determination of acetic acid in DOTA-TOC samples
R. Lipka
Strasbourg, September 2016

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Radionuclides and radiopharmaceuticals for therapy
R. Mikołajczak
Town Meeing on the IFMIF/ELAMAT Complementary Scientific Program (Poland, Rzeszów, 2016-04-14 - 2016-04-15)

Experiences in Somatostatin Receptor Scintigraphy and Future Developments
R. Mikołajczak
Scientific Workshop on FP7 MAGBIOVIN Project: Future Direction in Diagnosis and Therapy: Multifunctional Radiolabelled Nanoparticles (Serbia and Montenegro, Novi Sad, 2016-04-16 - 2016-04-16)

New developments in nuclear medicine therapy (^{177}Lu, ^{227}Th, ^{90}Y)
R. Mikołajczak
Galway Radium Week (Ireland, Galway, 2016-04-18 - 2016-05-22)

Radioizotopy i ich zastosowania w medycynie
R. Mikołajczak
IX Sympozjum Instytutu Fizyki Doświadczalnej Wydziału Fizyki UW (Poland, Warszawa, 2016-11-28 - 2016-11-28)

Oral Presentation

Badania porównawcze stabilności i powinowactwa receptorowego znakowanych peptydów DOTATATE i HA-DOTATATE.
M. Radzik, **M. Maurin**, **P. Garnuszek**, **A. Sawicka**
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Radionuclides produced in Radioisotope Centre POLATOM and its application
I. Cieszykowska, **R. Mikołajczak**
IAEA Technical Meeting (F1-TM-52895) on Specific Applications of Research Reactors: Production and Use of Radiotracers (Austria, Wiedeń, 2016-06-20 - 2016-06-24)

Tandem peptide radionuclide therapy with $^{90}Y/^{177}Lu$-DOTATATE clinical results and long term side effect - 10 years'experience.
J. Kunikowska, **D. Pawlak**, MBąk, B. Kos-Kudla, **R. Mikołajczak**, L. Królicki
Annual Congress of the European Association of Nuclear Medicine, EANM 16 (Spain, Barcelona, 2016-10-15 - 2016-10-19)

Theoretical computational comparison of DOTA-minigastrin analogue (CP04) complexes with ^{68}Ga and ^{177}Lu.
P. Garnuszek, A. Wodyński, **M. Maurin**, **R. Mikołajczak**
3rd International Symposium on Functional Metal Complexes that Bind to Biomolecules, 4th Whole Action Meeting of the COST Action CM1105 (Spain, Palma de Mallorca, 2016-04-28 - 2016-04-29)

Values of the ionization quenching parameter kB used in the LSC technique
R. Broda, **T. Ziemek**, **A. Listkowska**
Meeting of the ICRM Liquid Scintillation Counting Working Group (Italy, Rome, 2016-11-07 - 2016-11-08)

Wpływ utleniania metioniny w ^{99m}Tc-HYNIC-Eksendyna-4 na aktywność biologiczną radiofarmaceutyku do obrazowania receptorów GLP-1
B. Janota, **U. Karczmarczyk**, **P. Garnuszek**, **M. Radzik**, **R. Mikołajczak**
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Badania in vitro radiotoksyczności znakowanych nanocząstek ^{177}Lu-AgulX na linii komórkowej raka trzustki (AR42J).
M. Orzełowska, **M. Maurin**, **P. Garnuszek**, **R. Mikołajczak**, C. Truillet, F. Lux, A. Clabaut, O. Tillement
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Terapia znakowanymi analogami somatostatyny „tandem therapy" $^{90}Y/^{177}Lu$-DOTATATE –10 lat doświadczeń.
J. Kunikowska, **D. Pawlak**, **R. Mikołajczak**, L. Królicki
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Current status of the TDCR system with gamma detector and the FPGA digital board at POLATOM
T. Ziemek, **A. Jęczmieniowski**, **R. Broda**, **A. Listkowska**, **E. Lech**
Meeting of the ICRM Liquid Scintillation Counting Working Group (Italy, Rome, 2016-11-07 - 2016-11-08)

Badania nad otrzymaniem, kontrolą jakości i stabilności preparartu ^{68}Ga –PSMA.
P. Ochman, **R. Mikołajczak**, **P. Garnuszek**, A. Sackiewicz, M. Dedecjus
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Miejscowe leczenie glejaków z zastosowaniem 213Bi-DOTA-Substancja P. Doświadczenia własne.
L. Królicki, A. Morgenstern, J. Kunikowska, H. Koziara, B. Krolicki, M. Jakucinski, **D. Pawlak**, C. Apostolidis, F. Bruchertseifer
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Opracowanie zestawu do sporządzania ^{68}Ga-PSMA w warunkach szpitalnych.
D. Pawlak, **M. Maurin**, **P. Garnuszek**, **U. Karczmarczyk**, **R. Mikołajczak**
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Obrazowanie receptorów somatostatyny u pacjentów z nowotworami neuroendokrynnmi : 99mTc-HYNIC-TOC SPECT lub SPECT/CT z vs 68Ga -DOTATATE PET/CT –znaczenie w decyzji klinicznej.
J. Kunikowska, R. Matyskiel, **D. Pawlak**, L. Królicki
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Alternatywne metody produkcji technetu-99m.
D. Pawlak, **W. Wojdowska**, **I. Cieszykowska**, **T. Janiak**, **T. Barcikowski**, **J.L. Parus**, **P. Garnuszek**, **R. Mikołajczak**
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Naczyniakowłókniak młodzieńczy-badanie ekspresji receptorów somatostatyny in vitro i in vivo.
J. Kunikowska, W. Kukwa, A. Cyran-Chlebicka, **D. Pawlak**, Ł. Koperski, Z. Gronkiewicz, B. Górnicka,

L. Królicki
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Badania biodystrybucji kompleksu ^{64}Cu-HL-1 -potencjalnego radio-chemoterapeutyku do wieloczynnikowej terapii przeciwnowotworowej.
D. Kłudkiewicz, **U. Karczmarczyk**, **M. Maurin**, **E. Laszuk**, **P. Garnuszek**, **R. Mikołajczak**
XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej (Poland, Bydgoszcz, 2016-06-01 - 2016-06-03)

Zastosowanie dyspersji cytrynianów itru i erbu w medycynie nuklearnej
W. Janusz, E. Skwarek, S. Pikus, E. Olszewska, **D. Pawlak**, **J. Parus**
III Ogólnopolskie Forum Chemii Nieorganicznej (Poland, Kraków, 2016-12-07 - 2016-12-09)

GRAN-T-MTC, ^{111}In-CP04 - A Novel CCK2/Gastrin Receptor Localizing Radiolabelled Peptide Probe for management of Patients with Progressive/Metastatic Medullary Thyroid Carcinoma (MTC): Rationale, Study Design and the Initial Promising Results of a Multicentre First Phase Study
A. Hubalewska-Dydejczyk, C. Decristoforo, P. Erba, **R. Mikołajczak**, H.R. Maecke, K. Zaletel, P. Kolenc-Peitl, T. Maina, **P. Garnuszek**, I. Virgollini, G. Geobel, M. Konijnenberg, M. DeJong, L. Froberg, W. Lenda-Tracz, C. Rangger, A. Kunzmann, A. Sowa-Staszczak, M. Trofimiuk-Muldner
1st SYMPOSIUM on the projects funded by TRANSCAN within the Joint Transnational Call 2011 on Validation of Biomarkers for Personalised Cancer Medicine (Italy, Rome, 2016-09-14 - 2016-09-14)

Secondary glioblastoma multiforme - local alpha emiters targetedtherapy with213Bi-DOTA-substance P
L. Królicki, A. Morgenstern, J. Kunikowska, H. Koziara, B. Królicki, M. Jakuciński, **D. Pawlak**, C. Apostolidis, F. Bruchertseifer
Annual Congress of the European Association of Nuclear Medicine, EANM 16 (Spain, Barcelona, 2016-10-15 - 2016-10-19)

Preparation of ^{100}Mo metallic target for ^{99m}Tc production in cyclotron
T. Janiak, **I. Cieszykowska**, **T. Barcikowski**, **M. Mielcarski**,
HANARO Symposium 2016, INTEC,KAERI (Korea, Daejeon, 2016-05-26 - 2016-05-26)

Poster

Application of AnaLig resin for ^{99m}Tc separation from molybdenum excess
W. Wojdowska, **D. Pawlak**, **J.L. Parus**, **P. Garnuszek**, **R. Mikołajczak**
18th European Symposium on Radiopharmacy and Radiopharmaceuticals (Austria, Salzburg, 2016-04-07 - 2016-04-10)

Wytwarzanie tarczy Mo-100 do produkcji Tc-99m w cyklotronie
T. Janiak, **T. Barcikowski**, **I. Cieszykowska**, **M. Żółtowska**, **M. Mielcarski**
VII Krajowa Konferencja Radiochemii i Chemii Jądrowej (Poland, Lublin, 2016-04-17 - 2016-04-20)

^{60}Co isotope content in iron meteorites
Z. Tymiński, **A. Burakowska**, **K. Tymińska**, A. Olech, M. Stolarz, P. Żołądek, M. Wiśniewski
79th Annual Meeting of the Meteoritical Society (Germany, Berlin, 2016-08-07 - 2016-08-12)
MAPS, Wiley No.51(S1) (2016)

Elektrochemiczne rozpuszczanie metalicznego ^{100}Mo w środowisku alkalicznym
I. Cieszykowska, **K. Jerzyk**, **M. Żółtowska**, **M. Mielcarski**
VII Krajowa Konferencja Radiochemii i Chemii Jądrowej (Poland, Lublin, 2016-04-17 - 2016-04-20)

Characterisation of activity content of ^{226}Ra in spikedmetallurgical slag using an interlaboratory comparison
F. Tzika, E. Garcia-Toraño, M. Hult, D. Arnold, **Z. Tymiński**
9th International Conference on Nuclear and Radiochemistry (Finland, Helsinki, 2016-08-29 - 2016-09-02)

Wzorce referencyjne o niestandardowych geometriach do pomiaru aktywności radionuklidów w przemyśle i środowisku
<u>Z. Tymiński</u>, **T. Dziel**, **A. Listkowska**, **R. Broda**, **E. Kołakowska**, **P. Saganowski**, **E. Lech**, **D. Cacko**, **A. Jęczmieniowski**, **T. Ziemek**, **M. Nowicka**, **J. Wojnarowicz**, **R. Sosnowiec**, **K. Tymińska**
VII Krajowa Konferencja Radiochemii i Chemii Jądrowej (Poland, Lublin, 2016-04-17 - 2016-04-20)

Oczyszczanie chlorku baru $^{133}BaCl_2$ od zanieczyszczeń radionuklidowych przy użyciu eteru koronowego 4,4\'(5\')-di-t-butylo-cykloheksano 18-korona-6
<u>M. Konior</u>, **R. Kiełek**
XI Międzynarodowa Konferencja CHROMATOGRAFIA JONOWA 2016 (Poland, Zabrze, 2016-04-20 - 2016-04-21)

Separation study of scandium radionuclides from excess of calcium.
<u>D. Pawlak</u>, **J.L. Parus**, **T. Dziel**, **P. Garnuszek**, **R. Mikołajczak**
Annual Congress of the European Association of Nuclear Medicine, EANM 16 (Spain, Barcelona, 2016-10-15 - 2016-10-19)

Odtwarzanie jednostki aktywności radionuklidów za pomocą techniki ciekłych scyntylatorów (LSC)- Realisation of radionuclides activity unit using the liquid scintillation counting (LSC)
<u>R. Broda</u>, **T. Dziel**, **A. Listkowska**, **T. Ziemek**
VII Kongres Metrologii (Poland, Lublin - Nałęczów, 2016-06-28 - 2016-07-01)
Informatyka, Automatyka, Pomiary w gospodarce i ochronie środowiska No 3 (2016) 28

Quality control procedure for [^{18}F]FECNT: A PET ligand for imaging of dopamine transporter (DAT)
<u>J. Pijarowska-Kruszyna</u>, **A. Jaroń**, **P. Garnuszek**, **R. Mikołajczak**
Annual Congress of the European Association of Nuclear Medicine, EANM 16 (Spain, Barcelona, 2016-10-15 - 2016-10-19)

PSMA-11 in a dry kit formulation for ^{68}Ga labelling
<u>R. Mikołajczak</u>, **D. Pawlak**, **M. Maurin**, **U. Karczmarczyk**, **P. Garnuszek**
4th THERANOSTICS World Congress 2016 (Australia, Melbourne, 2016-11-07 - 2016-11-09)

A novel CCK2/Gastrin receptor-localizing peptide probe for personalized diagnosis and therapy of Medullary thyroid Carcinoma - GRAN-T-MTC enrols patients in a multicentre Phase I study
<u>R. Mikołajczak</u>, PaolaA. Erba, ClemensDecristoforo, HelmutR. Maecke, KatjaZaletel, PetraKolenc-Peitl, TheodosiaMaina, IreneVirgolini, LorenzaScarpa, MariondeJong, MałgorzataTrofimiuk-Muldner, AgataJabrocka-Hybel, AlicjaHubalewska-Dydejczyk
4th THERANOSTICS World Congress 2016 (Australia, Melbourne, 2016-11-07 - 2016-11-09)

Structure and receptor affinity of DOTA-Gastrin analogue (CP04) complexes with radiometals
<u>M. Maurin</u>, **A. Wodyński**, **M. Orzełowska**, **U. Karczmarczyk**, **P. Garnuszek**, **R. Mikołajczak**
Annual Congress of the European Association of Nuclear Medicine, EANM 16 (Spain, Barcelona, 2016-10-15 - 2016-10-19)

Constraints for selection of suitable precursor for one-step automated synthesis of [^{18}F]FECNT, the dopamine transporter ligand
<u>J. Pijarowska-Kruszyna</u>, **A. Jaroń**, A. Kachniarz, B. Małkowski, **P. Garnuszek**, **R. Mikołajczak**
18th European Symposium on Radiopharmacy and Radiopharmaceuticals (Austria, Salzburg, 2016-04-07 - 2016-04-10)

Experimental radionuclide therapy with ^{177}Lu-labelled cyclic minigastrin and human dosimetry estimations
<u>E. VonGuggenberg</u>, C. Rangger, C. Mair, L. Balogh, Z. Pöstényi, **D. Pawlak**, **R. Mikołajczak**
18th European Symposium on Radiopharmacy and Radiopharmaceuticals (Austria, Salzburg, 2016-04-07 - 2016-04-10)

^{90}Y microspheres prepared by sol-gel method, promising material for medical application
<u>M. Konior</u>, **E. Iller**, W. Łada, D. Wawszczak
9th International Conference on Nuclear and Radiochemistry (Finland, Helsinki, 2016-08-29 - 2016-09-02)

Dry kit formulation for efficient radiolabeling of ^{68}Ga-PSMA
D. Pawlak, **M. Maurin**, **P. Garnuszek**, **U. Karczmarczyk**, **R. Mikołajczak**
18th European Symposium on Radiopharmacy and Radiopharmaceuticals (Austria, Salzburg, 2016-04-07 - 2016-04-10)

Opracowanie metody odzysku Mo-100 po procesie produkcji Tc-99m w cyklotronie
M. Żółtowska, **I. Cieszykowska**, **T. Janiak**, **M. Mielcarski**
VII Krajowa Konferencja Radiochemii i Chemii Jądrowej (Poland, Lublin, 2016-04-17 - 2016-04-20)
Petit SK Lublin No. (2016)

INTERNAL SEMINARS

Preclinical studies and preparation of pharmaceutical formulations HYNIC-Exendin-4, agonist of the GLP-1[a]
B. Janota
Warsaw, Institute of Nuclear Chemistry and Technology, 2016-01-14

Meteorites - from exploration to isotopic research.[b]
Z. Tymiński
Warszawa, Centrum Astronomiczne im. Mikołaja Kopernika PAN, 2016-05-25

Isotopes in meteorites.[a]
Z. Tymiński
Warsaw, Warsaw University, Nuclear Physics Division, 2016-06-02

From bench to the bed side.[a]
P. Garnuszek
Otwock-Świerk, Narodowe Centrum Badań Jądrowych, 2016-11-10

Determination of acetic acid in DOTA-TOC acetate active substance [a]
R. Lipka
Otwock-Świerk, National Centre for Nuclear Research RC Polatom, 2016-11-28

Validation of the method for determination of 2-oxopiperazine-1-y acetic acid in ethylenediamine N N diacetic acid (EDDA) active substances[a]
R. Lipka
Otwock-Świerk, National Centre for Nuclear Research RC Polatom, 2016-12-22

a) in Polish
b) in English

DIDACTIC ACTIVITY

R. Broda - Tutor of the Master's thesis performed at the Physics Faculty of the Warsaw University of Technology. - K. Klukowska. Quality assurance of activity measurements of radionuclides used in the palliative treatment of bone cancer.

P. Garnuszek - Lecture "Radiopharmaceuticals" for 5-year students of Faculty of Pharmacy WUM

U. Karczmarczyk - I was taking care of Anna Kędzierska the student from the Faculty of Chemistry, University of Warsaw during her monthly traineeship. She was introduced to peptide radiolabelling with gallium-68 and to quality control of obtained complexes.

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

I. Chwalińska
Europen Association of Nuclear Medicine, member

I. Cieszykowska
Member of Scientific Council of NCBJ

T. Dziel
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Polish Society of Medical Physics

P. Garnuszek
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Polish Society of Nuclear Medicine
Expert of Group 14 (radioactive compounds) European Pharmacopoeia,European Directorate for the Quality of Medicines & HealthCare, Council of Europe
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Member
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 Annual Congress of the European Association of Nuclear Medicine, EANM 16 in Barcelona, Spain
Member of Advisory Board on XV Zjazd Polskiego Towarzystwa Medycyny Nuklearnej in Bydgoszcz, 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
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

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
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Małgorzata Żółtowska, MSc
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REPORTS ON RESEARCH

ASTROPHYSICS, COSMIC RAYS & ELEMENTARY PARTICLE PHYSICS

NUCLEAR PHYSICS

PLASMA PHYSICS & TECHNOLOGY

ACCELERATORS, DETECTORS & ELECTRONICS

SOLID STATE PHYSICS, PHYSICS &ENGINEERING OF MATERIALS; APPLICATIONS

REACTOR PHYSICS, NUCLEAR TECHNOLOGY IN ENERGY GENERATION, MODELLING & CALCULATIONS

NUCLEAR TECHNIQUES IN HEALTH AND ENVIRONMENTAL PROTECTION MANAGEMENT OF HAZARDS

ASTROPHYSICS, COSMIC RAYS & ELEMENTARY PARTICLE PHYSICS

POLAR - X-ray telescope for Gamma Ray burst polarisation measurements

T. Batsch, K. Jędrzejczak, D. Rybka, J. Szabelski, T. Tymieniecka, A. Zwolińska
National Centre for Nuclear Research, Otwock-Świerk, Poland

POLAR is a space-borne experiment designed the measurement of GRB photons polarisation in the energy range 50-500 keV. Its concept was proposed in 2005 [1]. The instrument has a relatively large effective area and a field of view of nearly half the sky for Gamma Ray Burst (GRB) detection, and 1/3 of half the sky for GRB polarisation measurements. The detector was launched on the 15th September 2016 with the Chinese Tian-Gong 2 Space Station. A few days later POLAR was successfully switched on.

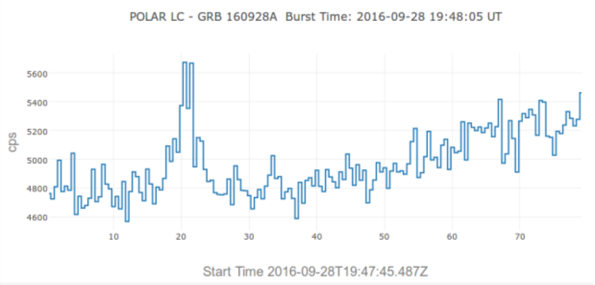

Fig. 1. Light curve of the first GRB observed by POLAR [3].

We know from other measurements made so far that GRBs originate at cosmological distances (the nearest GRB arrived from about 40 Mpc, and X-rays emitted by the most distant GRB observed travelled to the Earth from about 4000 Mpc for a time nearly equal to the age of the Universe; the parsec - pc ≈3.1· 10^{16} m). Because of the huge distances to the GRB origin, the energy emitted by the GRB source during the burst is extremely large. For a large GRB the observed emitted energy might correspond to a few tens of solar masses being converted to gamma photons, assuming isotropic emission of gammas.

GRBs last from a fraction of second to a few minutes. The huge emitted energy and short emission time make GRBs one of the most energetic events observed in the Universe.

The first detection of a GRB was made nearly 50 years ago. Nowadays, about one GRB event is observed per day, on average. Still, the physical mechanism of gamma production is unknown. Photons may be emitted in thermal emission (temperature dependent according to Planck's law), as in the case of light from the Sun, or in non-thermal processes in which photons are emitted in scattering processes of energetic particles. Non-thermal processes could emit photons in particular directions correlated with the energetic particle beam direction, whereas thermal emission is isotropic. We expect the that the gamma emission is a non-thermal process, but the so- called afterglow sometimes observed in UV, visible or infra-red light after aGRB is likely to be due to thermal emission.

Non-thermal gamma-ray emission requireds a beam of energetic particles. In this case the particles would be accelerated in the GRB source by an unknown mechanism. With a huge available energy in GRB emission, GRB sources are being considered as possible sources of ultra high energy cosmic rays.

Polarisation measurements open a new window in the exploration of the gamma ray production in GRBs. Most of models of GRB emission predict significant polarisation of emitted gamma ray flux. POLAR is the largest detector dedicated to the measurements of gamma ray polarisation from GRBs.

POLAR is one of the first and the largest device dedicated specially to measure gamma ray polarisation from GRBs. The method adopted is Compton scattering. A polarised photon beam shows azimuthal asymmetry (with respect to the beam direction) in elastic scattering with electrons (not necessarily polarised electrons). Measuring the positions of two subsequent photon scatterings with electrons it might be possible to measure the degree of polarisation of the photon beam. The pOLAR target is made of 1600 scintillating bars (5.8 mm x 5.8 mm x 17.6 cm) made of light material BC409. The bars are grouped in modules with 64 bars in each module viewed by 64-anode photomultipliers of R10551-00-M64 type. Each of 25 modules records data almost independently. The gate of signal collection is 40 ns, so all photon scatterings (electron ionisations) are recorded at the same time (the sequence is not known). This way we measure a projection of the scattering geometry on the PMT cathode surface. Interpretation of these data requires comparison with the results of simulations with the Geant4 code to obtain the polarisation level from the projection of the azimuth angle modulation measured in the detector. More details are given in [2].

The NCBJ group was involved in the POLAR detector construction (development of hardware and firmware of essential electronic subsystems, like the trigger, global control system, time synchronisation etc., design of the high voltage power supply and its engineering model, many tests of subsystems) and in data analysis (energy calibration with the use of accelerator data and simulations of the detector response). At the beginning of 2017 the framework of scientific cooperation of the POLAR group was formed, which continues analysis of the test data and works on simulations designed to enhance the simulation by taking into account non-uniformity and other physical processes occurring in the detector. The result of the work will be a common simulation code shared by the POLAR Collaboration.

References

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[2] S.Orsi et al., Astrophys. Space Sci. Trans. 7, 43-47(2011)

[3] GCN NASA, number 20126, GRB 160928A: The first GRB detected by POLAR

The NCBJ contribution to the first direct detection of gravitational waves

A. Królak (Leader of POLGRAW group)

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On 11th February 2016 the first direct detections of gravitational waves was announced. The detection was made by the two detectors of the Laser Interferometer Gravitational wave Observatory – LIGO. The interferometers are located in the villages of Livingston, Louisiana, and Hanford, Washington. The first detections was made on 14 September 2015. Gravitational waves have been discovered in data from both detectors by a team from the LIGO Scientific Collaboration, which includes the GEO Collaboration, the Australian Consortium for Interferometric Gravitational Astronomy and the Virgo Collaboration. The article describing the discovery was published in Physical Review Letters (PRL 116, 061102 (2016)) [1]. The signal, registered in both detectors, is in perfect agreement with the signal of gravitational waves coming from the merger of black hole binary with masses of 29 and 36 solar masses. The detection article was accompanied by 10 articles exploring various aspects of the discovery published on the same day. On 26th December 2015 a second gravitational signal from the merger of a black hole binary with masses of 7.5 and 14.2 solar masses was registrated [2].

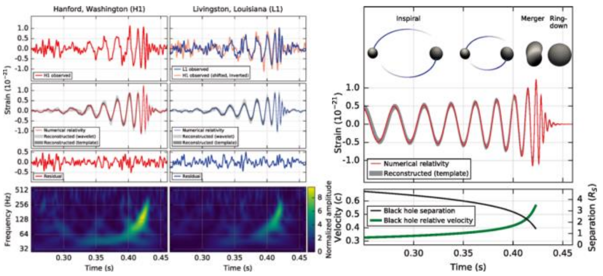

Fig. 1. (left) shows the gravitational wave registered in the Hanford and Livingstone detectors. First row shows strain in both detectors, second row presents signal, third row residua in both detectors. Forth row shows the time-frequency plot. 2, (right) shows: (upper) stages of the binary black hole merger, gravitational wave signal and its agreement with numerical relativity; (lower) relative black hole separation in the binary and its relative velocity. Images are taken from publication [1].

Gravitational waves, similar to black holes, are solutions of Einstein's equations. Albert Einstein predicted the existence of gravitational waves in 1916, by linearisation of the equations. However, for several years there have been doubts whether gravitational waves are a physical effect. Only a thorough analysis of Einstein's equations in the late fifties and sixties of last century showed that they allow gravitational radiation. After that work began on the direct detection of these waves.

The enormous importance of this discovery lies in the fact that the theory of relativity has been verified in a very extreme regime - around the event horizon of a black hole, and where speeds are close to the speed of light. Through this observation a new field was started - gravitational wave astronomy.

The POLGRAW team is a member of the Virgo project (Virgo Collaboration). The team is lead by Prof. Andrzej Królak of NCBJ. Nine members of the team, including three from NCBJ are co-authors of the article in Physical Review Letters presenting the discovery.

Fig. 2. POLGRAW press conference on the first detection of gravitational waves at the Pałac Staszica in Warsaw on 11th February 2016. Held at the same time as the LIGO and Virgo press conferences.Photo: Marianna Zadrożna.

Employees of NCBJ - members of the POLGRAW research group developed the foundations of many algorithms and methods to detect and estimate the parameters of gravitational waves from binary systems (Prof. dr hab. Andrzej Królak), contributed to the precise modelling of the signal of gravitational waves from compact binary systems (Prof. dr hab. Andrzej Królak), searches for optical counterparts to gravitational waves (dr Adam Zadrożny). Andrzej Królak is a board member of the Virgo project and member of the Data Analysis Consortium LIGO-Virgo. He has contributed to the publication of the discovery.

Dr. Adam Kutynia has been contributed to the development of the Virgo detector, and Dr Orest Dorosh is contributing to the search for gravitational waves from rotating neutron stars.

Fig. 3. . Most of the members of thePOLGRAW group from left: Paweł Ciecieląg, Magdalena Sieniawska, Orest Dorosh, Izabela Kowalska-Leszczyńska, Dorota Rosińska, Adam Zadrożny, Michał Bejger, Andrzej Królak, Piotr Jaranowski, Tomasz Bulik. Meterials of POLGRAW group.

Members of the POLGRAW team, who are co-authors of the publication of the discovery, were honoured in 2016 by the Copernicus Medal of the Polish Academy of Sciences, the Polish Physics Society Medal im. Rubinowicza (team award), the Gruber Cosmology Prize and the Special Breakthrough Prize of the Milner Global Foundation. The Special Breakthrough Prize, and the Gruber Prize, were awarded to 1,015 scientists and engineers contributing to the detection of gravitational waves announced in February 2016. Observations of gravitational waves are opening new horizons in astronomy.

References

[1] PRL 116, 061102 (2016)
[2] PRL 116, 241103 (2016)

Test experiments for a large space borne UV telescope detector for ultra high energy cosmic ray measurements (*-EUSO)

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Ultra high energy cosmic rays (UHECRs) are particles with the largest energies per particle known in the Universe. The largest measured energy of one particle exceeded 10^{20} eV, more than 10 million times higher than the 7 TeV proton energy in the LHC accelerator at CERN. The existence of UHECRs is a wonder of Nature, which of the first look ignores statistical rules of energy dissipation. The first UHECR event was discovered by John Linsley in the Volcano Ranch extensive air shower (EAS) detector in 1962. Since then it has been a challenge for astrophysicists to understand the origin of UHECR and to identify their sources. If UHECRs are protons with great energies then their trajectories are only slightly bent in Galactic and extra-galactic magnetic fields, so their directions (relatively easy to measure) should point to the astrophysical sources (if they exist). However, from measurements made over the past 50 years we know that the flux of particles with energies above 10^{20} eV is extremely low, about 1 particle per 100 km^2 per year (or 2 particles per 100000 km^2 per day). Currently, results of UHECR measurements made by the Pierre Auger Observatory (PAO) observing particles from the Southern Hemisphere using a detector of area about 3000 km^2 are consistent with an isotropic distribution. Another huge detector of UHECR placed in the Nothern Hemisphere – the Telecope Array (TA) with a nearly 1000 km^2 surface detector reported large scale anisotropy. Both results created an experimental situation that is very complicated for astrophysical interpretation.

The JEM-EUSO Collaboration [1] will use one of the UHECR detection methods used by the PAO and TA experiments, namely measurements of scintillation in the atmosphere emitted by N_2 molecules excited by hundreds of billions of EAS particles. The advantage is to observe these events from the International Space Station (~400 km altitude) which allows for monitoring of an area of about 160000 km^2. Measurements could be made on the dark side of the Earth, with a duty cycle of about 0.4, and allow nearly 1 UHECR event per day to be measured. The Collaboration is working on the development of a large UV telescope with about 300000 pixels and a very fast camera (one frame per 2.5 microseconds) which can "film" an event lasting less than 30 microseconds [2]. The telescope would have sensors grouped in a modular structure (made up of about 140 units).

A large telescope which introduces new detection technics in space is very expensive, therefore smaller test measurements are required. The first was theEUSO-Balloon experiment, led by IRAP/CNES. One night balloon flight at nearly 40 km altitude was succesfully made on 24/25 August, 2014 from Timmins, Canada.

A similar detector was placed on the ground in Utah, USA, near the Telescope Array. The EUSO-TA experiment is still in use. We participated in the run made in 2016. Measurements were made in coincidence (trigger) with the Telescope-Array (TA). The small EUSO-TA detector has better angular and time resolution than the TA. Data are still being analysed, and in the preliminary results there are a few canditates or EAS detection in EUSO-TA.

Fig. 1: The EUSO-TA and SPB-EUSO team during tests in the Utah desert in 2016. Zb. Plebaniak is the 3rd from the right. EUSO-TA is on the right, SPB-EUSO is in the white container behind the group, and the large building is the TA Black Rock Mesa Fluorescence Detector (FD) of the Telescope Array (TA).

In the NCBJ Łódź Cosmic Ray Laboratory we have designed and built an innovative Cockcroft-Walton power supply with automatic fast switches of the PMT collection efficiency which increases PMT dynamics from 0 to 10^6 photo-electrons per 2.5 μs, and allows for continuous data taking even in the presence of large variations of the background. A new version of the high voltage power supply unit was made in 2016 in our Laboratory for the new test experiments **SPB-EUSO** and **Mini-EUSO**. The Super Pressure Balloon (**SPB**) is a very long duration balloon flight at stratospheric altitudes around Antarctica to be performed by NASA in early spring 2017. EAS measurements are planned. Mini-EUSO is one EUSO module detector for Earth UV emission measurements (including lightning, TLEs, meteors etc.) from the International Space Station. The launch is planned in the second half of 2017.

References

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[2] P. Barrillon et al., Journal of Instrumentation 11, no.1, C01075 (2016), M. Casolino et. at., Exper. Astron. 40 (2015) no.1, 19-44

Measurement of the CP-violating parameters in Bs0→J/ψ(→e+e-)φ(→K+K-) decay at the LHCb experiment

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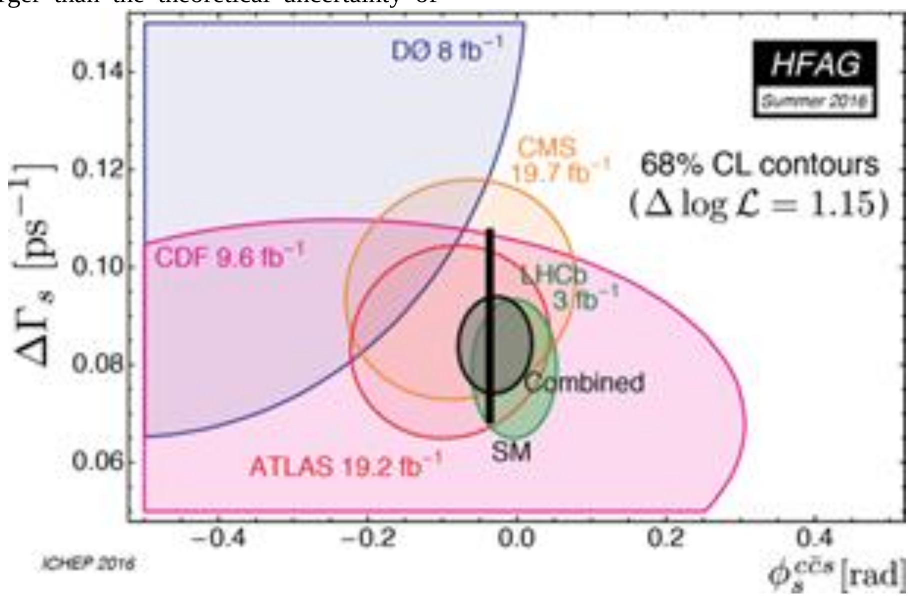
A study of neutral B meson decays into CP eigenstates allows for an observation of indirect CP violation. The interference between amplitudes of B0 mesons decaying directly and those decaying after oscillation is governed by a weak phase φ which can be approximated by the β angle of the unitarity triangles: φd=-2β, φs=-2β_s. A non zero phase will lead to a CP violation. The B^0_s→J/ψφ decay is used for a measurement of the CP asymmetry, which can be expressed in terms of the decay width difference of the heavy (H) and light (L) B^0_s mass eigenstates ΔΓs ≡ΓL-ΓH and a single phase φs. The SM prediction of the phase is precise, φ_s^{SM} = -2arg(-VtsVtb*/VcsVcb*) = -0.0363+0.0012-0.0014 rad. Possible contributions of non-SM particles to the box diagrams describing the B^0 – antiB^0 oscillations would affect the value of the phase φ. In particular, such contributions could lead to much larger values of φs=$\varphi s^{SM}+\varphi^{NP}$ where φ^{NP} is the New Physics contribution. Since both φs and $\Delta\Gamma_s$ are very precisely predicted in the SM any deviation from the prediction will be an unambiguous evidence for the existence of processes beyond the SM. Therefore, precision measurements of the phase φs are viewed as a stringent test of the Standard Model. The world's most precise measurement of the CP-violating phase φs was performed using pp collision data, corresponding to an integrated luminosity of 3.0 fb^{-1}, collected with the LHCb detector. It is based on a combined analysis of B^0_s→J/ψ(→μ+μ-)K^+K^- and B^0_s→J/ψ(→μ+μ-)π+π- channels with resulting φs of −0.010±0.039 rad [PRL 114 (2015) 041801]. The statistical uncertainty of the φ_s dominates the systematic one. Moreover it is significantly larger than the theoretical uncertainty of the SM prediction. Therefore, an increase of the data sample size by analysing another channel will improve the sensitivity of the global analysis. In addition, the analysis of the B^0_s→J/ψ(→e^+e^-)φ(→K^+K^-) channel will be a verification of the results from the golden channel, with muons in the final state, as the kinematics for both channels are expected to be identical. In comparison to the muon channels the precision of the e^+e^- pair momentum determination is worse while the combinatorial background complicates the signal selection.

The analysis performed by the NCBJ group focuses on the study of the CP symmetry and in particular its violation in an electron mode of the B^0_s→J/ψφ decay. A measurement of the weak phase φ_s will be carried out in a previously not studied decay channel of B^0_s, namely B^0_s→J/ψ(→e^+e^-)φ(→K^+K^-). It will be based on the full Run I data sample of the LHCb experiment corresponding to an integrated luminosity of L = 3.0 fb^{-1} at a pp centre-of-mass energy of √s = 7 and 8 TeV collected in 2011 and 2012, respectively. The number of signal B^0_s→J/ψ(→e^+e^-)φ(→K^+K^-) events is estimated at around 12% compared to the muon mode. The expected error for this measurement is estimated to be 0.14 rad. The method used in the analysis includes information about the decay time acceptance and resolution, angular acceptance and flavour tagging of the B0s meson decay. A significant addition to the analysis compared to the golden channel result is the utilisation of Boosted Decision Trees for improved selection of signal events. The main part of the analysis has already been completed and is under collaboration review



The combined analysis of neutrino and antineutrino data samples in the T2K experiment

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T2K [1] is a second generation long baseline experiment using an artificial neutrino beam sent from the J-PARC laboratory to the far water Cherenkov detector, Super-Kamiokande (SK). T2K is designed to probe precisely neutrino mixing parameters through measurement of oscillations of muon neutrinos.

Currently running and planned experiments aim at the close investigation of the three-flavour oscillation paradigm by precise measurement of the θ23 mixing angle, resolution of the mass hierarchy and searching for the CP violation in the lepton sector. CP violation can only be found in the appearance oscillation mode, which was discovered at T2K by observing the transition $\nu_\mu \rightarrow \nu_e$ [2].

T2K uses a very pure beam produced using the accelerator complex at Tokai in Japan and sent towards the SK detector 295 km away, with an off-axis angle of 2.5 degrees. T2K studies both disappearance of muon neutrinos and appearance of electron neutrinos thanks to the excellent SK capability to distinguish interactions of muon and electron neutrinos using the topology of the Cherenkov ring.

Two Near Detectors are located 280m from the neutrino production point to measure the unoscillated beam. The off-axis detector, called ND280, is a multi-purpose magnetized detector able to measure the spectrum and flavour composition of the beam. ND280 provides samples of events enriched in different neutrino reaction types and sampling different neutrino energy ranges. Such samples are then used in the fit of the (anti)neutrino energy flux and cross section parameters used in models of neutrino interactions in Monte Carlo simulations. The multi-dimensional fit is based on distributions of reconstructed muon candidate angle and momentum. As a consequence of the input from ND280 the expected (anti)neutrino spectra at the SK detector can be predicted with much better precision. The error on the number of expected events in SK associated with flux and cross section parameters is 2.9% (3.4%) for (anti)-νμ induced events and 4.2% (4.6%) for events originated by interactions of (anti)-νe. The NCBJ group is mainly involved in the analysis performed by ND280: we are responsible for the estimation of the external background and some of the systematic errors related to the ND280 detector and for the selection of antineutrino samples planned to be used in the near future.

T2K started to take data with neutrino beam in 2010 and collected 7.57×10^{20} protons on target. Since 2015 T2K has run mostly with an antineutrino beam, producing a set of data equivalent to 7.53×10^{20} protons on target. The results on the νe appearance and νμ disappearance have already been published in previous years [2,3]. In 2015, T2K also published the results of acombined νμ-νe analysis, in which both $\nu_\mu \rightarrow \nu_e$ and $\nu_\mu \rightarrow \nu_\mu$ oscillation channels were used simultaneously [4] and the first results for the antineutrino data were published in 2016 [5].

The oscillation analysis relies on a comparison of the event rates and distributions of the reconstructed neutrino energies (or lepton momentum and angle) for the observed (anti)-ν_μ and (anti)-ν_e candidate events with the model predictions. In 2016, T2K performed a combined fit to all neutrino and antineutrino data in which the following oscillation parameters were fit simultaneously: $|\Delta m^2_{32}|$, θ_{23}, θ_{13} and δ_{CP}, and the rest of the oscillation parameters were based on external measurements. Two possible mass hierarchies were tested independently. The allowed region for $|\Delta m^2_{32}|$ and θ_{23} is shown in Fig. 1, in comparison to the results from other experiments.

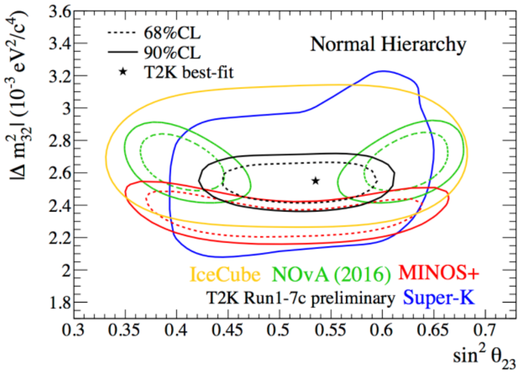

Fig. 1. Allowed regions for oscillation parameters $|\Delta m^2_{32}|$ and θ_{23} from several neutrino experiments.

The most interesting result of this analysis is the first hint of CP violation. The numbers of (anti)-ν_e appearance candidate events indicate that the value of δ_{CP} inducing the largest neutrino-antineutrino asymmetry is preferred by our data: -π/2. The T2K measurements reject the hypothesis of CP conservation in the neutrino oscillation with a 90% confidence level for both mass hierarchies.

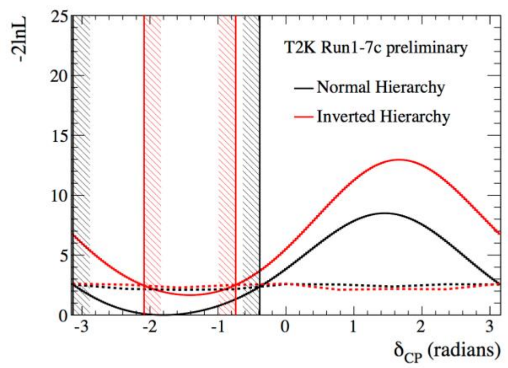

Fig. 2. 90% confidence level intervals in δ_{CP}.

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Nonextensive critical phenomena in the Nambu Jona-Lasinio model

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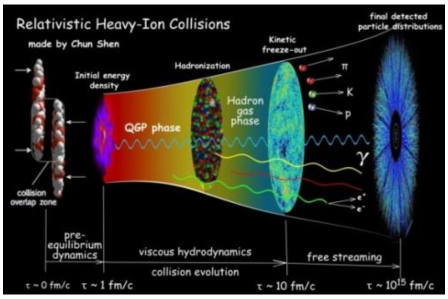
It is nowadays widely accepted that in many branches of physics experimental data indicate the necessity of a departure from the standard extensive Boltzmann-Gibbs (BG) statistics, which is then replaced by a non-extensive statistics. Here a non-extensive calculation in dense nuclear matter (NM) is proposed. We can distinguish two physical systems, in which knowledge of the nuclear Equation of State for a density several times larger than the density of atomic nuclei is significant: the interior of neutron stars and high-energy scattering of heavy ions. Higher density and higher temperatures of NM occur in the scattering of heavy ions, where quarks and gluons are the basic degrees of freedom of a description of NM.



Their mutual interactions have a long-range nature leading to correlations, which become important with the increase of density and persist above the temperature of the phase transition from hadron matter to quark-gluon matter. Such a strongly correlated system can be well described using the nonextensive Tsallis approach [1]. In this approach, the entropy of the system S_q is not the sum of the entropies of individual subsystems, and in addition to the standard parameter T (temperature) occurring in the conventional BG statistics, there is a new parameter q called the nonextensive parameter. The quantity $|q-1|$ is the measure of departure from equilibrium (usually to the state of being some type of stationary state). Relations $S_q(q>1) > S_{BG}(q=1) > S_q(q<1)$ in the literature determine appropriate systems as being “superadditive”, “additive” and “subadditive”. This happens wherever the investigated system is “small” (which means that it is of a size comparable to the range of the operating forces), when non-statistical fluctuations, correlations and all types of “memory” effects occur in it. Thermodynamically this means that the so-called “heat bath” is finite and inhomogeneous. In Ref. [2] analyzing a Fermi Gas model we compare and discuss these distributions following the method presented in [3], both for the momentum dependent fermion distributions $n_q(p)$ and for anti-fermion distributions. Based on the above results, a nonextensive variant of the NJL model was formulated for dense quark matter, with the liquid and gas phase, in Ref. [4].

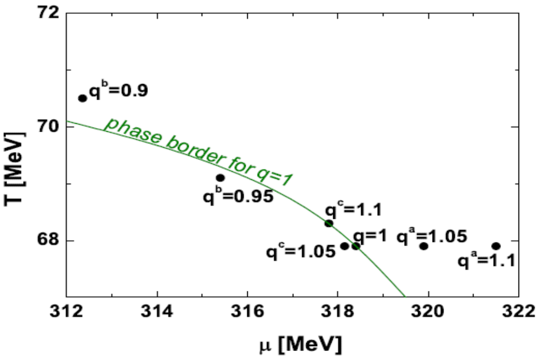


Fig. 1. Phase boundary in non-extensive Nambu Jona-Lasinio model obtained for different values of non-extensive parameter q: $q=1$, $q^a>1$, $q^b<1$; q^c - hybrid.

Here, among others, we analysed, in the area of the phase transition, the critical temperature as a function of the departure from the BG statistics, given by the parameter $|q-1|$. Thus, the dependence of pressure, entropy, specific heat and baryon susceptibility (related to the observed fluctuations of the baryon numbers) from the nonextensive parameter q, density and temperature T, was calculated. The behaviour of these parameters in the critical area (that is for density and temperature near the phase transition) allowed the examination of possible changes of the phase transition for nonextensive systems. The nature of the phase transition and the location of the Critical End Points - Fig.1, in the coordinates of density and temperature depend on this (same in Fig. 9 in [4]). The main result of this part of the paper is the presentation of differences between the NJL calculations with different arrangements (entropies) of the quark system (see Fig. 3 in [4]). With a better ordering, there is smaller entropy of the quark system (q<1), and NM is characterized by a lower pressure in the critical area. The expected phase transition is smoother compared to the system of higher entropy (q>1) in which changes of such critical parameters, like specific heat or baryon susceptibility, have a more singular course.

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On the one loop $\gamma^* \to qq$ impact factor and exclusive diffractive cross sections for the production of two or three jets

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One of the most important legacies of HERA is the fact that almost 10 % of the γ^* p $\to$ X deep inelastic scattering (DIS) events contain a rapidity gap between the proton remnants and the hadrons coming from the fragmentation region of the initial virtual photon. This subset of events, called diffractive deep inelastic scattering (DDIS), thus looks like γ^*p $\to$ X Y, where Y is the outgoing proton or one of its low-mass excited states, and X is the diffractive final state. Apart from the inclusive DDIS data, one can further focus on more specific interesting observables, like diffractive jet(s) production, or exclusive meson production.

Due to the existence of a rapidity gap between X and Y, it is natural to describe diffraction through a Pomeron exchange in the t−channel between these X and Y states. This is a common concept underlying the approaches to describe diffraction within perturbative QCD.

In the collinear framework, justified by the existence of a hard scale (the photon virtuality Q^2 of DIS), a QCD factorization theorem was derived. Similarly to DIS on a proton, here one introduces diffractive structure functions. In this resolved Pomeron model, these distributions describe the partonic content of the Pomeron, similarly to the usual parton distribution functions for proton in DIS.

At high energies, it is natural to model the diffractive events by a direct Pomeron contribution involving the coupling of a Pomeron with the diffractive state X of the nvariant mass M. For low values of M^2, X can be modelled by a qq pair, while for larger values of M^2, the cross section with an additional produced gluon, i.e. X = qqg, is enhanced.

In Ref. [1] we perform a complete next-to- leading order (NLO) description of the direct coupling of the Pomeron to the diffractive X state. The calculation was done within Balitsky's high energy operator expansion. Together with our previous result for the $\gamma^* \to$ qqg Born impact factor it allows one to derive cross sections for 2- (one loop) and 3-jet (Born) difractive electroproduction. For the 2-jet cross section we demonstrate the cancellation of infrared, collinear and rapidity singularities. Our result can be directly exploited to describe the recently analyzed data on exclusive dijet production at HERA and used for the study of jet photoproduction in ultraperipheral proton or nuclear scattering.

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Vibronic framework for a quantum mixmaster universe
Nonadiabatic bounce and an inflationary phase in the quantum mixmaster universe

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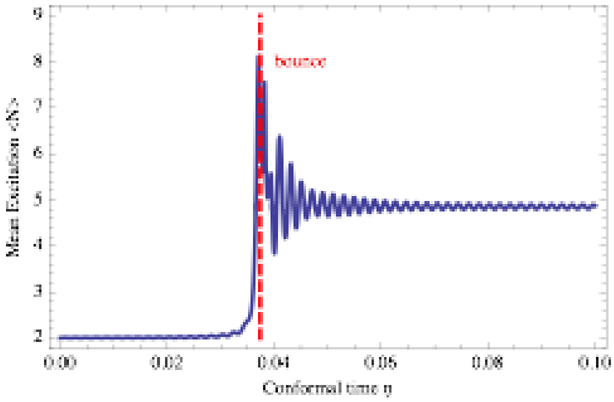
A spatially homogenous cosmological model of general relativity, the Mixmaster universe, exhibits rich behaviour on the approach to the big-crunch/big-bang singularity and is a focal point of many investigations into the singularity problem. It describes a non-linear gravitational wave coupled to an isotropic background. The singularity of the Mixmaster universe can be resolved via affine quantization. A repulsive potential that issues from this quantization procedure generates a bounce which replaces the classical singularity. Due to the formal analogy between the Hamiltonians of the Mixmaster universe and of molecular systems, the quantum dynamics of the former has been studied with the adiabatic approximation known from molecular physics. The papers [1,2] extend the analysis of the quantum Mixmaster dynamics to the nonadiabatic regime.



The paper [1] provides a complete and consistent set of equations of motion for the quantum Mixmaster universe within the so called vibronic framework. The anisotropy variables are given a full quantum treatment, whereas the isotropic variables are studied at the semiclassical level. The result is a set of coupled Schrodinger and Hamilton equations. A numerical study shows that the contraction and expansion phases are adiabatic, whereas the bounce can be nonadiabatic and excite anisotropy oscillations (see the figure). The anisotropy oscillations can in turn produce an extended phase of accelerated expansion following the bounce.

The paper [2] provides a qualitative analysis of the dynamics derived in [1]. In particular, it identifies two factors which determine if a quantum bounce is nonadiabatic. The first factor is the initial eigenstate of the gravitational wave energy. The larger the eigenvalue N the more rapid the contraction and the smaller the volume at which the contraction is stopped and reversed. The smaller the volume at which the universe rebounds the more abrupt the bounce and the more likely the adiabatic behaviour is to break down. The other factor is a free parameter whose value determines the strength of the repulsion. The smaller the parameter the smaller the volume at which the universe bounces and the more abrupt, or the less adiabatic, the bounce is. Nondiabatic bounces induce a post-bounce accelerated expansion which can last indefinitely long. This finding suggests that perhaps one could reproduce the predictions of inflationary models concerning the large scale structure in the Universe without postulating the existence of inflation, since the quantum effects in the cosmological background dynamics could be responsible for triggering and sustaining the inflationary phase.

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NUCLEAR PHYSICS

Influence of single-neutron stripping on near-barrier ^{6}He + ^{208}Pb and ^{8}He + ^{208}Pb elastic scattering

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New precise data for the elastic scattering of ^{8}He from a ^{208}Pb target at a beam energy of 22 MeV enabled a comparison with existing data for ^{6}He + ^{208}Pb at the same energy [1]. The angular distributions for the two systems differ significantly (see Fig. 1) and optical model fits found that while the imaginary part of the optical model potential has a longer range for ^{6}He the overall absorption, as quantified by the total reaction cross section, is greater for ^{8}He. It was speculated that this might be due to the greater importance of neutron-stripping reactions for ^{8}He, since the breakup thresholds are lower for ^{6}He.

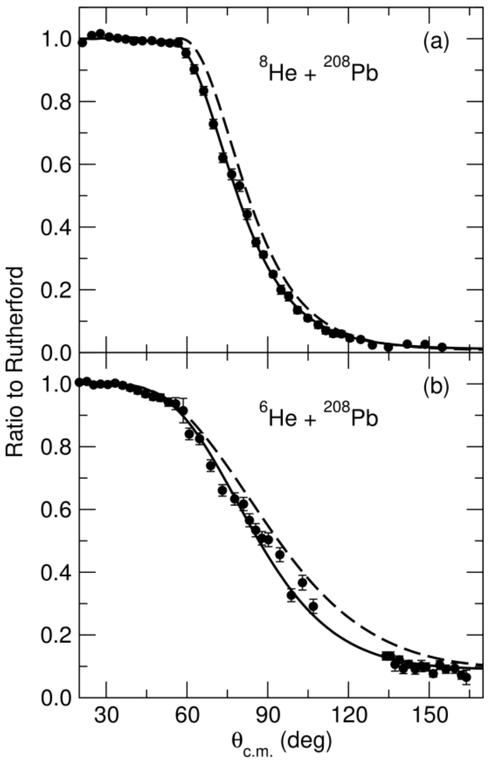

Fig. 1. (a) 22 MeV ^{8}He + ^{208}Pb elastic scattering angular distribution. (b) 22 MeV ^{6}He + ^{208}Pb elastic scattering angular distribution. The solid and dashed curves denote full CRC and no-coupling calculations respectively.

In a recent publication [2] we presented coupled reaction channels (CRC) calculations including couplings to the (^{8}He,^{7}He) and (^{6}He,^{5}He) single-neutron stripping reactions to investigate this hypothesis. Full details are given in Ref. [2].

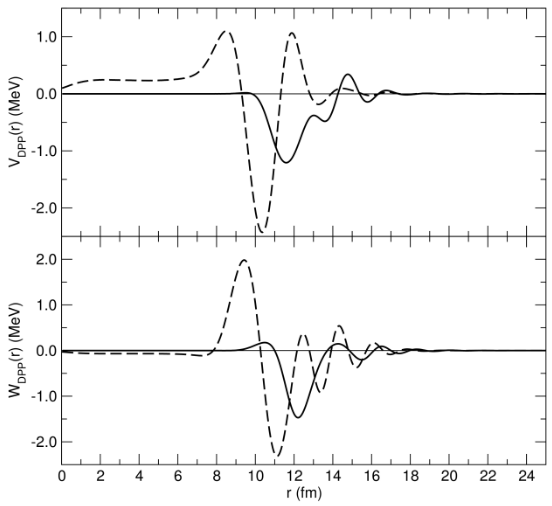

Fig. 2. Real and imaginary parts of the DPP due to single neutron stripping for 22 MeV ^{8}He + ^{208}Pb (solid curves) and ^{6}He + ^{208}Pb (dashed curves).

In Fig. 1 we show the results of our calculations. It will be noted that for ^{8}He the single-neutron stripping coupling has a significant effect on the elastic scattering for angles around 60°, where the Coulomb rainbow peak would normally occur, in contrast to ^{6}He where it has a negligible effect in this region. The coupling influence as quantified by the effect on the imaginary parts of the optical model potentials is larger for ^{8}He and scales well with the difference in spectroscopic factor for the two projectile-ejectile overlaps.

The dynamic polarisation potentials (DPPs) due to the stripping couplings were derived from the CRC scattering matrices by S matrix to potential inversion. These showed significant differences, in particular the absorption due to single-neutron stripping takes place at larger radii for ^{8}He than for ^{6}He, in contrast to what was found for the total absorption [1], see Fig. 2.

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Determination of impact parameters in aligned breakup of projectile-like fragments in ^{197}Au + ^{197}Au collisions at 23*A* MeV

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Collisions of very heavy nuclear systems, such as ^{197}Au + ^{197}Au, attract the interest of researchers mostly because of the complete elimination of fusion processes which cannot occur due to the Coulomb instability of such super-heavy composite systems. Consequently, a wide range of impact parameters corresponding to semi-peripheral and near-central collisions is open to fast dynamical rearrangements of nuclear matter and new exotic processes. Ternary breakup of heavy nuclear systems [1, 2] proceeds as a rule sequentially, in two stages. In the first stage a large portion of kinetic energy is dissipated and an excited projectile-like fragment (PLF*) and excited target-like fragment (TLF*) are formed as a result of the exchange of many nucleons between the target and projectile: ^{197}Au + ^{197}Au → TLF* + PLF*. In the second stage of the reaction either the PLF* or TLF* breaks up. In the case of an initially symmetric system both decay modes are identical, so it is sufficient to study half of the events in which the PLF* breaks up.

The experiment was performed at the INFN LNS in Catania, Italy. A beam of ^{197}Au ions from the LNS Superconducting Cyclotron was accelerated to an energy of 23A MeV and bombarded a ^{197}Au target placed inside the Charged Heavy Ion Mass and Energy Resolving Array (CHIMERA) [3]. The CHIMERA multidetector is arranged in 4π geometry and contains of 1192 two-layer ΔE − E telescopes, each consisting of a planar 275 μm-silicon detector and a CsI(Tl) scintillator.

In a recent publication [4] we studied pairs of fragments F1 and F2 formed in the process PLF* → F1 + F2, where F1 denotes the heavier fragment of mass number A_{F1} and F2 denotes the lighter one of mass number A_{F2}. Experimental data were analyzed as a function of the ratio $f = A_{F2}/(A_{F1} + A_{F2})$ which is a measure of the asymmetry of the breakup. Some quantitative results for the most probable events for a given asymmetry are collected in the Table. The first three columns show separately the asymmetry parameter bin width and the corresponding mass numbers A_{F1} and A_{F2}, respectively. Column four shows the value of the total kinetic energy (*TKE**) of the reconstructed PLF* and complementary TLF* (calculated from momentum balance).

F	A_{F1}	A_{F2}	TKE* (MeV)	L (ħ)
0.10-0.15	149	22	1493	1030
0.15-0.20	142	30	1412	1003
0.20-0.25	135	40	1329	976
0.25-0.30	127	49	1330	976
0.30-0.35	118	57	1458	1017
0.35-0.40	111	67	1622	1066
0.40-0.45	103	77	1699	1091
0.45-0.50	94	85	1699	1091

In order to obtain information on the localization of the PLF* breakup reactions in impact parameter/angular momentum space, we carried out calculations using the well tested nuclear dynamics model HICOL of Feldmeier [5]. Provided the inertia of the colliding system is calculated in HICOL sufficiently realistically, the inelasticity of the reaction (i.e. the *TKE** value) unambiguously determines the resulting localization of the reaction in L−space. The HICOL calculations have been done for all asymmetry bins. Surprisingly, independently of the asymmetry of the breakup, the reactions turned out to be localized in quite a narrow range of L-values, $L \approx$ 1000-1100 $\hbar$ (see the last column in the Table). This corresponds to a very large but not complete damping of the available kinetic energy. The grazing trajectory angular momentum for these reactions is $L_{graz} \approx 1570\ \hbar$.

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PLASMA PHYSICS & TECHNOLOGY

Research on high-current discharges of the plasma-focus type*

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In the first quarter of 2016 the TJ5 team submitted a revised paper on studies of fast electron beams and soft X rays from PF experiments reported in the Annual Report for 2015. The electron beams escaping from the PF-360U facility (in the upstream direction) were studied by means of a magnetic analyzer equipped with Cherenkov detectors. HXRs and neutrons were recorded with a scintillation probe, and time-integrated SXR images were taken with a filtered pinhole camera. Correlations of fast electron beams and plasma micro-structures were found [1].

Within the framework of a scientific collaboration between NCBJ, IFPiLM and CVUT, new experiments at the PF-1000U facility were performed. A joint team investigated the influence of a thin Al-wire (fixed along the axis) on transformations of a plasma column. It was observed that the insertion of the Al-wire did not prevent the formation of a pinch column, as shown in Fig. 1.

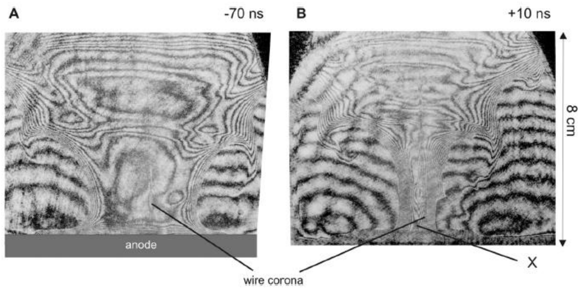

Fig. 1. Interferometric images from shot #10633, obtained: (A) at the current sheath implosion, (B) at the formation of the 1st dense plasmoid.

The interferometric images, as recorded during the plasma column stagnation in PF-discharges carried out with and without the Al-wire, did not reveal any strong differences, as shown in Fig. 2.

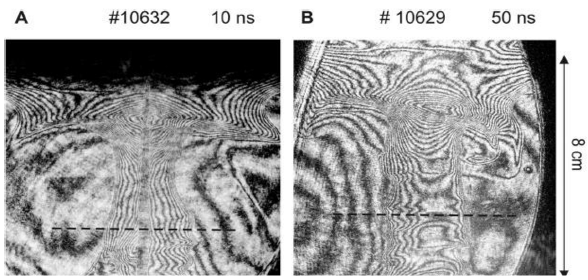

Fig. 2. Interferometric images recorded during the stagnation of the pinch column: (A) for shot #10632 performed with the Al-wire, (B) for shot #10629 without any wire.

An important difference was only observed in the plasma electron density. For shots with the Al-wire its value near the pinch axis (at r = 2 mm) was almost three times higher than that for shots without the wire. Some characteristic features of shots with the Al-wire were observed particularly in the earlier phases of the PF-discharge, as shown in Fig. 3.

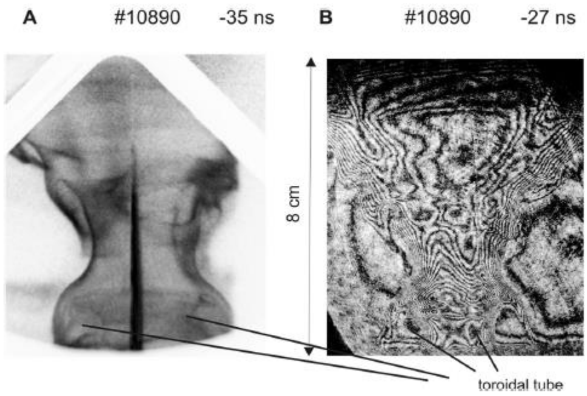

Fig. 3. Toroidal micro-structures inside the Al-wire corona and dense plasma column during the first SXR-pulse emission, as observed: (A) on the XUV frame, (B) on the interferometric image.

On the basis of the observations it was stated that the Al-wire corona did not prevent the formation of dense plasmoids and the production of fusion-neutrons. It was also found that the fusion-produced neutrons are emitted mainly during the transformation of the pinch column, when the wire corona is not interrupted [2].

Other experiments at the PF-1000U facility concerned the influence of a nitrogen admixture on the evolution of the deuterium pinch column. Particular attention was focused on XUV images, as shown in Fig. 4.

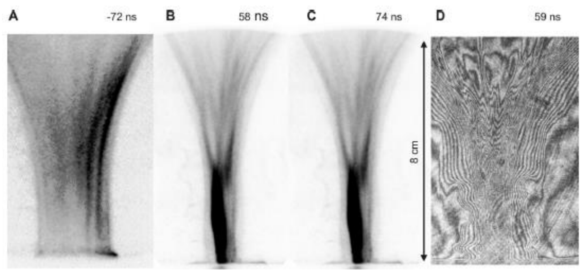

Fig. 4. XUV images recorded at various instants of shot #11200: (A) at -72 ns, (B) at +58 ns, (C) at +74 ns. The interferometric image (D) was taken at the same instant as (B), and its upper part also showed some filaments.

Particular attention was focused on an analysis of interferometric images recorded at different instants and the study of some plasma micro-structures, as shown in Fig. 5.

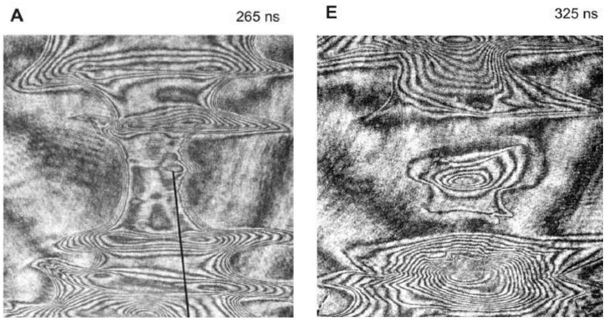

Fig. 5. Interferometric images of different phases of shot #11189: (A) - constriction of plasma column, (E) - the pinch interruption and formation of separate plasmoids.

On the basis of these studies it was found that the current filaments (recorded during the implosion and the pinch phase) were 1-2 mm in diameter, and the electron density amounted to (3-7) x 10^{18} cm^{-3}. It was also deduced that reconnections of magnetic field lines (generated by current filaments) induced strong electrical fields, which could accelerate electrons and ions to energies ranging up to hundreds of keV [3].

Different phases of the PF-discharges were also investigated by means of an XUV camera. The recorded images delivered additional information about the plasma structures, as shown in Fig. 6.

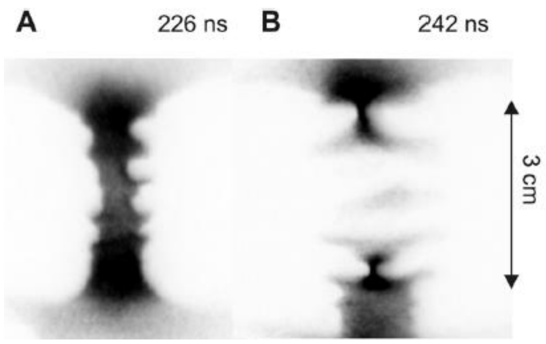

Fig. 6. Shot #11200. XUV images from shot #11200, which show the final phase of a regular constriction: (A) - before the HXR and neutron emission, (B) - during this emission.

The next experiments at the PF-1000U were performed by the same international team, and they concerned detailed interferometric measurements and X-ray diagnostics of pinched helium plasma in a PF-discharge with an Al-wire on the axis [4]. The dynamics of the helium pinching was investigated with a laser interferometer, as presented in Fig. 7.

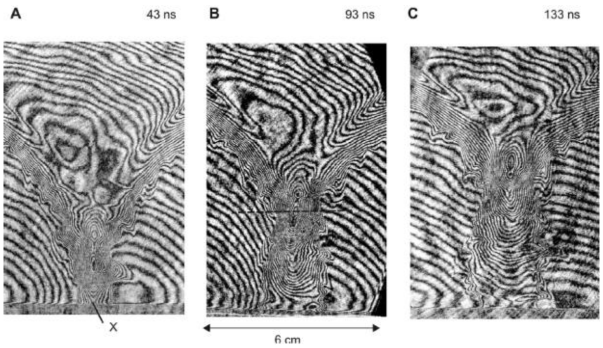

Fig. 7. Interferometric images of shot #10912 with He-filling, as recorded: (A) at the SXR maximum, (B) after HXR peak maximum, (C) after all the X-ray pulses.

The data obtained showed that helium discharges also produce spontaneously organized helical-, toroidal- and plasmoidal-structures, but the dynamics was slower (the central plasmoid was formed in 100 ns). The production of HXR pulses was different; in deuterium shots they were emitted during the evolution of instabilities, while in helium shots – during the formation of the 1st plasmoid. The use of the Al-wire did not influence the production of plasmoids and HXRs considerably [4].

The most important results of the recent research on high-temperature plasma, which were performed at NCBJ in 2015-2016, were summarized in an invited lecture at the ICPPCF-2016 conference in Kharkov and published in PAST [5].

All the results of the experimental research on fast electron beams and X-ray emission which were obtained at thePF-1000U and PF-360U facilities have also been summarized by W. Surala in his Ph.D. Thesis [6].

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* Scientific collaboration between NCBJ, IFPiLM, and CVUT.

Investigation of X-ray emission, estimation of plasma electron temperature in PF-discharges, and research on plasma-target interactions*

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In the first quarter of 2016 the TJ5 team prepared revised versions of two papers. The 1st paper summarized experimental studies of plasma interactions with tungsten targets at the PF-1000U facility, which were described in the Annual Report for 2015. Optical spectra of plasma produced at the W-target sample were analyzed and compared [1]. Particular attention was paid to W-sample erosion induced by intense plasma streams, as shown in Fig. 1.

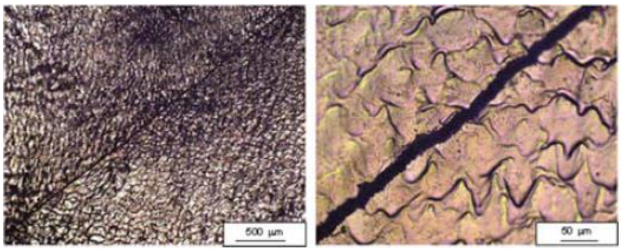

Fig.1. Pictures of the W-sample surface (at different magnifications) which was placed at a distance of 6 cm from the PF-1000U electrode outlets and irradiated by 3 plasma shots performed at p_0 = 1,6 hPa (D_2) and U_0 = 21 kV.

The 2nd paper described studies on interactions of plasma streams with CFC targets in the Rod Plasma Injector facility, which were also partly described earlier. Attention was focused on comparison of optical spectra obtained for a free plasma stream, and those observed for shots with the CFC-sample [2], as shown in Fig. 2.

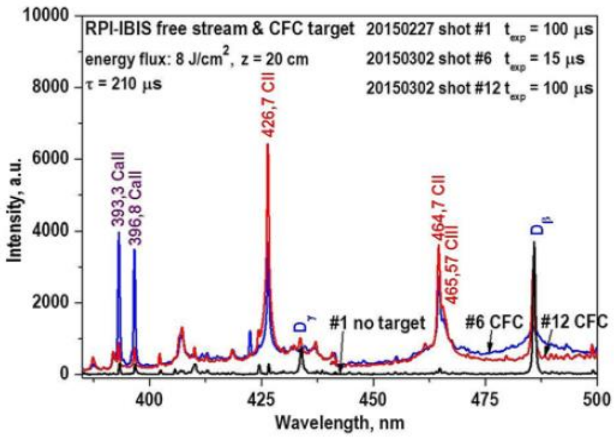

Fig. 2. Comparison of optical spectra from a free plasma stream (black) and those from 2 shots performed with the CFC target (blue at t_{exp} = 15 µs, red at t_{exp} = 100 µs).

Within the framework of the international collaboration a joint team carried out experimental research on the simulation of plasma-surface interactions in a future fusion reactor by means of intense plasma streams generated in the QSPA facility [3]. Recent results and prospects for future experiments were considered. Particular attention was paid to the erosion of W-samples, as presented in Fig. 3.

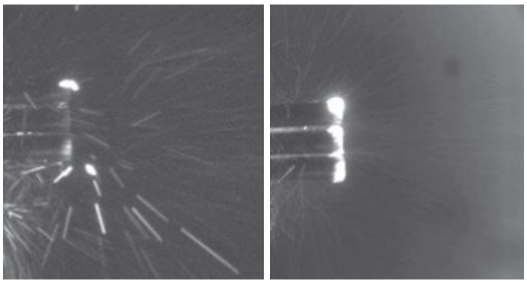

Fig. 3. High-speed pictures of the tungsten brush-like target, which were taken during the 20th shot (left) and during the 30th shot (right), at t = 3.6 ms after the irradiation start, and at a frame exposure time equal to 1.2 ms.

Erosion of the irradiated surfaces was also investigated with a microscope, as shown in Fig. 4.

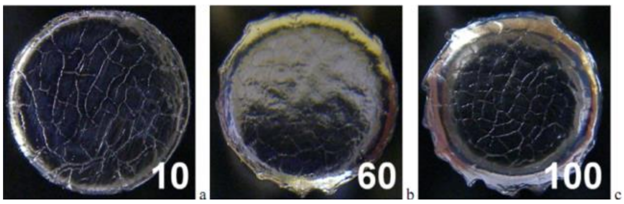

Fig. 4. Pictures of the front surface of a single rod from the centre of the W-brush target after its irradiation by 10, 60, and 100 plasma pulses in the QSPA facility.

Other experiments concerned optical emission spectroscopy (OES) of plasma during discharges used for coating deposition by means of the Gas-Controlled Impulse Plasma Deposition (GCIPD) technique [4]. The experiments concerned the deposition of TiN layers by means of gas-controlled discharges in a plasma coaxial-gun facility. The gun was equipped with titanium electrodes, and the working gas was nitrogen. Detailed analysis of the OES measurements made it possible to identify numerous spectral lines of Ti- and N-ions, as shown in Fig. 5.

**Scientific collaboration between NCBJ, IFPiLM, IPP KIPT, and the Kurchatov Institute*

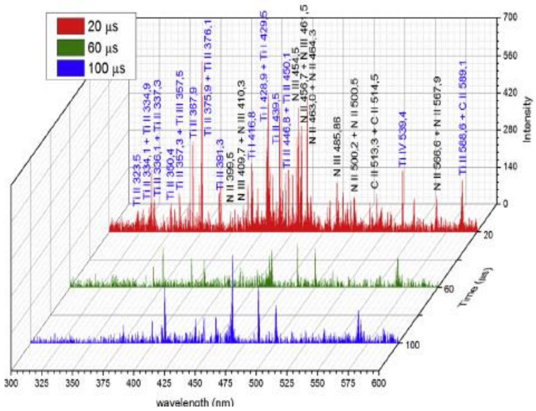

Fig. 5. Temporal changes of the optical spectrum of plasma generated at IPD energy equal to 1600 J.

Much effort was devoted to research on soft X rays emitted from high-current plasma-focus (PF) discharges and estimation of plasma electron temperature [5]. These studies were carried out at the PF-1000U facility. To record soft X ray (SXR) signals use was made of two silicon PIN diodes placed behind filtered pinholes, which observed a chosen region (of about 30 mm in diameter) at the anode outlet. The measurements were performed under different gas conditions and they enabled us to record SXR peaks in correlation with dI/dt, HXR and neutron pulses, as shown in Fig. 6.

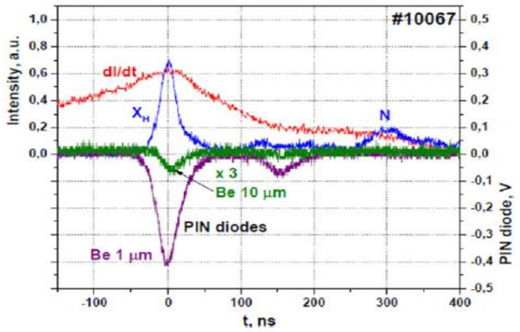

Fig. 6. Typical waveforms and SXR peaks recorded for a PF-1000U shot performed at the D_2 filling (without puffing).

The most important result was the estimate that the electron temperature (Te) in a region near the electrode outlets during deuterium discharges was 150-170 eV, while for neon discharges with deuterium puffing it amounted to 330-880 eV [5].

More detailed studies of the SXR emission were performed with two couples of PIN diodes observing different regions of the pinch [6]. On the basis of the SXR signals it was possible to estimate T_e values in the chosen parts of the plasma column. For discharges with additional gas puffing 2-3 SXR-peaks were observed in each region. It was found that Te could reach 210-550 eV at z = 3 cm and 110-115 eV at z = 6 cm, as shown in Fig. 7. More detailed studies of the SXR emission were performed with two couples of PIN diodes [6]. It was possible to estimate T_e values in the chosen parts of the plasma column. For discharges with additional gas puffing 2-3 SXR-peaks were observed in each region. It was found that T_e could reach 210-550 eV at z = 3 cm and 110-115 eV at z = 6 cm, as shown in Fig. 7.

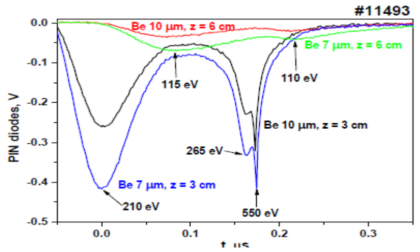

Fig. 7. SXR signals from two pairs of the filtered PIN diodes for shot #11493 performed with the additional deuterium puffing (2 ms before the discharge initiation).

Deuterium-discharges with a small admixture of neon were also investigated. In this case some filamentary plasma structures and several SXR peaks were recorded, which might correspond to "hot-spots" [6].

The most important data obtained from studies of the visible radiation and X rays as well as from estimates of Te values in PF-type discharges, were summarized by D. Zaloga in his Ph.D. Thesis [7].

The recent experiments at the PF-1000U facility were performed in collaboration with the Kurchatov Institute. The main aim was to perform OES measurements of long deuterium- and helium-plasma jets, which might be used for astrophysical studies in the laboratory [8]. A picture of such a jet is shown in Fig. 8.

Fig. 8. Time-integrated picture of a plasma jet, taken in the PF-1000U facility during discharge #11541 performed at p_0 = 1.2 hPa D_2, U_0 = 16 kV, and I_{max} = 1.4 MA.

In addition to detailed OES measurements the dimensionless parameters, i.e. Mach, Reynolds and Pecklet numbers, and density contrast were determined [8].

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Acceleration of protons in plasma produced from a thin plastic or aluminum target by a femtosecond laser

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The acceleration of protons in the plasma produced from thin mylar (3.5 μm) and Al (2 μm) targets by 45 fs light pulses with energy of 400 mJ and intensity of up to 10^{19} W/cm^2 was investigated. The irradiation source used in this experiment is an ultra-intense femtosecond laser operated at the IPPLM (PULSAR) at a repetition rate of up to 10 Hz. The maximum pulse energy is more than 500 mJ in 40 fs pulses at a wavelength of 810 nm, which corresponds to a power of 10 TW. In the experiment the laser beam was focused onto a small spot of 15 μm diameter which correspond to a power density at a level of 10^{18}–10^{19} W/cm^2. In the measurements special attention was paid to the dependence of the proton beam parameters on the laser focus position in relation to the target surface which resulted in an intensity change within a factor of ~ 10. A variety of diagnostics were applied (Fig. 1) in order to investigate: the ion velocity distribution and average velocity and energy, and also ion current change and X ray characteristics.

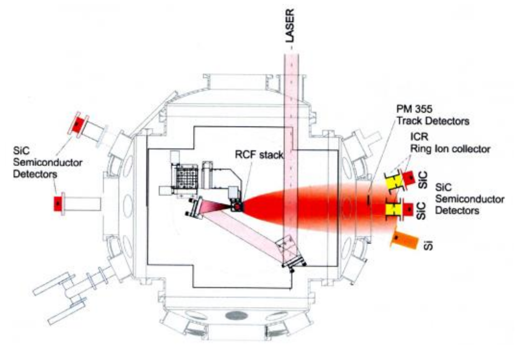

Fig. 1. Experimental arrangement and diagnostic tool location.

A stack of RCF (RadioChromic Film) detectors covered with 3.5 μm Al foil was installed to observe fast protons and X-rays emitted from the laser produced plasma. The energy spectra of fast protons were investigated by two SiC detectors (in the high energy range) and Ion Collectors (IC) in the low energy range. Track detectors were covered by different filters (from 1.5 μm up to 30 μm) to register ions with energies greater than respectively: 170, 450, 850, 1.25 and 2.1 MeV (Fig. 2). For both targets the experimental series included a number of laser pulses with targets installed in different positions with respect to the focal point of the laser beam – from – 200 μm to 200 μm for Mylar foil and from – 500 μm to 500 μm for the Al foil were performed (Fig. 3).

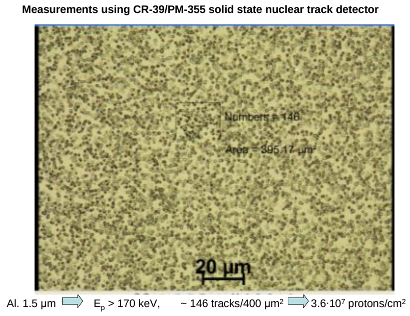

Fig. 2 . Tracks induced by energetic protons in a sample of PM-355 nuclear track detector.

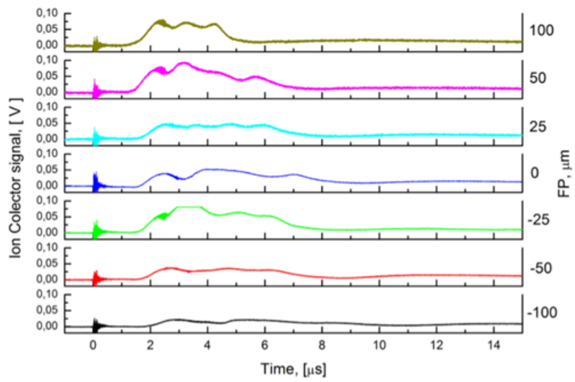

Fig. 3. Mylar foil target. Ion collector signals in dependence of the laser focal position with respect to the target surface.

It can be concluded that the first experiment with the high power femtosecond PULSAR laser at the IPPLM has been completed successfully. Aluminum and Mylar foils were investigated in order to find the dependence of the protons and X-rays emission from the target on the focal spot position of the laser beam.

The application of track detectors allowed energy spectra of the emitted particles (protons) to be measured and the presence of high energy protons (up to 2.1 MeV) to be confirmed. Based on the results obtained with the SiC detectors it was found that for the Al target the dependence of the maximum proton energy on the laser beam intensity was rather small. For the Mylar target this dependence is more clear.

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Studies of fast electron streams in tokamaks with Cherenkov-type diagnostics

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Fast electrons produced in high-temperature plasma and escaping from tokamak-type facilities are of particular interest for diagnostics, because investigation of such electron streams can deliver information about processes occurring inside the bulk plasma. The control of intense high-energy electron beams also plays a significant role in tokamak operation, because it enables to the avoidance or mitigation of plasma disruptions and reduces damage to the first wall of the vacuum chamber.

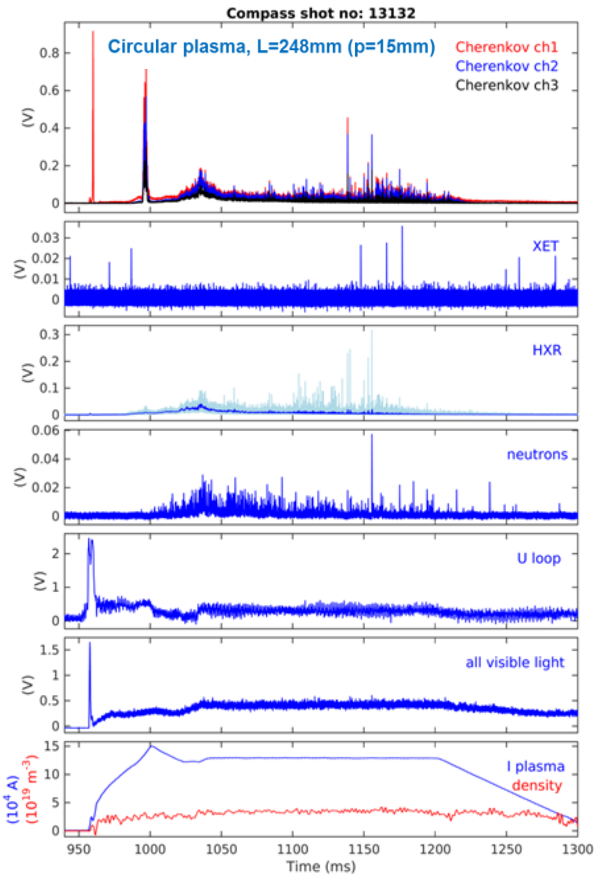

Fig. 1. Comparison of hard X ray signals (HXR), photo-neutrons, U_{loop} and visible light emission with electron-induced signals from a three-channel Cherenkov probe (intensity [V] versus time [ms]). The plasma current was positive, and density reached 3×10^{19} m^{-3}.

Studies of fast runaway electrons, as carried out within the framework of the EUROfusion Consortium, were intensively performed at the COMPASS tokamak located at the Institute of Plasma Physics AS CR during two experimental campaigns in 2015 [1]. In order to investigate the electron-beam energy distribution a three-channel probe equipped with Cherenkov-type detectors (sensitive to different electron energies) was constructed. The radiators in these detectors were made of CVD-type diamond polycrystals. They were covered by thin molybdenum filters (of different thickness) which determined the electron energy thresholds: 58 keV, 145 keV and 221 keV, respectively. In 2016 studies were continued in the framework of Work Package MST1, as a MST1-ST16-2 project. The Cherenkov three-channel probe was applied during the 2016 COMPASS campaign as a diagnostic technique helpful in research on the generation and mitigation of runaway electrons in this tokamak. The first channel of the probe was once more calibrated with a 100-keV electron beam obtained from an auxiliary accelerator. The measurements, which were performed by means of this probe during the December 2016 campaign, showed that the first fast-electron peak usually appears during the current ramp-up phase, even before the hard X ray (HXR) pulse. Some electron signals can be also observed during subsequent HXR emissions, as shown in Fig. 1. For a D-shape plasma discharge, the most distinct electron peaks appeared in all energy channels mainly during the plasma disruption. The correlation of the Cherenkov signals with MHD activity was also investigated. A scan over the measuring head radial distance from the axis of a plasma core was performed for a circular plasma discharge with a massive gas injection (Ar-puff). A very strong dependence of the Cherenkov signal intensity on this parameter was observed. In some circular plasma discharges with a massive Ar-puff post-disruptive runaway electron beams were recorded, which were corroborated by the Cherenkov signals and other traces.

Acknowledgements: This research was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2016, allocated for the realization of international co-financed projects.

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ACCELERATORS, DETECTORS & ELECTRONICS

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 carried out within the European Joint Programme, co-financed by EUROATOM, the Research and Training Programme of the European Atomic Community (2014 - 2018) Complementing the 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 the international co-financed project.

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. The 4.4 MeV gamma line is emitted in the reaction:

$$^{9}\boldsymbol{Be} + \boldsymbol{\alpha} \rightarrow\ ^{13}\boldsymbol{C} \overset{\boldsymbol{n}}{\rightarrow}\ ^{12}\boldsymbol{C}^{*} \xrightarrow{\gamma(4.44\ MeV)}\ ^{12}\boldsymbol{C}_{\ g.s.}$$

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.

The following projects are currently being carried out by NCBJ within the 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. Upgrade of 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 $CeBr_3$ scintillators were used with a decay time of about 20 ns. Since in such experiments short output signals are needed, we used a transimpedance amplifier (TIA) to obtain signals as short as 110 ns. In addition, TIA minimizes gain shift, by stabilizing the detector parameters, defining both static and dynamic working points, when the detected event count rate rapidly changes in time.

The Multi Pixel Photon Counter (MPPC) is one of the devices called a silicon photomultiplier. 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 magnetic fields. The MPPC gain is temperature dependent, so it is necessary to use a device which allows to a constant value of MPPC gain to be maintained. A detector, based on a $CeBr_3$ scintillator, is equipped with MTCD@NCBJ, MPPC Temperature Compensation Device to stabilize MPPC gain. We studied the performance of Hamamatsu MPPCs as a function of both temperature and bias voltage. A climate chamber was used to control the change of detector temperature. A detector system consisting of an MPPC, MTCD@NCBJ, TIA and a fast scintillator is considered to replace detectors based on CsI:Tl in the present JET Gamma-ray Camera. The results obtained prove the correct and effective operation of a detector consisting of an MPPC, MTCD@NCBJ, TIA and a scintillator in measurements at count rates up to ~1 MHz.

In 2016 we delivered to JET a new detector for the Gamma-ray Spectrometer based on a 3”×3” $CeBr_3$ scintillator coupled to a photomultiplier tube. A dedicated active voltage divider was designed for this detector. In the case of measurements at NCBJ a strong ^{137}Cs source with an activity of ~400 MBq was used to check the stability of the detector performance at high count rates. The results of at already performed tests NCBJ and JET have shown that the new detector based on $CeBr_3$ with the active voltage divider is well suited for measurements at count rates up to ~1 MHz.

Our activities are presented in more detail in subsequent articles of the NCBJ Annual Report 2016.

This scientific 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.

MPPC-based detectors for high count rate DT campaigns at JET

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The gamma-ray camera is one of the diagnostic tools used to study fast ions as well as confined α particles. The data acquired with the upgraded Gamma-ray Camera will be an excellent addition to the high resolution spectroscopy measurements collected with the Gamma Spectrometer [this AR]. In the future deuterium-tritium (DT) campaigns high count rates are expected, so it is necessary to upgrade the entire gamma-ray diagnostics.

For measurements at high count rates we use an active solution based on a transimpedance amplifier (TIA) to obtain signals as short as 130 ns without losing operational stability. The TIA is able to minimize gain shift, when the registered event count rate rapidly changes over time.

The detector system based on a fast scintillator, e.g., $CeBr_3$ or $LaBr_3$:Ce, consists of a multi-pixel photon counter (MPPC), a MPPC Temperature Compensation Device (MTCD@NCBJ) and an active base (TIA) or a passive RC circuit with a pole zero cancellation base (RC). Such detectors will replace presently used detectors, based on CsI:Tl coupled to PIN diodes. Two prototypes of detectors with $CeBr_3$ crystals and passive bases have already been installed at JET in channels 9 and 10 of the Gamma Camera [1].

In Fig. 1 the output pulses measured with a 20×15 mm^2 $CeBr_3$ crystal coupled to an MPPC are shown. The pulse shape is described by the rise and fall time: the rise and fall times are here defined as the interval between the times at which the pulse reaches 10% and 90% of its maximum amplitude on the leading and falling edge, respectively. In the setup with RC, by changing the capacitor a signal can be shortened, almost without limit, but at the cost of the amplitude. In the setup with the TIA, shortening of a signal is limited by the amplifier properties. The relative loss in amplitude is much smaller for the TIA than for RC.

This detector setup, based on $CeBr_3$ coupled to an MPPC with a TIA and MTCD, was also tested during high count rate measurements at the Legnaro National Laboratories (LNL), where a beam of 10 MeV protons from the TANDEM-ALPI accelerator was collimated onto a target of 27Al placed in a cylindrical vacuum chamber, and at the ENEA Frascati. More details can be found in [2].

Results obtained in measurements performed both under laboratory conditions and with an accelerator and a neutron generator show that this device guarantees stable working conditions.

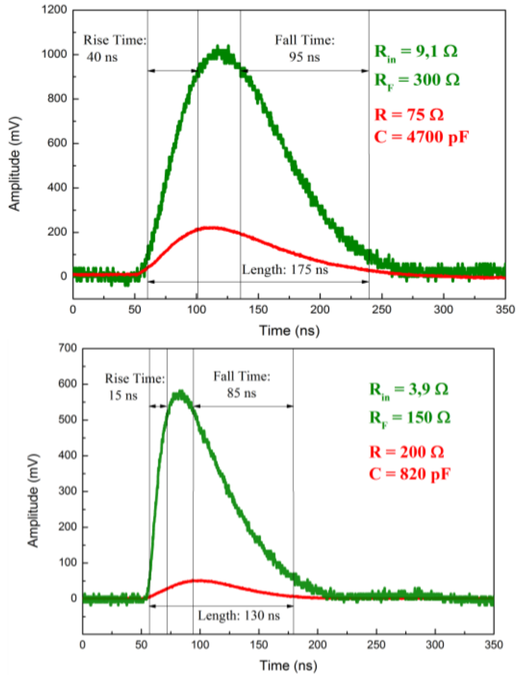

Fig. 1. Output pulses from a 20x15 mm^2 $CeBr_3$ scintillator coupled to an MPPC with an RC circuit (red) and TIA (green).

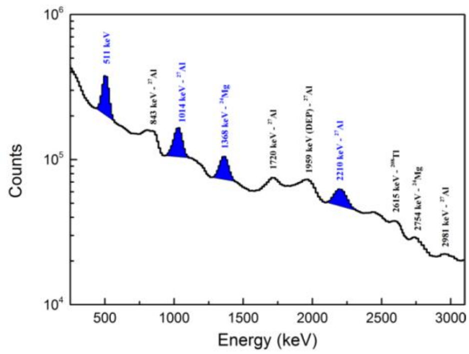

Fig. 2. Typical spectrum obtained at LNL for a 20×15 mm^2 $CeBr_3$ coupled to an MPPC, with a TIA and MTCD measured at 30 nA current with a maximum rate of ~340 kHz for 120 s.

References

[1] I. Zychor et al., High performance detectors for upgraded gamma ray diagnostics for JET DT campaigns, Phys. Scr. 91 (2016) 064003 (9pp)

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This scientific work was partly supported by the the Polish Ministry of Science and by Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of international co-financed projects.

Energy calibration of the gamma spectrometer at JET

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Within the Gamma-ray Spectrometer Upgrade (GSU) project at the JET experimental facility new detectors will be installed to replace the BGO scintillators with fast crystals, characterized by a decay time of ~20 ns. The 3"×3" $CeBr_3$ crystal from Scionix fulfils this condition. A CAEN Desktop Digitizer DT5720 with DPP-CI firmware was used for recording spectra.

This scintillator was tested under laboratory conditions at both NCBJ [1] and JET.

At JET, calibration sources were used, emitting gamma rays with energies up to 2734 keV, see Fig. 1.

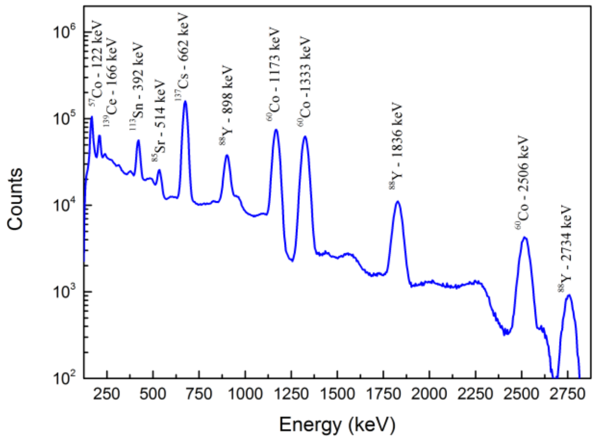

Fig. 1. Calibration spectrum recorded with a 3"×3" $CeBr_3$ scintillator at JET.

The spectrometer based on the $CeBr_3$ scintillator is characterized by very good linearity, see Fig. 2. The energy resolution at 662 keV was 4.5%.

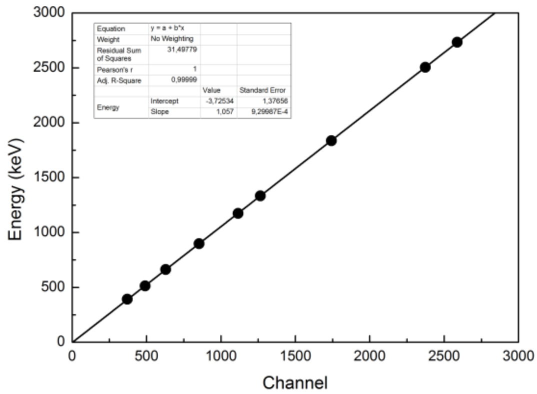

Fig. 2. Energy calibration of the spectrometer based on the $CeBr_3$ scintillator. Solid line is a linear fit to the experimental points.

In addition to measurements with radioactive sources, a natural background spectrum was recorded at JET and all peaks were identified, see Fig. 3. Such an unambiguous identification was possible due to the good linear performance of the detector and will later help to perform calibration at JET without radioactive sources but using only natural background gamma lines.

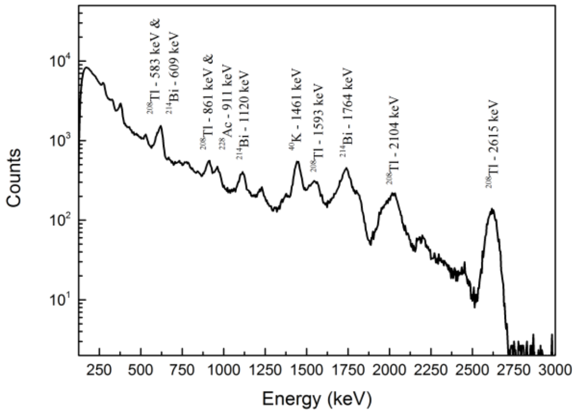

Fig. 3. Background spectrum measured at JET.

At JET both an AVD@NCBJ active [2] and a standard Scionix passive voltage divider were used in tests, see Fig. 4. We found that the detection efficiency as well as energy resolution determined during measurements with the low rates available at JET, corresponding to non-intensive gamma-ray fluxes, are independent of the divider used. Measurements at high counting rates were performed at NCBJ and details are presented in [1].

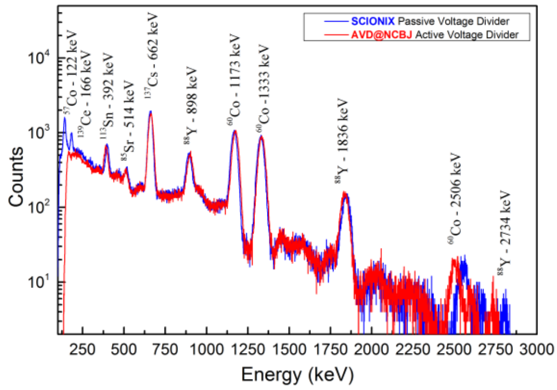

Fig. 4. Spectra recorded using AVD@NCBJ active and Scionix passive voltage dividers.

References

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This scientific 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.

POLAR is in orbit and transmitting data

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On 15th of September 2016 the Chinese rocket Long March 2F was launched, successfully placing the Chinese spacelab TG2, together with the POLAR detector, in orbit. The event was widely covered by Chinese, Swiss and Polish media. Since the launch the instrument has run stably bringing useful data to Earth based computing centre. Up to now it has registered several important observations. Data are available for to consortium members.

The aim of the POLAR experiment is to measure the polarization of GRB's – Gamma Ray Bursts - appearing isotropic on the celestial sphere, lasting from a few milliseconds up to several hours, sudden increases of the gamma radiation intensity in a small area of the sky. Sources of GRBs are extragalactic, located billions of light-years from Earth. It is expected that information on the GRBs polarization will explain the mechanism of their formation.

The compact POLAR detector, dedicated exclusively to GRB observations, had to ensure:

- large effective area,
- large modulation factor,
- large field-of-view.

The energy range of the detected photons had to cover 50 keV to 500 keV, a region where the Compton scattering effect is dominant.

The above requirements led to the basic concept of POLAR:

- 1600 scintillator bars, made of fast and low Z plastic scintillator, form an array of 40x40 elements read by Hammamatsu multianode photomultipliers MAPM8500.
- the detection target achieves:
  - an effective area of 400 cm^2,
  - a modulation factor of about 35 percent,
  - a field-of-view covering about one third of the sky.
- passive shielding protects POLAR against low energy cosmic rays.
- the main readout electronics is housed under the detection target.

POLAR was developed by an international collaboration of several institutions from Switzerland, China and Poland. Thanks to the funds obtained it was possible to carryout a significant part of the work in Świerk. This relates to the development of digital electronics, first of all the central trigger, the heart of the on-board electronics performing global control of the instrument, control of HV and LV power supplies, global triggering of the experiment, time synchronization and communication with all frontend modules. The fine pitch multilayer printed circuit board utilizes three flash-based FPGA chips from Microsemi. All are programmed using the VHDL language.

Fig. 1. POLAR module mounted on the Chinese space lab TG2 (courtesy of ISDC Uni, Geneva).

It should be mentioned that NCBJ's contribution to the project was enlarged by our colleagues from the NCBJ branch in Łódź. Under commercial conditions they delivered the prototype of the HV power supply.

Fig. 2. Launch of TG2 (courtesy of ISDC, Uni Geneva).

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[1] N. Produit, et. al., Polar, a Compact Detector For Gamma-Ray Bursts Photon Polarization Measurements, Nuclear Instruments and Methods A, 2005, 550(3): 616-625)
[2] For more information on POLAR see: http://www.isdc.unige.ch/polar/

This work was supported by the grant " Information Technologies for Astrophysical Observations in Wide Range of Energy", a part of the Swiss Contribution fund.

Central task processing unit for the space-borne gamma polarimeter, POLAR

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The Polar instrument has been operating in space on the Tiangong-2 Chinese space lab since 15th November 2016. This joint European-Chinese experiment is a novel compact space-borne Compton polarimeter optimized for detection of the prompt emission of Gamma-Ray Bursts (GRB) and precise measurements of polarization in the hard X-ray energy range, 50-500 keV.

The detector of the Polar instrument consists of a matrix target of 40×40 low-Z plastic scintillator bars. The incoming photons undergo Compton scattering in the bars and produce a modulation pattern. Simulations and experiments have shown that the polarization degree and angle can be retrieved from this pattern with the accuracy necessary for pinning down the GRB mechanisms. The scintillator bars are organized into groups of 64 and constitute 25 independent modular units (front-ends). Detection of the polarization signal requires measurement of the coincidence signals between at least two channels, not necessarily from the same front-end module [1]. The experiment is controlled by a Central Task Processing Unit.

The functionalities of the Central Task Processing Unit are distributed over three flash-based FPGA chips from Microsemi. The Central Processing Unit performs global control of the instrument: generation of housekeeping data, data transfer from the Central Concentrator Unit and the Central Trigger Unit to the platform, control of high and low voltage power supplies. The Central Concentrator Unit is responsible for communication with frontend modules: data readout, commanding, slow control. The Central Trigger Unit implements the global trigger of the experiment: pre-trigger signal analysis, generation and distribution of global trigger signals, trigger events data generation, time synchronization between all front-end modules.

The event triggering system of the experiment consists of two stages (see Fig. 1). The first level, the local trigger, is realised in the front-end module, while the global trigger is implemented in the Central Trigger FPGA chip located in the Central Task Processing Unit.

The most important events are those in which at least two dispersions of a gamma photon are detected in a very small trigger time window of the order of 150-200 nanoseconds. The quantity of energy deposited in the detector is also considered when selecting potentially interesting instances, in order to reject events corresponding to high-energy cosmic radiation. The central trigger system makes it possible to modify the parameters of events being searched for remotely via commands transmitted from Earth, reducing or expanding the range of measurements transmitted back to Earth. Additionally, seemingly unimportant events can be registered and used for diagnostics or calibration.

The author, as an employee of the National Centre for Nuclear Research as well as the Paul Scherrer Institute, was responsible for the design of the Central Task Processing Unit board and the firmware for all three subsystems.

References

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[2] D. Rybka, et. al., Realisation of Events Trigger System for space-borne Gamma-Ray Burst Polarimeter, Polar, Proceedings of 33th International Cosmic Ray Conference 2013

Acknowledgments

This scientific work was partially supported by the grant "Information Technologies for Astrophysical Observations in Wide Range of Energy", part of the Swiss Contribution programme.

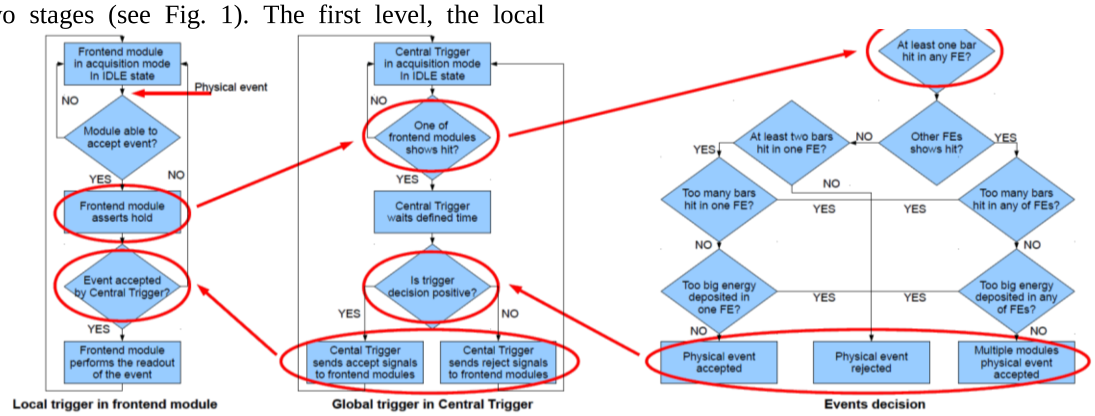

Fig. 1. Event triggering.

On the mutual variability relations of the gas gain with regard to conventional avalanche counter spectrometric mode characteristic curves at moderate specific ionization

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It should be realized that the spectrometric properties of conventional avalanche counter depend not only upon statistical fluctuations of the charge generated in the interelectrode space, which are affected by the basic ionization processes, but also upon some additional factors. It is obvious that the additional factors further broaden the recorded spectral distribution undesirably, thereby deteriorating the detector energy resolution (ER). However, the effect of additional factors can be minimized [1]. Therefore, investigation of the spectrometric properties of parallel-plate avalanche counters (PPAC) is also interesting from a cognitive point of view.

The ultimate energy resolution, characterized by the relative standard deviation of the charge collected on the counter anode, is described by the Frisch-Fano equation:

$$\sigma_v/v=[(F+b)\times W/(dE/dx \times d)]^{1/2},$$

where F – Fano's coefficient, depending on the gas type, represents the fluctuations of the charge generated in the primary ionization process; b – represents the fluctuations of the charge generated in the gas gain process; W – ionization work; dE/dx – specific particle energy loss; d – gap between the electrodes. The quantity b depends on the gas mean gain value, it is a function of U/pd, where U is the counter supply voltage and p is the gas pressure.

It has been found [2] that at moderate specific ionization in n-heptane the empirical ER curves of PPAC detectors have a plateau range that extends with an increase in both the n-heptane vapour p and the gap-d. The range is limited by the U_l and U_u-supply voltages (the U_l-voltage relates to the lower end of the detector ER-plateau range, and the U_u-voltage relates to the upper end of the ER-plateau range). This plateau range falls within that section of the gas gain (M) curve which has a strictly linear shape in a semilogarithmic coordinate system, limited by the U_{min} and U_{sch}-supply voltages (the U_{min}-voltage relates to the lower end of the M-curve's strictly linear course, and the U_{sch}-voltage determines the beginning of the space charge effect in the PPAC [3]).

This means, generally, that the fluctuations of the charge generated in the gas gain process are – within the determined ER-plateau – approximately constant. Hence, the expression $\sigma_v/v=k/(dE/dx \times d)^{1/2}$ is valid within the plateau, where k is a certain characteristic constant. One can presume, on the grounds of flat responses (see fig. 1), that for low n-heptane vapour pressures in general the gas gain fluctuations are a relatively weak function of pressure changes. Thus, it is interesting to meet mutual variability of the M-values within the two ranges whose ends are determined by the U_l, U_u and U_{min}, U_{sch}-supply voltages, respectively.

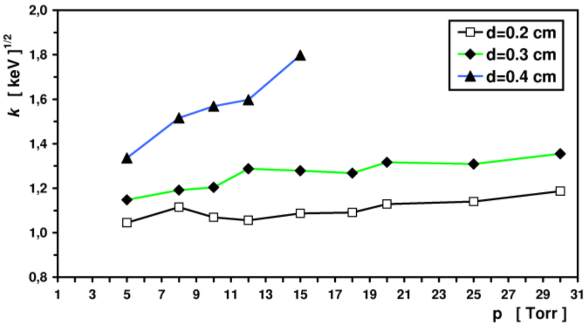

Fig. 1 Mean values of the constant k – relating to individual plateau ranges of PPAC energy resolution – vs. n-heptane pressure. The change in pressure was accompanied by a simultaneous change in the specific ionization (see ref. [3]).

The purpose of this investigation is to determine the mutual variability relations of the absolute values of the effective gas amplification (M_{abs}) concerned with the ER-plateau range of PPAC detectors and the M_{abs} linear variability in a semilogarithmic coordinate system and to determine the dynamics of the M_{abs} relative variability within the ER-plateau range vs. n-heptane vapour pressure. The general equations of the absolute gas gain characteristics, which are justifiable for PPACs filled with n-heptane vapour, were used [3].

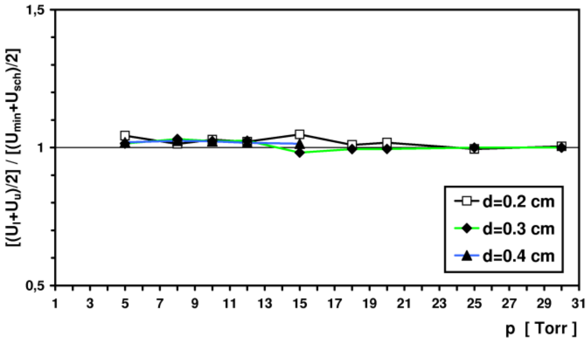

Fig. 2. Ratios of the PPAC detector supply voltage mean value change within the detector ER-plateau range to the PPAC voltage mean value change within the effective gas amplification linear variability range in a semilogaritmic coordinate system; for the U_l, U_u, U_{min} and U_{sch}-supply voltages see text.

The empirical curves of the detector certain voltage and gas amplification relations are shovn in figs. 2-4. It can be seen that the relations under study, generally, are relatively weak functions of p. The PPAC ER-plateau range shifts to the detector lower supply voltages with the n-heptane vapour pressure rise (see fig. 2), and the gas amplification within the ER-plateau range slightly decreases (see fig. 3).

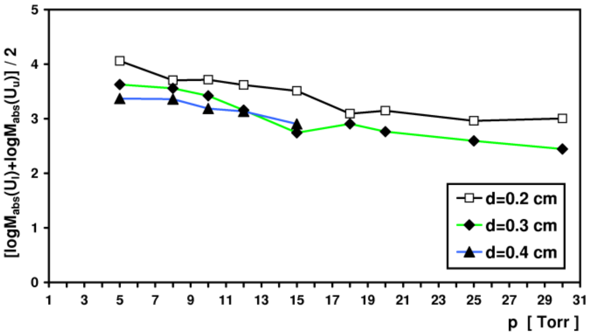

Fig.3. Mean effective gas amplification change within the PPAC ER-plateau range; for the U_l and U_u-supply voltages see text.

In turn, the gas amplification relative variability within the ER-plateau range slightly increases (see fig. 4).

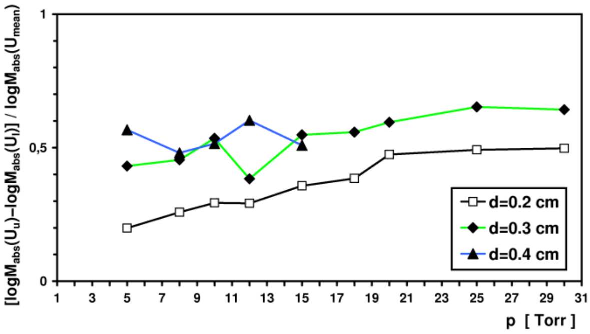

Fig.4. Relative variability dynamics of effective gas amplification within the PPAC ER-plateau range; the $U_{mean}=(U_l+U_u)/2$-supply voltage relates to the detector ER-plateau range (see fig. 3).

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Temperature investigation of CsI:Tl scintillators

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Recent intensive modelling of the light generation process in CsI:Tl crystals requires precise experimental data concerning the energy resolution, non-proportionality and decay time of the light pulses. To clarify theoretical models, especially those depending on self-trapped hole and self-trapped exciton migration, independent experimental results are needed. Thereby, the temperature dependence of many of the transport and rate terms can be put into the model without the need for fitting or guesswork [1].

Many of the transport and rate equation term coefficients, especially those depending on self-trapped hole (STH) and self-trapped exciton (STE) migration as well as detrapping rates such as from Tl^0, are governed by activation energies that are known from independent experiments. Fitting the temperature dependence in a model calculating pulse shape and proportionality can therefore be an important part of testing such models and validating their parameters, and of better understanding the scintillation mechanisms.

The aim of this work was to investigate the properties of caesium iodide activated by thallium in a range from 0.001 to 0.081% mole at temperatures down to -70°C. The CsI:Tl measurements were triggered by previous studies performed by the NCBJ group [2].

Tested CsI:Tl scintillators were grown by the ISMA laboratory in Kharkov (Ukraine). The experimental setup consisted of a scintillator coupled to the XP5212 photomultiplier from Photonics, and was placed in a climatic chamber. Achievable temperatures ranged from +30°C to -70°C were done. Results were obtained by measuring the response of the detection system to gamma rays in the energy range from 10 to 900keV.

We used two different methods to determine the properties of CsI:Tl. In the first one, the signal from the PMT was fed into a charge sensitive preamplifier and then a spectroscopy amplifier. All measurements were performed for two peaking times (PT) equal to4.8µs and 24µs. A PC-based multichannel analyser was used to record the energy spectra.

An example of the non-proportionality of a CsI:Tl scintillator with thallium concentration equal 0.032% mole is presented (see Fig. 1). We can observe that longer integration of the light improves the non-proportionality, while cooling causes the crystal to be more non-proportional.

For a better understanding of the non-proportionality processes we use a second method, wherein the output signal from the PMT was sent directly to a digital oscilloscope. The signal was triggered by the full energy peak selected by the single channel analyzer from the energy spectrum. To describe the pulse light shapes three components (fast, slow and tail) were quantified as a sum of three exponential curves. Figure 2 presents the percentage contribution of each of the components to the total light pulse. What is noteworthy is that this contribution is temperature dependent.

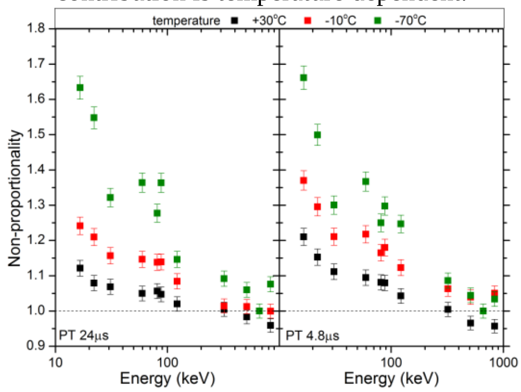

Fig. 1. Non-proportionality characteristics of a tested CsI:Tl crystal measured at two peaking times in the aaamplifier. Data presented for CsI:Tl scintillator with Tl concentration equal 0.032% mole, at three temperatures: +30°C,-10°C and -70°C.

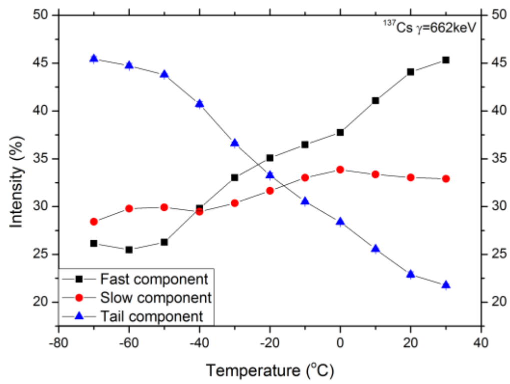

Fig. 2. Intensities of three light pulse components. Data presented for CsI:Tl (x_{Tl} = 0.032mole%) with ^{137}Cs γ source (662keV).

Our experiments brings us closer to an understanding of luminescence phenomena in CsI:Tl scintillators and gives input for theoretical modelling and interpretation.

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Raw material scanner for online control of cement production, based on neutron activation analysis and a neutron generator

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This is a short presentation of the RaM-scaN project carried out between 01.01.2014 and 31.12.2016, supported by the Polish Programme of Applied Research, grant number: PBS2/B2/11/2014. The National Centre for Nuclear Research was the leader of this project, which was carried out in cooperation with two Polish companies: SysKon - Control Systems of Industrial Processes and POLON Nuclear Technology Centre in Wrocław, Ltd.The level of impurities and quality of materials used for cement production are the key factors determining its class. The aim of the project was to create a system of controlling the chemical composition of raw materials used in cement production. The system operates in continuous mode and monitors a stream of material moving on a conveyor belt. The principle of operation of the device is based on prompt-gamma neutron activation analysis (PGNAA) and its key part is a deuterium-deuterium neutron generator emitting particles with an energy of 2.45 MeV. The generated neutrons, after thermalisation, are absorbed (captured) by the inspected material resulting in its activation and the emission of characteristic, prompt gamma rays. Detection and analysis of this radiation with scintillation detectors allows the determination of the chemical composition of the raw materials, in particular the content of such compounds as: CaO, SiO_2, Al_2O_3, Fe_2O_3, SO_3 and others.

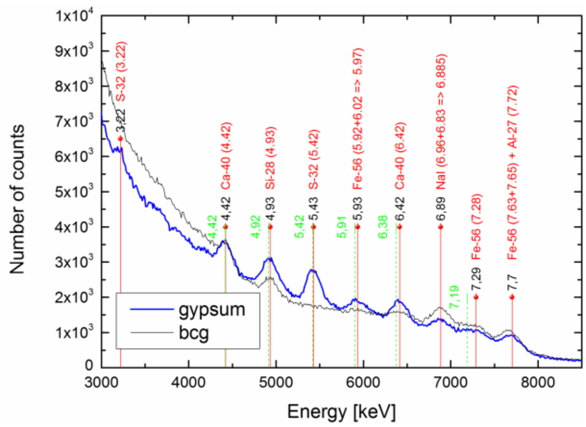

Fig. 1. Example of the PGNAA spectrum of a gypsum sample (from a cement plant in Kazakhstan) registered at NCBJ using a laboratory setup.

Fig. 1 shows an example of the PGNAA spectrum registered at NCBJ under laboratory conditions. The sample here was gypsum – one of the raw materials used in a cement plant in Shetpe (Kazakhstan).

Fig. 2. The test installation of the RaM-scaN system demonstrator on a conveyor belt in the "Folwark" mine in Poland.

Fig. 2 presents the test installation of the RaM-scaN system demonstrator on a conveyor belt in the "Folwark" mine in Poland. The mine supplies raw-materials to the largest cement plant in Europe – Górażdże. At present the RaM-scaN system operates in real industrial conditions and is installed in series (on the same conveyor belt, at a distance of around 10 m) with the other commercial system from the Sodern company (France). In Fig. 3 the preliminary results of the calcium oxide content analysis are presented.

The measurements confirm the high performance of the RaM-scaN analyzer.

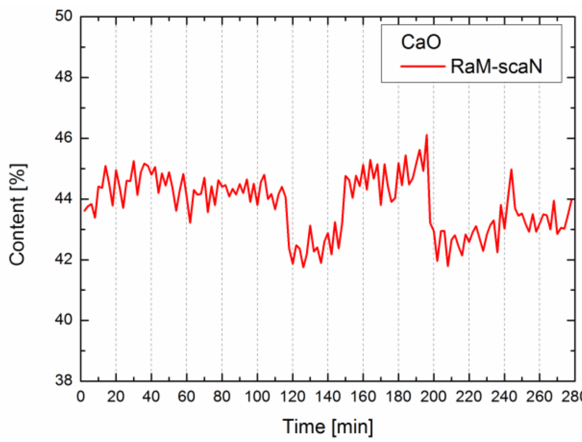

Fig. 3. Preliminary results of calcium oxide content calculationson the basis of the RaM-scaN demonstrator data.

Timing resolution of ronolithic scintillators coupled to large SiPM arrays

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Timing resolution is one of the most important parameters of scintillation detectors in many applications. One of the major fields in which timing resolution with SiPMs is studied are pixelated detectors for medical imaging and TOF PET. However, there are many applications in which timing information from large, monolithic crystals is needed. The aim of this work is to study the timing resolution of large SiPM arrays in the readout of various, monolithic scintillators. The measurements were made with a S12642-1616PB-50(X) Hamamatsu TSV MPPC array having a 50x50 µm cell size and effective active area of 48x48 mm (16x16 channels). During the tests, the MPPC was treated as a single, large detector. Different active areas of the MPPC were investigated by readout of subareas of the device. The measurements were made in four configurations with 4x4, 4x8, 8x8 and 16x16 channels connected in parallel creating the single output pulse.

In the first part of the study, experiments were made with the smallest 10x10x5 mm LSO scintillator and various numbers of readout channels in order to understand the influence of the detector area (or capacitance). The main and well known problem with common readout of SiPM arrays is their large capacitance that affects the rise time and fall time of the recorded pulses. Measurements with various amplifiers showed that huge improvement could be achieved by using a Phillips Timing/Charge Pick-Off Preamplifier 6955. Examples of direct pulses and pulses after this amplifier (x10 gain) are presented in Fig. 1. As can be seen, the pulse is differentiated and has an improved rise time to about 26-33ns. Timing resolution of a single detector (after subtraction of the reference detector contribution) obtained for a 10x10x5 mm LSO read by 4x4, 8x4, 8x8 and 16x16 channels is equal to 338 ± 12 ps, 419 ± 14 ps, 495 ± 16 ps and 672 ± 21 ps, respectively. In each case optimization of the electronics consisted of setting the lowest possible discriminator threshold and choosing the optimal bias voltage.

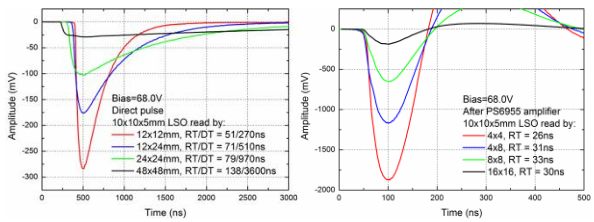

Fig. 1. Example of the output pulses recorded using an oscilloscope, at 50 ohms, for a detector consisting of a10x10x5 mm^3 LSO read by 4x4 (red), 8x4 (blue), 8x8 (green) and 16x16 (black) channels selected in the 16x16 channel MPPC array.

In the second part of the study 4 types of 1 inch and 2 inch scintillators were used: $LaBr_3$, $CeBr_3$, BC408 and NaI(Tl). The measurements with 1 inch crystals were made with 8x8 channel area, whereas for the 2 inch crystal the whole 16x16 channels were used. Again, the shape of the direct output pulse from the MPPC array is strongly affected by the capacitance of the device. The integration effect is the strongest in the case of the slowest NaI(Tl) scintillator leading to rise times of 250 ns and 370 ns for 1 inch and 2 inch crystals, respectively. Again, application of the PS6955 amplifier allowed improvement of the rise times for signals from all the crystals. Timing resolution spectra for 1 inch and 2 inch detectors are presented in Fig. 2

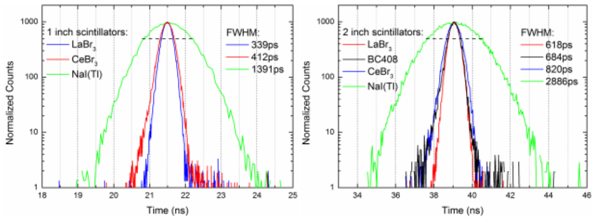

Fig. 2. Normalized timing spectra recorded with a detector consisting of 1 inch (left) and 2 inch (right) scintillators: LaBr3 (red), CeBr3 (blue) and NaI(Tl) (green) read by 16x16 channels of the MPPC array.

As in the case of the tests with the 10x10x5mm LSO, the optimal bias voltage range was between 68.0V and 68.2V. Higher voltage deteriorated the timing with fast and bright scintillators like $LaBr_3$ and $CeBr_3$. However, in the case of NaI(Tl) and BC408 with low output amplitude the best timing resolution required the voltage the increased to 68.6V. This supports the conclusion from earlier studies with small LSO that the discriminator threshold dependence is stronger than the bias voltage optimization.

Despite the poor rise time and fall time characteristics of the MPPC pulses, the recorded timing resolution is promising. In the case of fast scintillators like $LaBr_3$, $CeBr_3$ or BC408 plastic their timing resolution is always below 1ns which is enough for many applications, e.g. for coincidence windows in trigger logic. Timing resolution with NaI(Tl) is strongly affected by its slow decay time, which, together with the integration effect in a large MPPC, leads to slow rise time of pulses sent to a discriminator (even after differentiation in a PS6955). In addition, the amplitude of these pulses is small and does not allow a low enough discriminator threshold to be set.

This work was supported in part by the Polish Programme of Applied Research, grant number: PBS2/B2/11/2014, RaM-scaN.

Measurement of relative light yield of GAGG:Ce scintillators below 1 keV

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In the following study 1% Cerium doped Gadolinium Aluminum Galium Garnet (GAGG:Ce) scintillators having various Al-Ga ratio were exposed to alpha particles. During measurements performed at JINR, a transactinide laboratory-grade radioactive source (activity of 120 Bq) emitting alpha particles with a maximum energy of 8.78 MeV was used. It was observed that the energy deposition of the alpha particles differs significantly between GAGG:Ce scintillators with different Al-Ga ratios. An alpha-to-gamma (α/γ) ratio, described as the ratio of the energy at the alpha particle deposited in the scintillator to that emitted by the alpha source was obtained for the GAGG:Ce scintillators. The energy of the measured alpha peak is lower due to the non-radiative quenching processes in the scintillator. An α/γ ratio of 0.294 was obtained for GAGG:Ce with Aluminium-to-Galium (Al-Ga) ratio of 2.6 – 2.4. The ratio is very close to 0.30, ascribed to scintillator with almost ideal non-proportionality characteristics. During further study at NCBJ we used a ^{241}Am alpha source and delta detectors (energy attenuators) for the scintillators irradiation. By conversion of the alpha particle energy to velocity and calculating the electron energy equivalent for such a velocity [1,2], it was possible to obtain the non-proportionality trend of these scintillators for energies down to 42 eV. The tested scintillators are listed in Table 1.

Table 1. The GAGG:Ce scintillators used in the present investigation

Scintillator	Size (mm^3)	Al-Ga ratio
GAGG:Ce	5 × 5 × 5	2.0 – 3.0
		2.3 – 2.7
		2.6 – 2.4

The GAGG:Ce scintillator - $Gd_3(Al,Ga)_5O_{12}$:Ce, introduced in 2012 [2], is known to be an attractive material for applications in many fields of nuclear science, industry and medical imaging. In particular, it can be applied in Radioisotope Identifiers, Computer Tomography (CT) or Positron Emission Tomography (PET). The scintillators are known to have high density (6.63 g/cm^3), good light output - between 40.000 and 55.000 ph/MeV - and fine energy resolution, even as good as 3.7% at 661.7 keV measured with a Hamamatsu S8664-1010 Si Avalanche Photodiode (APD) [3].

Non-proportionality of the scintillation light yield, known also as the measurement of relative light yield, is usually investigated by means of gamma-ray absorption spectroscopy down to several keV. In this study, we introduced an investigation with low energy alpha particles from a radioactive source, allowing for precise measurement below 1 keV.

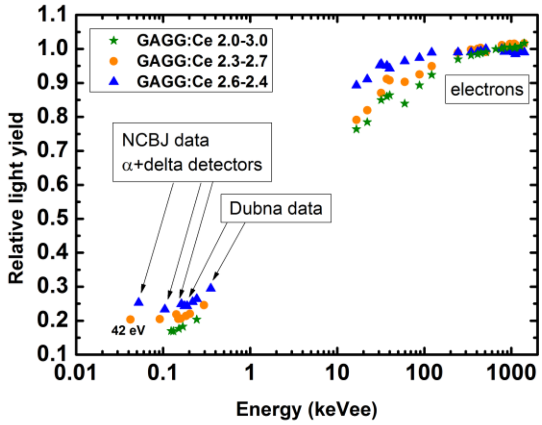

Fig. 1. Non-proportionality of the GAGG:Ce scintillators measured over a wide energy range.

Summarizing, for the first time we showed the non-proportionality of the scintillator light yield down to 42 eV with very good precision. Another new observation is a saturation effect of the light yield nonproportionality in the low energy region, where the relative light yield becomes constant.

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CsI:Tl scintillation pulse shapes measured with a SiPM photodetector in a liquid nitrogen cryostat

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Luminescence may occur in scintillators due to various mechanisms (e.g. recombination of self-trapped excitons (STE) or deexcitation of activator states). As these processes contribute to scintillation in different ratios at various temperatures, it is important to study in detail the scintillation properties over a wide range of temperatures. Recently, a model was proposed by the group of R.T. Williams to explain the origin of such effects in alkali iodides [1].

Therefore, a custom designed cryostat was constructed to measure the response of a CsI:Tl scintillator at temperatures close to the boiling point of liquid nitrogen (LN_2). The scintillation light was collected by an HUV-HD SiPM from FBK with 6×6 mm^2 area and 25×25 μm^2 cell pitch [2]. The crystal size was 5×6×7 mm^3. All surfaces except that facing the SiPM were covered with Teflon tape to enhance light collection by the photodetector. The crystal was mounted on a copper frame placed inside the LN_2 cryostat.

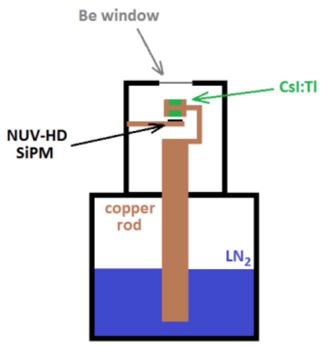

Fig. 1. The LN_2 cryostat with the CsI:Tl crystal and the NUV-HD SiPM mounted on separate copper frames.

Since our goal was to measure the scintillation decay profiles and the SiPM response at low temperatures becomes substantially slower than that observed at room temperature [3], the SiPM was mounted on a separate copper frame connected with the outer housing to keep it close to room temperature. The separation between the crystal surface and the SiPM was about 1.5 mm at room temperature, and it became smaller once the setup was cooled down to LN_2 temperature (LNT), but even so the crystal and the photodetector were still separated. The experimental setup is presented in Fig. 1.

This approach allowed us to analyze the scintillation pulse shapes of CsI:Tl at LN_2 temperatures. A comparison of the scintillation pulse shapes of CsI:Tl recorded at RT and close to LNT is presented in Fig. 2. Please note that the amplitudes of the pulses are displayed on a logarithmic scale. As one may see, due to the low light output at LNT the contribution of Cherenkov radiation to the pulse profile becomes significant. Based on the result of a double exponential fit to the registered decays (neglecting the part of the pulse influenced by the rise time and the Cherenkov response), we evaluated the light output at LNT to be 8 % of the value observed at RT.

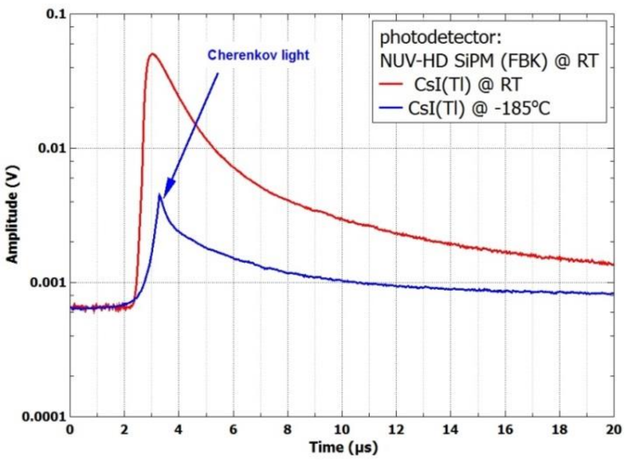

Fig. 2. CsI:Tl scintillation decay profiles measured at RT (red line) and at -185°C (blue line).

This work was supported in part by the Polish Programme of Applied Research, grant number: PBS2/B2/11/2014, RaM-scaN.

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A new method for designing dual foil electron beam forming systems

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Dual foil beam forming systems, also known as passive systems, transform the "pencil" beam extracted from a particle accelerator into a beam that is spread uniformly over a large area of an irradiation field. Such systems are employed in all medical linacs currently serving electron beam therapy, as well as in some proton therapy facilities (particularly for treatment of eye cancers). In a passive system, the primary beam is first scattered by a set of two foils and subsequently collimated to the area of a designated field. The first foil is flat while the second foil, usually labelled the flattening foil, has a Gaussian cross section given by $h(r) = H \exp(-r^2/R^2)$, where $h(r)$ is the thickness of the foil at a radial distance r from the beam axis.

At NCBJ passive systems were recently designed and constructed for the prototype of a novel mobile linac for intraoperative electron radiation therapy [1] and for an experimental high dose-rate irradiation facility at Wroclaw Technology Park (WPT) [2].

Despite the conceptual simplicity, designing an actual dual foil system is a rather laborious task. This is because all previously known design methods are based on approximate analytical models applied in an unrealistically simplified geometry [3]. Corrections necessary to account for effects not included in the models, such as scattering off the inner walls of collimating devices, have to be calculated separately and accounted for in a lengthy iterative procedure.

In this work a new design method was developed. Our approach is based on direct calculation, in a discretized space, of certain functions describing the system performance. Of crucial importance in designing passive system is a function, here labelled $f(H,R)$, that assumes the value of the flatness of an off-axis dose profile as a function of parameters describing the geometry of the flattening foil. We have demonstrated on a real life example that using Monte Carlo calculations in the complete system geometry and with detailed physics models $f(H,R)$ as well as other important functions, can be computed in a relatively short time and with relatively modest computing resources [4]. Knowledge of these functions provides deep insight into system performance and allows for instant discovery of optimal values of all its important parameters, such as H and R describing the thickness profile of the flattening foil.

In Fig. 1 a Geant4 geometry model of a passive electron beam forming system for a facility at WPT is shown. Fig. 2 illustrates the function $f(H,R)$ calculated in this system. Calculations took only about 14h on a single node of the computing cluster of the Świerk Computer Centre (64 physical cores). It is evident that: (i) $f(H,R)$ assumes low values (corresponding to a well flattened dose profile) for many different flattening foils (yellow colour in Fig. 2), however, (ii) the truly optimal system is one with the minimum possible thickness, H, of the flattening foil, i.e., the system corresponding to the tip of the "horse shoe" like valley of low values of $f(H,R)$.

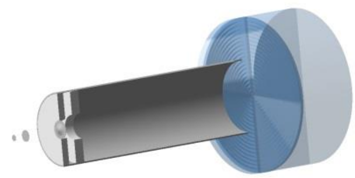

Fig. 1. Geometry model. From left to right: accelerator exit window, scattering foil, flattening foil (Gaussian shape), steel flange, tubular applicator and a water phantom for dose calculation. (See [4] for details).

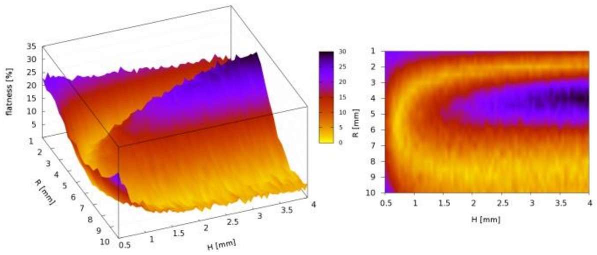

Fig. 2. The function f(H,R) calculated in a model of the complete beam forming system depicted in Fig. 1.

Besides savings on design labour (overall design time is reduced from months to days) the new method can deliver better results compared to previously known methods. It allows, practically for the first time, for simultaneous optimization of multiple objectives (e.g. dose uniformity and dose rate). By providing insight into system behaviour the method allows for educated and well balanced decisions on difficult design issues that often demand a compromise between contradictory requirements. Finally, a designer is able, also practically for the first time, actually to proove that the proposed solution is optimal under given constraints.

Details of the concept and implementation of the new method are given in a set of recent publications [3,4].

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NCBJ contribution to the DONES beam dynamics calculations performed with the tracewin code

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Introduction

The Early Neutron Source (ENS) project is part of the International Fusion Materials Irradiation Facility (IFMIF) project of the Bilateral Agreement between the EU and Japan. Part of this project is the DEMO Oriented Neutron Source (DONES) system. DONES is designed to provide an accelerator-based D-Li neutron source that produces high energy neutrons with sufficient intensity to simulate the first wall neutron spectrum of future nuclear fusion reactors.

Objectives

The main objective of this work was to optimize the Superconducting Radio-Frequency Linear Accelerator (SRF-L). Optimization should be achieved by finding the optimal RF field phase values for each of 42 separate accelerating cavities.

The aim of the beam dynamics calculations was to find the RF field phase values for each accelerating cavity separately while meeting two requirements at the same time: the beam energy must be higher than 40 MeV at the end of the SRF-L and the energy losses should be lower than 1 W at each arbitrarily selected 1 metre-long section of the accelerator.

Design

The simulated part of the accelerator system consists of the initial section (MEBT) and a main section with four accelerating cryomodules (Fig. 1). The first two modules have identical cavities with low beta parameters, separated by solenoids (one solenoid for one or two cavities); the last two modules have high beta cavities, and solenoids are separated with three cavities [2].

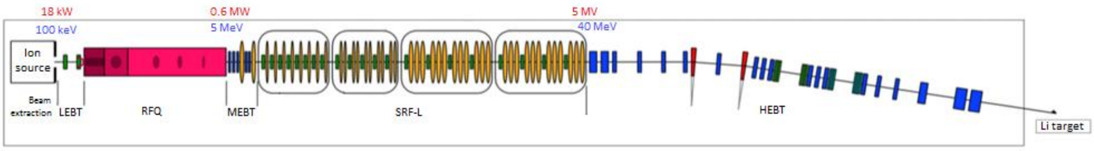

Fig. 1.Layout of the DONES Accelerator Facility[Błąd! Nie można odnaleźć źródła odwołania.]*. Location of calculated area: the blue arrow shows the area to be optimized; the red arrow shows the calculated area.*

Beam dynamics

Beam dynamics calculations were performed based on the technical data provided by the French Atomic Energy Commission (CEA). The 66 main variants of the accelerating system were investigated with the TraceWin code. Phase values for each accelerating cavity were different in each calculation variant. Beam energy at the exit of SRF-L was kept over 40 MeV in each variant, but until now no variant fulfilling the loss criterion has been found. In the best results, the beam energy was 40.19 MeV, and the total beam losses were 18.96 W; the highest beam losses over a length of one metre are about 8.36 W/m. While this result is not as good as hoped, it is much better than the highest energy losses of 550 W/m observed in the initial calculations along the MEBT and SRF-L sections.

Conclusions

On the basis of this work, a change of design of the accelerating cryomodules is considered. Further calculations of the system with the TraceWin code will then be performed.

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NCBJ contribution to ENS beam dynamics calculations – preliminary verification with the GPT code

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Objectives

Beam dynamics calculations in the ENS project were performed with two simulation codes (TraceWin[1] and General Particle Tracer, GPT [2]). The main aim of the presented work was to model the Superconducting Radio-Frequency Linear accelerator (SRF-L) with an independent simulation code, in order to verify and validate results obtained with the TraceWin code.

Beam dynamics calculations with GPT

TraceWin input data for each simulated element of the accelerator as well as the selected parameters, boundaries and relative positions of the electromagnetic fields, were translated into GPT format. All data (starting from the input beam phase space file, fields of RF cavities and magnetic fields of focusing elements) were rewritten in the proper format. Verification of calculations and comparisons between codes were performed after each element of the linac, to assure that translation of parameters between codes was done correctly and the full length of the accelerator can be simulated in GPT.

The comparison between the codes is not for the best variant that was found using TraceWin. The presented variant is the one with the smallest beam losses that was found when the translation of parameters from TraceWin to GPT format was initiated.

GPT versus TraceWin Calculations

Beam density in six phase spaces (X-Y, X-X', Y-Y', X'-Y', Phase-Energy and Z-dp/p) at the end of SRF-L, as well as localisation of beam losses across the Medium Energy Beam Transport (MEBT) section and the SRF-L obtained with GPT and with TraceWin were compared. Emittance calculated for each phase space was also compared.

In the geometrical spaces (X-Y, X'-Y', X-X', Y-Y'), the TraceWin calculations gave a bunch of particles that is slightly less focused than was found in the GPT simulations (fig. 1, top); however the beam is less divergent with the TraceWin simulations than that obtained with GPT. In the energetic spaces (Phase-Energy and Z-dp/p) the energy distribution is similar (fig. 1, bottom), but the emittance values calculated with GPT are much lower. Beam losses appear to be two times higher for the GPT calculations. Due to the low number of macro-particle losses (less than 0.005% for the TraceWin calculations and less than 0.01% for the GPT calculations) compared to the initial particle number, a proper estimation of the inaccuracy of the beam loss calculations is still needed.

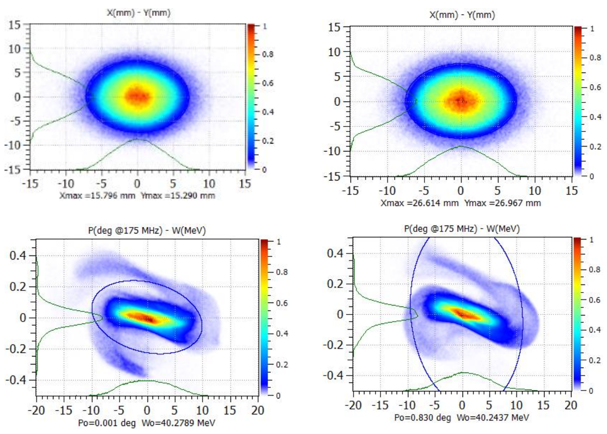

Fig. 1. Comparison of beam distribution. Top: X-Y space; bottom: phase-energy space; left: GPT results; right: TraceWin results.

Next steps

The next phase of activities includes:

- Calculations with the GPT code using the parameters taken from the variant with the lowest energy losses found with TraceWin;
- Optimization using GPT will be performed, with the goal of independent optimization of the RF field phases and focusing magnetic fields in the General Particle Tracer code. Results then will then be compared to the optimal parameters obtained with the TraceWin simulations.

References

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NCBJ participation in the GBAR (Gravitational Behaviour of Antihydrogen at Rest) project at CERN

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The delivery of the accelerator for scientific applications at the beginning of 2017 finished the preparatory stage of work connected with the manufacturing and running of the accelerator for the GBAR project at CERN in cooperation with 18 research centres from Europe and Asia.

This klystron-based electron linac designed to achieve 9 MeV beam energy and 300mA peak current includes new technical solutions, derived from synchrotron light sources. It was possible thanks to the outstanding cooperation with the SOLARIS synchrotron radiation centre in Cracow and with the MAX IV Laboratory at Lund University.

In the first months of 2016 purchases of the components for the device were completed together with technical discussions on operational and environmental safety related to the of the linac localisation in the neighbourhood of the other experiments in the AD hall at CERN. During a collaboration meeting in May 2016 at NCBJ, the final shape of the project was established.

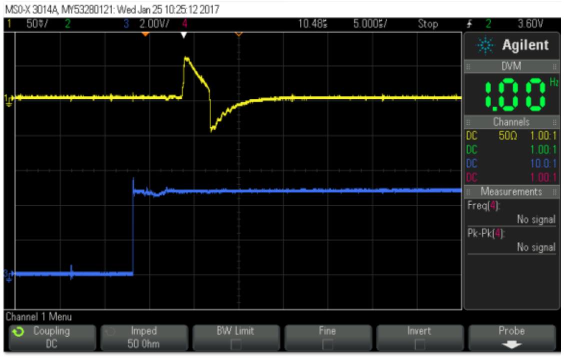

Fig. 1. Beam current measurement made during the collaboration meeting.

Fig. 2. Klystron modulator during FAT.

The milestone of the linac manufacturing process was the factory acceptance tests of the klystron modulator at the Swedish supplier, Scandinova.

These tests, first planned for June, had to be rescheduled for September due to production problems at the cooperation partner.

As the modulator was delivered in October, it was possible to start the full integration of the device. In the experimental hall in building 5 at NCBJ, all components of the accelerator were installed, tested and successfully integrated with software in January 2017.

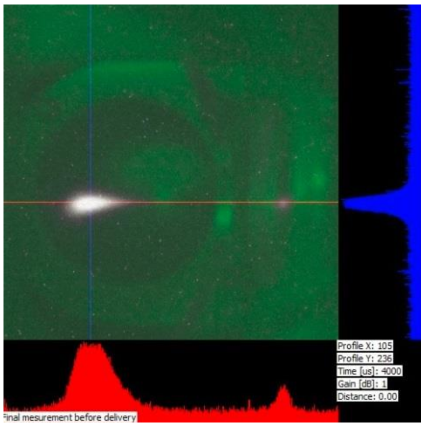

Fig. 3. Beam image reached on the YAG screen during accelerator preparation.

The accelerator was then disassembled and shipped to CERN.

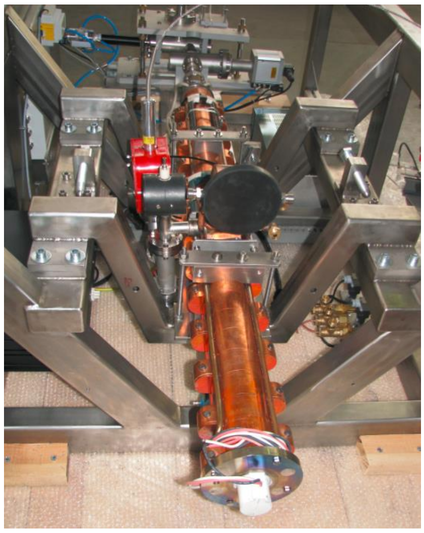

Fig. 4. Accelerator ready for delivery.

Monte-Carlo modelling of an X-ray tube

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Low energy X rays used in imaging medical procedures can cause specific damage to live cells. To explore these radiation effects in live cells, an experimental setup for radiobiological studies was created and built at the Jan Kochanowski University in Kielce, Poland. The system uses an X-ray Diffraction (XRD) C-tech tube, and the first experiments were carried out to show the survival curve of CHO-K1 cells. NCBJ took part in this project by performing a MC simulation of the X-ray tube, which is presented below. To verify the doses measured in the radiobiological studies, the experimental setup was also simulated at NCBJ, and the results are presented on the following page of this Annual Report.

Monte-Carlo calculations were performed using the code FLUKA 2011, version 2c.4 [1,2], installed on the computer cluster at CIS [3].

To optimize the calculation it should be divided into two stages. The key part of the first stage of the calculation is the conversion target, in which electrons generate bremsstrahlung and characteristic photon radiation. A molybdenum disc 1mm thick and 2 cm in diameter was used as a conversion target. The output of the X photon beam is a round beryllium window with a diameter of 4mm and a thickness of 300μm. The window is placed in a tungsten cover 1.5mm thick. The interior of the cover surrounding the target is under vacuum. In order to reproduce the experimental conditions, the whole geometry of the X-ray tube is positioned at an angle of 6^0. The geometry of the X-ray tube is shown in Fig.1. The end result of the first stage calculation is a phase space file containing the photons emitted from the outer surface of the beryllium window into air.

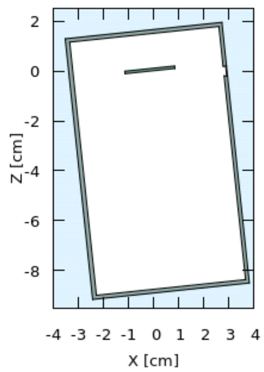

Fig. 1. Cross-section in the XZ plane of the X-ray tube.

A mono-energetic primary electron beam of 60keV was used for the Monte-Carlo calculation. The spatial size of the parallel beam (12mm×0.4mm) reproduces the actual focal spot in the X-ray lamp. Transport and production cutoff of photons and electrons was set at 1keV. In the first stage of the calculation, photon and electron spectra were recorded at the boundary of the Be window and air region, and photon and electron fluence in the region of the conversion target and Be window. In the second stage of the calculation, photon spectra at the boundary of the air and the segmented detecto, photons and electron spectra in the area of the dish, the dose equivalents for all geometry were registered, focusing particularly on the dish region.

In the first calculations, 5.0·1011 electrons from the primary beam were used. 5.0·106 photons emitted through the Be window of the X-ray tube were obtained and registered in the phase space file. 74(9) electrons contaminating the photon beam were obtained.

The average photon energy emitted from the Be window is 20.050(15)keV, the average electron energy is 8.2(13)keV. The photon spectrum is shown in Fig. 2.

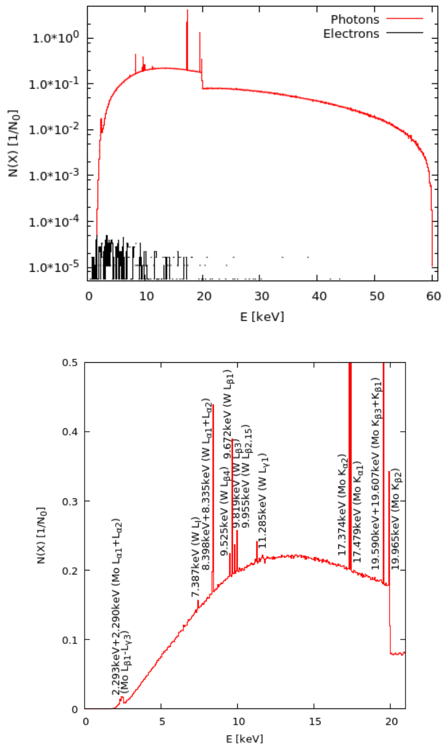

Fig. 2. Photon beam spectrum on the Be window. One can see the characteristic radiation emitted from Mo and the L series from W.

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[1] "The FLUKA Code: Developments and Challenges for High Energy and Medical Applications" T.T. Böhlen, F. Cerutti, M.P.W. Chin. A. Fassò, A. Ferrari, A. Mairani, P.R. Sala, G. Smirnov, V. Vlachoudis, Nuclear Data Sheets, 120, 211-214 (2014)

[2] "FLUKA: a multi-particle transport code" A. Ferrari, P.R. Sala, A. Fassò, and J. Ranft, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773

[3] http://www.cis.gov.pl/

Monte-Carlo calculation of radiation emitted from an X-ray tube and propagating in the system containing the test sample

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Monte-Carlo calculations were performed using the code FLUKA 2011, version 2c.4 [1,2], installed on the computer cluster at CIS [3].

The second stage of the calculation assumed multiple use of photons generated at the end of the first stage, in order to increase statistical power and reduce the uncertainty of the spectra and doses obtained in the area of the Petri dish. The surface detector of the photon spectrum is placed at a distance of 49.9cm from the centre of the output window of the X-ray tube. The detector is circular in shape, with a diameter of 4.8cm. The circle is divided into 4 rings and 4 sectors, see Fig.1. The model of the Petri dish to be tested consisted of a circular rubber lid and a polyethylene lid, which was placed at a distance of 50cm from the centre of the Be window. The interior of the dish was filled with water. A coverslip (24mm×24mm×0.17mm) was placed 31μm above the flat surface of the polyethylene lid, asymmetrically in order to reproduce the influence of gravity. A layer of irradiated cells 12.9μm thick and the same dimensions as the coverslip, was placed directly on the coverslip surface closest to the radiation source. It was assumed that for the calculations, the layer of cells would consist only of water. The applied scheme of the Petri dish is shown in Fig. 2.

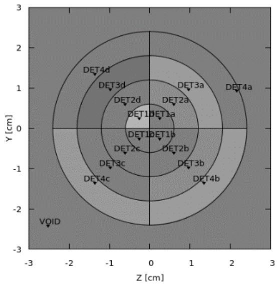

Fig. 1. Geometry of the segment detector.

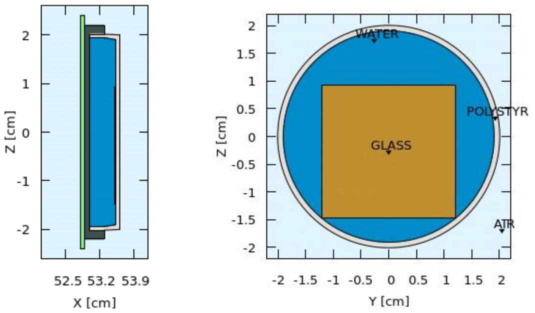

Fig. 2. Cross-section in the XZ & YZ plane of the Petri dish.

The results of the dose equivalent calculations outside the X-ray tube and in the plane of the segment detector are shown in Figs.3-4. The average photon energy recorded in the segment detector was in the range of 21.79keV to 22.82keV. The largeat differences were between the low energy part of the spectra recorded in the sectors of ring 4. However, the spectra recorded in all segments of the detector do not differ much from each other, so the photon beam can be treated and analyzed as a single entity.

The Monte-Carlo calculation results for the radiation dose in the beam area 49.9cm from the centre of the Be window of the X-ray tube are in accord with the measurements [4]. One can see the skewness of the photon beam along the Z axis and the good beam flatness along the Y axis.

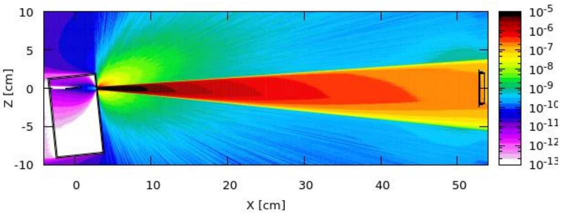

Fig. 3. Dose equivalent in pSv/N_{e0} in thesecond stage of the calculation. The size of the test Petri dish is smaller than the dimensions of the main photon beam.

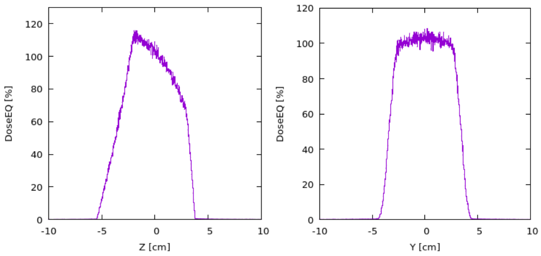

*Fig. 4. **S**ections of the photon beam obtained in the segment detector plane along the Y and Z axes.*

The fluence of photons irradiating the cells backwards is 0.8% of the photon fluence irradiating the cells directly from the source. The fluence of electrons irradiating the cells backwards is 3.33 times greater than the electron fluence from the direction of the X-ray tube. The photon spectrum irradiating the cells backwards contains characteristic radiation of Ca and Si atoms present in the glass of the coverslip.

References

[1] "The FLUKA Code: Developments and Challenges for High Energy and Medical Applications" T.T. Böhlen, F. Cerutti, M.P.W. Chin. A. Fassò, A. Ferrari, A. Mairani, P.R. Sala, G. Smirnov, V. Vlachoudis, Nuclear Data Sheets, 120, 211-214 (2014)

[2] "FLUKA: a multi-particle transport code" A. Ferrari, P.R. Sala, A. Fassò, and J. Ranft, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773

[3] http://www.cis.gov.pl/

[4] J. Czub, UJK, Kielce, private message

Nanodosimetry with the Jet Counter – progress report

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The Jet Counter (JC) [1] nanodosimeter has been developed for measuring the track structure of ionizing particles in a gas target equivalent to a nanometric site in condensed matter. High purity nitrogen is used for the majority of the experiments performed by this device. A parameter of a great importance for this device is the efficiency of detection of single nitrogen ion created by a charged particle crossing the interaction chamber. The task to increase the efficiency of the Jet Counter from a level of around 40% has been undertaken and the results are presented here

Materials and method

The NCBJ ion counting nanodosimeter Jet Counter described in detail elsewhere [2] consists of an interaction chamber (IC), where a sensitive volume is obtained by nitrogen expansion from a gas reservoir. The gas jet is created by a pulse operating piezoelectric valve with a repetition rate adjustable to 1-8 Hz. The interaction chamber has a cylindrical form (10 mm in diameter; 10 mm in height) with a wall of 1 mg/cm^2 Mylar (Al covered on both sides). The size of an equivalent nanometric target is established from the combination of the pressure in the reservoir and the voltage applied to the piezoelectric valve and monitored by measuring the transmission of a 1 keV electron beam. Nitrogen molecules are ionized by a single ion crossing the sensitive volume forming ionization clusters.

Positive nitrogen ions formed in the IC are extracted and guided towards a discrete dynode electron multiplier type AF180H (channeltron) using an electric field created by a set of grids (G1 to G4). The configurations (before and after the changes) of the set of grids and the corresponding voltage are shown in Figure 1.

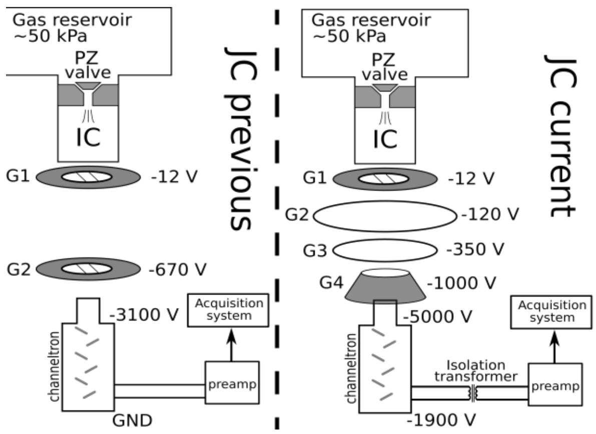

Fig. 1. Schematic layouts of the previous (left) and current setups of the Jet Counter with the key changes (not to scale).

To increase the ion counting efficiency the acceleration potential was increased from 3.1 kV to 5 kV, keeping the bias voltage of the multiplier unchanged. Also, the guiding structure (grids G2 to G4) have been optimized (right on fig. 1).

The effect of increasing the efficiency of single ion counting is controlled by measuring the ionization cluster distribution (ICSD) created by analpha particle beam crossing the IC with the evaluation of the first moment of these ICSD's. The results are shown in Figure 2.

Results and Discussions

In addition to the measurements the PTra Monte Carlo code is used to simulate the expected ICSDs as quality checks of the experiments performed as well as to assess the ICSD for 100% efficiency. Figure 2 shows the results of the measurements with the previous and current setups for the same target size together with the MC simulation for the corresponding efficiencies. The values of mean cluster size i.e first moment, of a ICSD ,M1, for each case are presented in table 1.

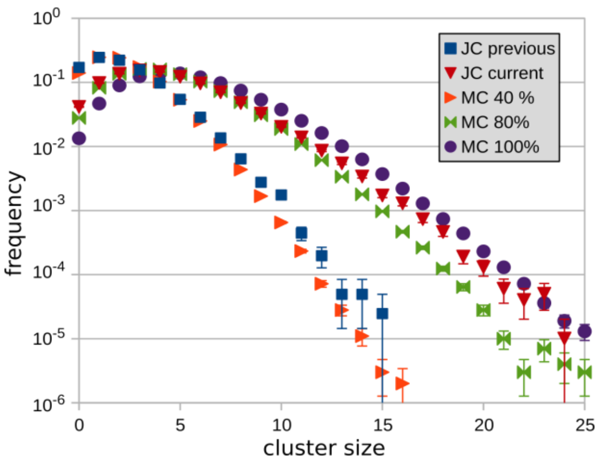

Fig. 2. Ionization cluster-size distributions for 3.8 MeV alpha particles irradiating a 0.32 µg/cm² nitrogen target.

Table 1. Mean cluster sizes with statistical uncertainties.

	JC previous	JC current	MC 40%	MC 80%	MC 100%
M1	2.19±0.016	4.42±0.026	2.21±0.003	4.42±0.007	5.53±0.009

As seen from these results the change of the accelerating potential of the nitrogen ions from -3.1 kV to -5 kV increases the counting efficiency almost by a factor of two i.e. from 40% to 80%. It is interesting to note that the shape of the ICSD (80%) measured shows some excess of larger cluster sizes compared to the calculated one. This effect is also seen for 40% efficiency. The reason for this effect may be due to a wall effect which generates additional delta rays not accounted for in the Monte Carlo code.

The rise of efficiency of single ion counting to 80% achieved by the appropriate voltage on the grids (optimization) and the increase of the acceleration potential shows that there is room for a further increase in the efficiency of the system, close to 100%. Further work on increasing the acceleration potential up to 8 kV is planned.

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[1] S. Pszona, J. Kula, S. Marjańska, Nucl. Instrum. Meth. Phys. Res. A447, 601-607 (2000)
[2] A. Bantsar, Ph D Thesis, e-Print: arXiv:1207.6893 (2011)

SOLID STATE PHYSICS, PHYSICS & ENGINEERING OF MATERIALS; APPLICATIONS

Applications of pulsed electron beams

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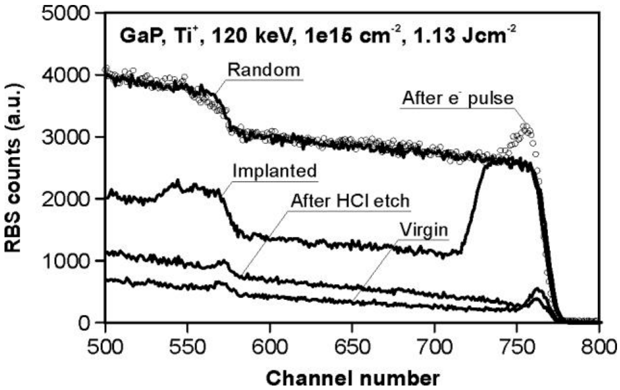
Attempts were undertaken to manufacture a semiconductor material suitable for impurity band solar cells (IBSC). In such a material, an additional impurity related conduction band is formed after the impurity concentration exceeds a limit referred to as the "Mott transition". The **aitional** band widens the spectral response of the cell and may lead to a significant increase of the cell efficiency. However, the Mott transition usually occurs above the solubility limit of the impurity and special methods are required to raise this limit such as pulse annealing of the implanted impurity.

Titanium implanted gallium phosphide was used as the research material. After implantation, the samples were treated with electron beam pulses of a duration of about 2 µs and energy density between 1 and 3 J/cm^2. The samples were studiedusing channelled RBS (cRBS). A typical result is presented in the Figure below, which shows the cRBS spectra of a sample implanted with a Ti dose of 1*10^{15}ions/cm^2 and pulse melted with a pulse of energy density of1.13 J/cm^2.

The channelled spectrum after implantation (”implanted”) reveals the presence of a damaged (amorphous) surface layer. The spectrum after pulse treatment (”after e- pulse”) is disturbed with the presence of a gallium Surface layer originating from dissociation of GaP at high temperatures. After removal of this layer by etching in HCl (”after HCl etch”) we observe a spectrum similar to the spectrum of the unimplanted sample (”virgin”) which indicates a perfect restoration of the crystallographic lattice. Additional PIXE measurements confirm the presence of Ti in the implanted and pulse annealed layer.

This research confirms the full restoration of the GaP crystallographic lattice in Ti implanted GaP after electron beam pulse. The results were published in the Journal of Applied Physics [1]



Reference

[1] Z. Werner, M. Barlak, R. Ratajczak, P. Konarski, A. M. Markov, R. Heller, Electron pulse annealed Ti-implanted GaP, J.Appl.Phys.120 (2016)085103

Technology secrets of precious metal artifacts from the Nidajno bog site in Poland

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[2]Institute of Archaeology and Ethnology PAS, Warsaw, Poland
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The Nidajno Project has been carried out since 2010 when this unique archaeological site was discovered within the area of the former lake Nidajno (north-eastern Poland) [1]. The results of the field-work situate the site as one of the most important offering-places (next to the famous Jutland sacrificial bogs at Illerup, Thorsberg and others), which is proved by golden and silver artifacts of probable Eastern Mediterranean provenance (among them golden sword fittings, figurines of a vulture and others). The aim of the archaeometallurgical research was to recognize the method the ancient metallurgical workmanship: conditions of the ancient casting and ornamentation techniques and the impact of environmental factors on the form and texture of the objects observed at present.

The elemental and structural composition of 13 precious metal objects was investigated (see figures in Results). Complementary non-invasive and micro-invasive instrumental analysis techniques were used. SEM/EDX (scanning electron microscopy with X-ray microanalysis) gave information about the elemental composition of artifacts including their state of preservation and thus metallurgical technology differences, i.e. ornamentation type, gilding and silvering processes, solding technique. The SEM-EDX analysis were performed using a Carl Zeiss EVO MA10 Scanning Electron Microscope equipped with a Bruker XFlash Detector 5010 (123 eV resolution). The Bruker Qunatax 200 program was used to analyze the mesured X-ray spectra. Additional by the results were confirmed by reference measurements with: ED-XRF, XRD and LA-ICP-MS.

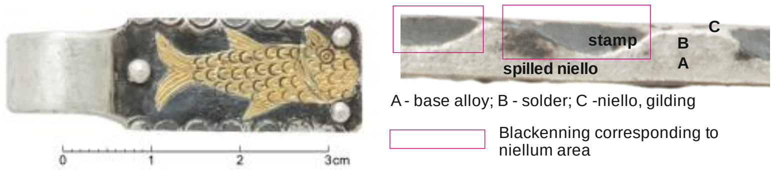

Fig. 1. Belt hanger with fish representation: view of the surface (left) and MO cross section of artifacts (right).

Micro-sampling gave information about types of solders used i.e. mercury amalgam and indium binders were reported which is untypical for this period. The surface of gold ornaments were made by the fire-gilding process. Furthermore the niellum technique used in ornamentation was based on silver, copper and lead sulphurs [2].

XRF (energy dispersive X-ray fluorescence) methods. The LA-ICP-MS (laser inductively coupled plasma mass spectrometry) technique was also applied to obtain lead isotope ratios in order to make a preliminary study of alloy provenance. The results obtained by use Kernel Density Estimation show that the raw metal alloy originated from similar ores [2].

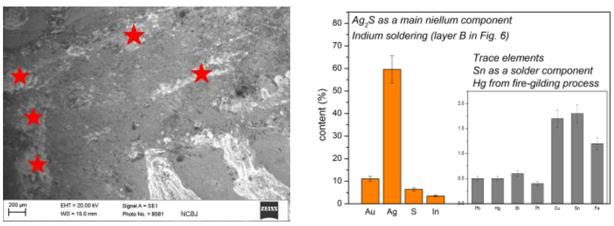

Fig. 2. (left) SEM image with corrosion cavity (in the range of μm) which allows layer composition to be determined: A, B, C on Fig. 1 and the presence of higher indium content in cavities: B ★ and average results of SEM/EDX μ-analysis of belt hanger (right).

The results gave information that generally most of these objects were made in a secondary process which makes the indication of the origin of the objects more difficult. Additional analyse were performed using ED-

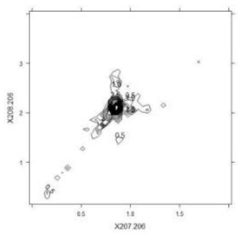

Fig. 3. Lead isotope ratio calcualted using the Kernel Density Estimation statistical method.

References

[1] Nowakiewicz T., et al., Lake Nidajno near Czaszkowo in Masuria: a unique sacrificial site from Late Antiquity, Warsaw 2012, ISBN: 978-83-89499-92-9

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Origins of silver and production of coins and jewelry in early medieval Poland

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This research project is focused on studies of silver coins and jewelry from the X and XI century in Poland (Piast Dynasty). Until now there was no certain knowledge about the sources of silver and manufacturing techniques used for making these objects. Of great need are data from ornaments which are a very large material, one of the largest in Europe, consisting of female earrings, pendants and other pieces of various types formally with origin in late antique art and further development in the first Slav state of Great Moravia in the ninth century AD. Based on materials research modern archaeometallurgy gives answers about the technological and deposit provenance of objects. The main goal of this project is to reveal the origin of Polish medieval silver based on a determination of the lead isotope ratio and elemental composition of ancient objects and geological ores which were extracted in the period. The elemental composition of objects was determined by use of SEM-EDX, ED-XRF and LA-ICP-MS.

SEM-EDX (Scanning Electron Microscopy with X-ray Energy Dispersive Microanalysis) allows morphological changes to be studied and the quantitative elemental composition to be determined [1-3].

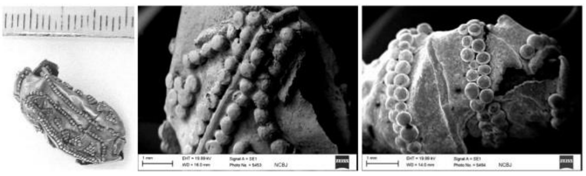

Fig. 1. Photo of jewelry: granulated silver bed, SEM images of surface with granulate mounting to surface by copper-tin solder. EDX results (wt%) Ag/Cu/Sn: 74.7/3.0/0 for surface, 73.9/2.1/0.7 for granulate and for solder 1.7/23.4/7.4 with higher content of oxygen 38.1 (hot treatment).

ED-XRF (Energy Dispersive X-ray Fluorescence Analysis) was used as a complementary technique. Due to the deeper penetration of X-ray (~100 µm for Ag-Cu alloy) it gives information about the alloy matrix while SEM-EDX gives data only from the surface (electron range ~2 µm).

In order to obtain the lead istope concentration LA-ICP-MS (Laser Inductively Coupled Plasma Mass Spectrometry) was used with a specially constructed statistical method (Kernel Density Estimation) which recalculates the data and gives theaverage value of the lead isotope ratio.

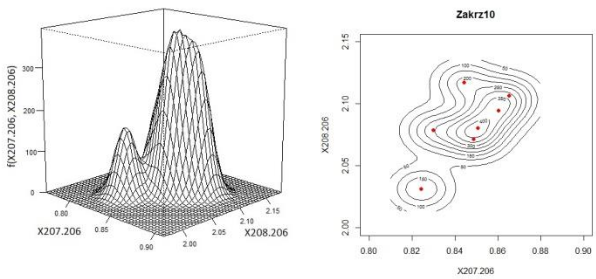

Fig. 2. 3D and 2D lead isotope ratio.Distribution for one object after statistical treatment. Dispersion of results indicates that secondary smelting may have been used.

Through the materials study of archaeological artifacts summarized with data from the literature we will be able to vivificate and establish trade routes in the period. By determining the propagation of technological innovations it will be possible to infer the origin of the first Polish lord from the Piast Dynasty. The Ag-Cu distribution in a Palatyn Sieciech coin determined by different techniques with different penetration depths gave information about the surface and sub-surface elemental composition.

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Cu-N layers synthesized by pulsed magnetron sputtering with variable frequency plasma generation

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Cu-N layers were synthetized using the Pulsed Magnetron Sputtering method (PMS), operating with various conditions of frequency modulation. Fig.1. We have studied how this parameter affects the mechanism of layer growth. Changing the conditions of plasma generation resulting from the possibility of controlling its frequency and life time has a strong effect on the quantity and activity of plasma particles and the interaction between the plasma components with the substrate. It allows us to control the mechanism of the layer growth, its microstructure, and phase composition, as well as the properties of the layers Fig 2, Fig 3. The low frequency modulation contributes to the fragmentation of the structures and perturbs columnar growth that are characteristic for the structure of the Cu-N layers synthetized under high frequency modulation.

Our investigation revealed that the use of variable frequency modulation is a very important parameter of the synthesis process that can inaugurate new a paradigm in future implementation of PMS-based methods.

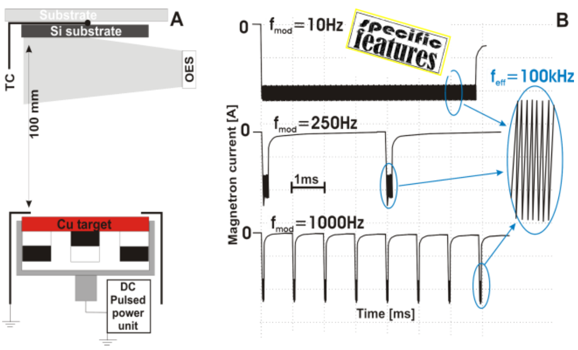

Fig. 1. Schematic view of the experimental setup and current waveforms that show the pulsed manner of plasma generation by the PMS method.

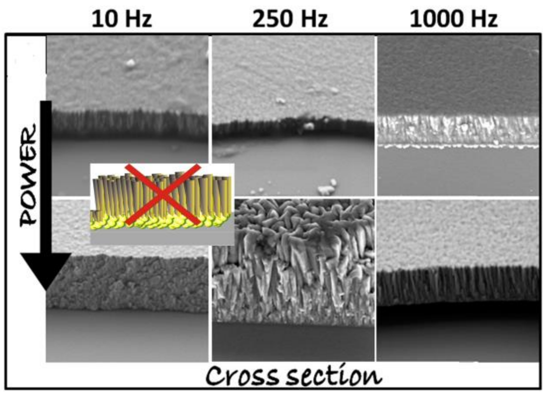

Fig. 2. Cross section views of the Cu-N layers.

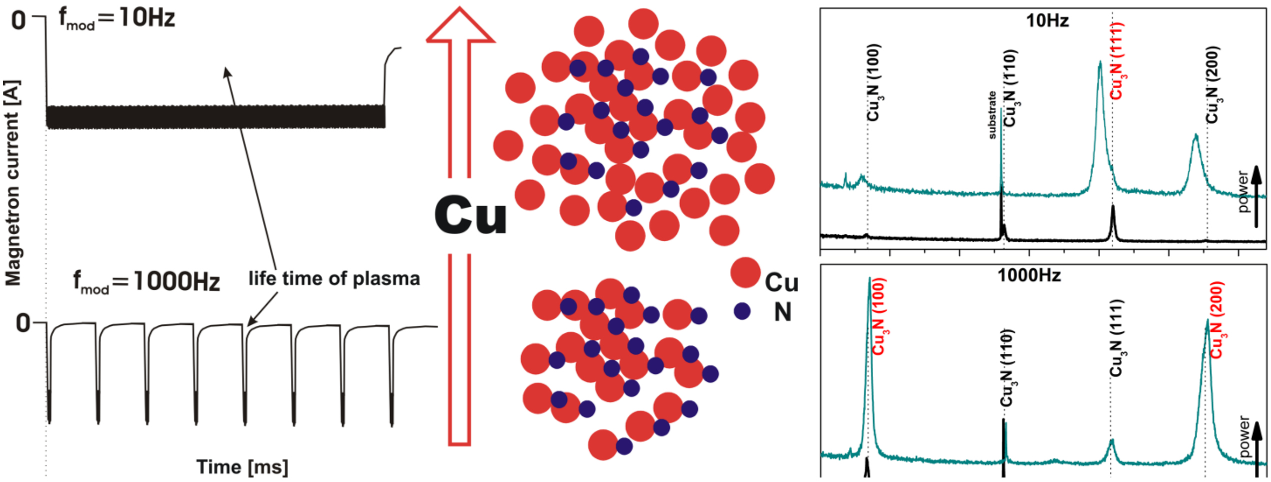

Fig. 3. Schematic illustration of the influence of the duration of each plasma pulse, on the sputtering phase duration (left). The X-ray diffraction patterns of the Cu-N layers- phase composition.

Reference

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Pulsed electron beam modification of the wettability and roughness of a wood surface

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Cellulose is the most common natural polymer and the main structural component of wood. As a polymer with a high degree of polymerization, it is characterized by excellent strength properties. The properties of lignocellulosic materials can be improved by modifying the basic component of wood, which is mainly cellulose. The existing methods of wood modification consist in the use of chemical (saturation by liquids) [1] and physical (the impact of temperature, pressure) methods [2]. As part of the materials research, it is proposed to study surface modification of lignocellulosic particles (chips), especially by electron beam irradiation of the surface. Based on reports in the literature, the proposed idea has not been used thus far in forest sciences in the field of wood technology. Implementation of the proposed methods of wood particle modification aims to improve the surface properties owing to a significant increase of the free surface energy. This approach allows us to develop methods producing wood particles with minimum adhesive binders. Adopting the proposed methods in the manufacturing of wood materials leads to the development of ecological, low-carbon, formaldehyde-free materials used for furniture production [3-4].

In our work, samples of beech 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 beams of microsecond duration, which generates a fairly homogeneous wide-aperture electron beam up to 10 cm in diameter [5].

The main parameters of the modification process were:

- modified materials: 70×20×1.5 mm^3 beech veneer,
- working gas: Ar,
- working gas pressure: 8e-4 Tr,
- electron energy: from 14 to 30 keV,
- energy density of pulses: about 1, 3 and 7 J/cm^2,
- pulse duration: about 2 μs,
- number of pulses: 1, 5, 10 and 15.

Any modified or newly developed material should be characterized in terms of itssurface properties determining further behaviour in an aggressive environment (e.g. water or organic solvents) and - as a consequence - susceptibility to degradation including hydrophilicity of lignocellulosic materials, which makes bioattacks more likely. Moreover, the surface properties of a material strongly affect gluing, finishing or impregnation. The water contact angle is a quantity allowing for characterization of surface properties.

A single measurement provides a few important parameters: surface free energy, contact angle, wetting coefficient or work of adhesion [6]. Characterization of surface properties allows for prediction of interactions with wetting materials (lacquers or adhesives). Surface properties of materials obtained in our research were determined using a Phoenix 300 contact angle analyzer - the free surface energy was determined according to the Owens-Wendt method [7-8].

Water wettability of electron irradiated samples was investigated in sessile drop tests. The sessile drop results are shown in Fig. 1. They demonstrate scattered relations as regards the effect of pulse energy and the number of pulses. We may conclude that the effects of the number and the energy of pulses are too weak to grant applicability.

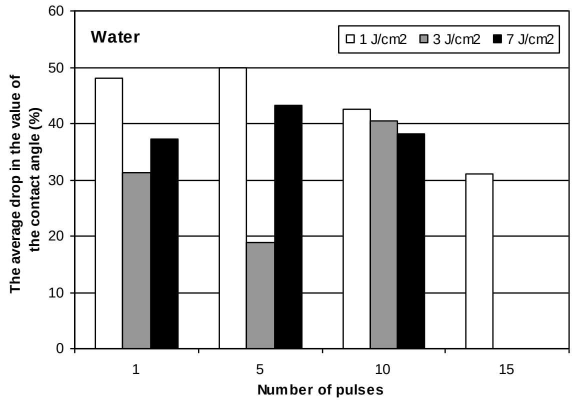

Fig. 1. The average drop in value of the contact angle vs. number of pulses and pulse energy density.

The measurement of surface roughness was conducted using a MITUTOYO SJ-201contact profilometer with a stylus with a radius of 0.01mm at a press force of 4 mN. The measurement distance was 12.5 mm (5 elementary sections with a length of 2.5 mm each). The roughness parameter R_a (mean deviation of profile) was applied according to PN-84/D-01005 [9].

The results show statistically insignificant influence of the number of pulses on surface roughness (Fig. 2) and statistically significant influence of the energy density of pulses (Fig. 3). An increase in the energy density of pulses leads to a significant increase in the surface roughness parameter R_a of beech wood. This result is consistent with the investigation of Wilkowski et al. [10] which concerned oak and ash wood after thermal modification.

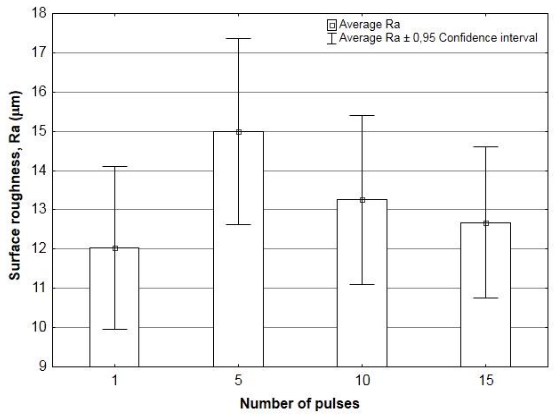

Fig. 2. Influence of the number of pulses on surface roughness.

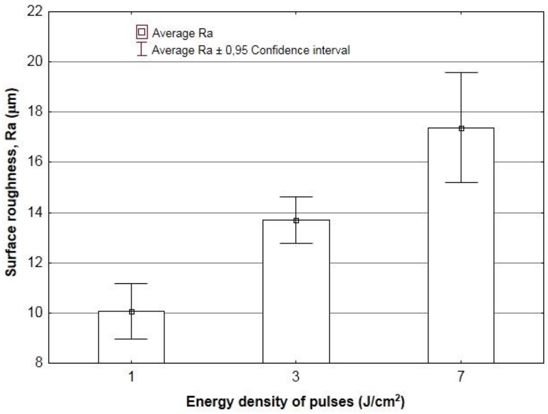

Fig. 3. Influence of the energy density of pulses on surface roughness.

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Preparation of superconducting Pb photocathodes for TESLA/XFEL-type photoinjectors – continuation

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Work on the preparation of lead-layer photocathodes on a niobium substrate, destined for XFEL-type, 1.6-cell, superconducting RF electron injectors was continued in 2016. Our previous activities in this field resulted in the selection of methods of lead deposition and smoothing [1]. Ultra high vacuum arc lead coating followed by pulsed plasma ion treatment in a rod plasma injector were found to be promising in this context. The smoothing procedure was optimized by performing heat transfer computation from pulsed plasma ion beams. The calculation results were verified experimentally by treating arc deposited layers with Ar^+ ion pulses in the IBIS multi-rod plasma generator at NCBJ followed by SEM observation of the film surfaces. The tests confirmed the computational results which predicted that sufficiently flat, continuous lead surface layers can be reached after treating with five-seven 1.5 J/cm^2 plasma pulses of 17 – 20 µm thick Pb layers. Alternatively, planar layers could be reached by smoothing 10 µm films with 25 pulses of energy fluence reduced to 1 J/cm^2. Resonant quality factor measurements of e-gun cavity are typically preceded by a standard installation and cleaning procedure including exposure to air and deionised water, buffered chemical polishing (BCP) supplemented by electro-polishing. Thanks to the advantage of using a detachable photocathode plug, this treatment is performed before mounting the plug. Nevertheless, the procedure is completed with high pressure water rinsing (HPWR) with the plug installed. To test lead layer endurance in typical cleaning procedures a 20 µm thick film on Nb plate was subjected to water rinsing in a stand which reproduced in 1:1 scale the basic features of a superconducting RF e-gun with a 1.3 GHz tesla-type cavity. The rinsing is typically performed with a rigid shield which protects the lead layer from the direct water stream. In our tests a shielded film remained undamaged after 1 min. of rinsing with a water stream at a pressure of 30 bar. On the other hand the tests with no shielding revealed that the layer can only be exposed to a weak water flux (up to 1.5 bar) but not to high pressure water rinsing.

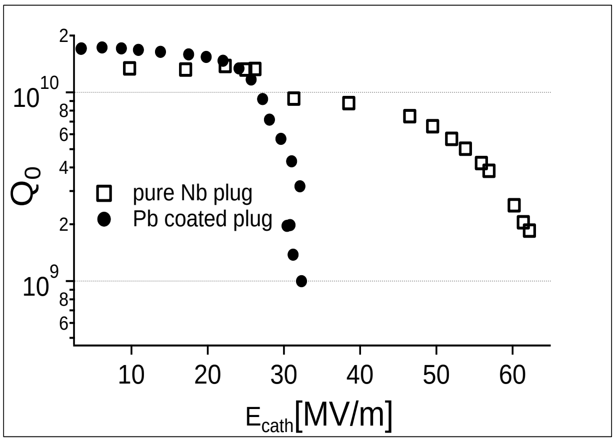


Fig. 1. 1.6-cell electron gun (left) and Q_0 measured for uncoated and direct arc coated and pulsed plasma annealed photocathodes.

Studies on the Pb layer photocathode RF performance in the e-gun cavity and quantum efficiency measurements were performed in the framework of a collaboration between the National Centre for Nuclear Research (NCBJ), the Deutsches Elektronen Synchrotron (DESY) and Brookhaven National Laboratory (BNL). A dedicated 1.6 cell structure has been built for which the resonant quality factor Q0 was measured at DESY and BNL. Qo tests were conducted at DESY with an e-gun equipped with a niobium cathode plug both, without and with a 18 µm thick lead film deposited in a UHV arc and smoothed by six plasma ion pulses of 5 J/cm^2 in fluence. A quality factor value of $5{\cdot}10^9$ was reached in both cases at a cathode peak electric field of 52 MV/m and 32 MV/m, respectively (Fig. 1). The result proved that the plug covered with a clean and smooth Pb film did not deteriorate the cavity performance. The quantum efficiency of the lead film on this plug photocathode was measured in the wavelength range from 200 to 320 nm at BNL within a UV beam generated by a deuterium lamp equipped with a monochromator of the above wavelength range. The values obtained prior to laser cleaning ranged up to $5{\cdot}10^{-7}$ for 260 nm and up to $3.5{\cdot}10^{-5}$ for 200 nm, which are typical values measured for air-stored lead. The plug surface was subsequently irradiated with laser pulses of 248 nm in wavelength and 0.06 mJ/mm^2 in fluence. After 1000 pulses the QE rose to $1.5 \cdot 10^{-4}$ and $9.8{\cdot}10^{-4}$, for the above mentioned wavelengths respectively. After extending the cleaning up to 10000 pulses further emission enhancement was reached up to $3.2 \cdot 10^{-4}$ and 2.2 10^{-3}, respectively (Fig. 2).

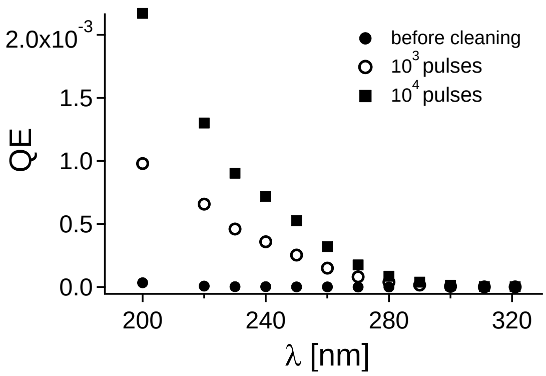
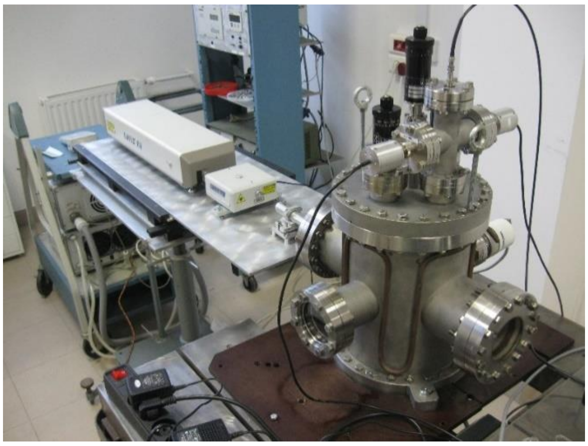


Fig. 2. Quantum efficiency results for an arc coated and pulsed plasma annealed photocathode.

In order to study systematically a long series of lead layer samples from the point of view of their photoemission and dark current a new QE –measuring system was arranged at NCBJ, composed of a Nd-Yag laser generating green light (λ= 532 nm), combined with a converter to ultraviolet radiation (λ= 266 nm) and a specially designed vacuum chamber equipped with photocurrent and black current measuring systems (Fig. 3). Preliminary tests conducted in a collaboration between NCBJ and Warsaw University of Technology proved that a the system of this type is effective in performing in-situ laser cleaning of samples and in QE –measurements.



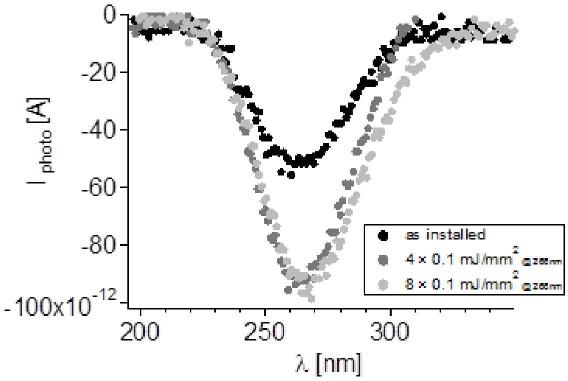


Fig. 3. The system for testing QE and dark current from Pb layer photocathodes under assembly at NCB . Photocurrent measurement showing 100 pA corresponding to QE = $6\cdot10^{-4} \pm 5\cdot10$-^{4}at 266 nm.

Reference

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The photoluminescence response to structural changes of Yb implanted ZnO crystals subjected to non-equilibrium processing (*J. Appl. Phys., 2016*)

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ZnO is a very promising material for semiconductor device applications. It has a direct wide band gap in the near-UV spectral range, and large free-exciton binding energy so that excitonic emission processes can persist at or even above room temperature. This, in turn, has led to a revival of the idea of using ZnO as an optoelectronic material. The basic light emission from ZnO is in the violet-blue spectral range, but it can be modified through doping. Recently, studies on rare earth (RE) doped materials have received considerable interest for their possible applications in visible light-emitting phosphors (for displays) and monochromatic light sources.

Ion implantation is a strongly non-equilibrium process which allows any kind of atoms to be introduced into solids with concentrations well above their solid solubility limit. Moreover, by selecting the ion fluence and ion energy precise control of the dopant depth distribution and concentration is possible [1]. Unfortunately, the ballistic nature of this process produces lattice damage.

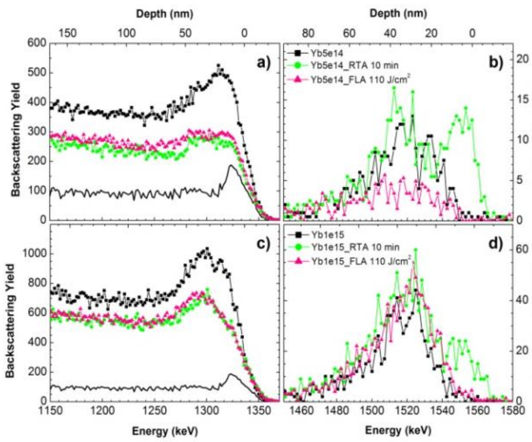

Fig. 1. Random and aligned RBS/c spectra for a ZnO single crystal implanted with Yb ions to fluencies of $5x10^{14}$ (a,b) and $1x10^{15}$ /cm$^{2($ c,d) in the as-implanted stage and after different types of annealing. RTA were performed at 800^{O}C for 10 min and FLA for 20 ms with flash energy of 110 J/cm^{2}.

In the as-implanted stage most of dopants are neither electrically nor optically active. In order to promote the structure recovery and activation of implanted dopants post-implantation thermal treatment has to be applied [2-5]. Up to now, the most common lattice reconstruction of implanted crystals is performed using conventional equilibrium thermal processing like rapid thermal annealing (RTA) or Furnace Annealing (FA). Although after such thermal treatments of an implanted ZnO crystal lattice recovery can be achieved it is accompanied by RE-atom out-diffusion and agglomeration on the surface. In order to cope with this problem millisecond range flash lamp annealing (FLA) has been tested.

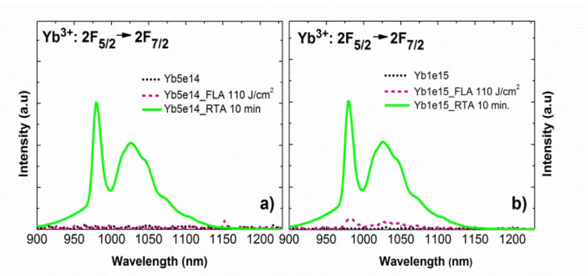

Fig. 2. RT PL spectra for a ZnO single crystal implanted with Yb ions to fluencies of $5x10^{14}$ (a,b) and $1x10^{15}$ /cm^2 (c,d) for as-implanted sample and after different types of annealing. RTA was performed at 800^OC for 10 min and FLA for 20 ms with flash energy of 110 J/cm^2.

In the present work, the structural and optical properties of Yb-implanted ZnO single crystals prior to and after annealing were studied in details. It was shown that both annealing techniques remove defects formed during ion implantation, but in contrast to RTA the diffusion of implanted Yb during FLA treatment is completely suppressed. At present, the highest intensity of the NIR PL emission was observed after RTA performed in oxygen at relatively low temperature (800oC). This radiation is apparently due to the displacement of Yb ions from substitutional to interstitial positions and formation of Yb-oxygen clusters. The Yb ions occupy Zn positions and hence they are in the optically inactive 2+ oxidation state. We believe that further optimization of ion implantation and FLA parameters will allow usto obtain single crystalline ZnO layers with RE optically active centres. A detailed description of our study can be found in the Journal of Applied Physics.

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 Funds for co-financed international projects (Grant No 3418/SPIRIT/2015/0) and the co-financed project by Helmholtz Zentrum Dresden-Rossendorf (HZDR) in the framework of the programme Access to Infrastructure (15100222-ST and 15000594-ST) and by the FP7-REGPOT-CT-2013-316014-EAgLE Project.

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Laboratory for Nuclear Microanalysis – an overview of research achievements in 2016

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During 2016 Laboratory for Nuclear Microanalysis was stable with regard to number of employees. In this year our group worked an eight main projects. Some of them are already accomplished and some are still in progress. Eight papers were published plus three accepted and four submitted. Most of the papers were published in refereed journals. The total predicted number of impact factor for all publications is equal to 17.364 (7.587 – published, 9.777 – accepted/submitted).

In the past year investigations by our lab were mainly focused on the structural changes of materials after implantation; development and validation of McChasy – Rutherford Backscattering Spectrometry in channelling direction computer simulation tool and analysis of archeological relics. Project objectives were realized with close collaboration between our group and UW (Poland), IF PAN (Poland), HZDR (Germany), Paris-Sud University (France), CNRS (France) and several other national and foreign institutions.

Short summary of chosen projects carried out in 2016 (both accomplished and ongoing).

Light emitting photonic structures based on ZnO implanted with rare earth elements (projects ZnOLum and ZnOTrans).

Financial support of:

- The National Centre for Research and Development (PBS2/A5/34/). NCBJ in collaboration with IF PAN (leader) and ITME.
- The Polish Ministry of Science and Higher Education from the Science Funds for 2015–2016 fiscal years for execution of co-financed international projects (3418/SPIRIT/2015/0).

The aim of the projects was/is (ZnOLum – in progress) an optimization of the annealing process for ZnO single crystals and 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 GaN/Al_2O_3 substrate and commercial single crystals (MaTecK) implanted at room temperature with different RE ions: Yb, Eu, Er, Pr, Dy to the 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 are characterized by the RBS/c technique and by other complementary methods such as HRXRD and TEM. Subsequently, hotoluminescence (PL) studies of these samples were performed. It is expected that the control of the crystalline quality, damage recovery, RE-atom lattice site location and an optical efficiency study after FLA annealing will lead to important progress of ZnO in optical applications.

According to the schedule of the projects we completed the following objectives:

- Optimization of thermal annealing as a function of time and temperature to achieve the best structure recovery.
- Optimization of FLA as a function of the density of the energy deposited on the surface.
- -Influence of annealing on local structure changes was investigated for different ions (Yb, Eu, Pr, Dy) implanted in ZnO.
- Study of the photoluminescence response to structural changes occuring after RTA and FLA annealing.
- The Monte Carlo simulation code McChasy used for analysis of RBS/c spectra.
- Correlation of results obtained by the RBS/c, HRXRD and HRTEM techniques.
- Development of a new model for migration and agglomeration of defects in ion implanted ZnO.

The development of the McChasy simulation code in order to enable Nuclear Reaction Analysis (NRA).

Financial support of The Polish Ministry of Science and Higher Education (212727/E-78/M/2015, 16029-223)

The aim of the project was to develop a simulation tool able to reproduce experimental data collected by NRA in single crystals. NRA allows the localization of light elements as impurities (deuterium, helium, nitrogen etc.) and lattice defects in a pure matrix or cationic and anionic sublattices in a compound material (oxide, nitride or carbide) to be investigated. The ability to simulate RBS/c and NRA/c spectra and angular scans gives access to quantitative analysis of the evolution of structural properties of crystals exposed to irradiation.

The advantage of the McChasy code (name derived from Monte Carlo CHAnelling Simulations) is the ability (unique in the world) to reproduce RBS/C spectra recorded on crystals containing simple (point defects, displaced atoms etc.) and extended defects (deformations of atomic planes, such as dislocations or dislocation loops) [1]. Detailed tests and experimental fits are performed to validate the developed program.

- Summary of implementations made inside the McChasy code related to the project:
- Four deuteron-induced reactions i.e. $^{3}He(d,p)^{4}He$, $^{16}O(d,p)^{17}O$, $^{12}C(d,p)^{13}C$ and ^{16}O (d,p)^{14}N wereincluded.
- Experimental geometry, i.e. details of the experimental set-up as well as details of channelling mode implemented
- Kinematic equations of these reactions and corresponding nuclear cross sections [2] applied.
- Output file comparising RBS and NRA spectra with energy peaks corresponding to the energy of the reaction products.

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Water migration of quasi-2D systems

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Studies of the wetting of porous materials reveal such properties of the medium as the effective size of the pores and its wettability by the liquid used. We have found recently that in quasi two-dimensional systems like single sheets of tissues, textiles and paper, the motion of the wetting front does not conform to the classical dependence on the square root of time but can be approximated by a power law $d(t)\sim t^{\alpha}$ with the exponent α between 0.36 and 0.43 (±0.005) (Fig. 1). This value is distinctly different from the classical one of 0.5 predicted by capillary suction theories and observed for bulk porous systems.

In our studies dynamic neutron radiography was used for quantitative investigation of migration of hydrogenous liquids in porous media. Both imbibition and drying processes were investigated in rigid and loose porous media with neutron radiography, revealing non-classical or anomalous kinetics of the wetting and drying fronts. In this research we prove that the method is sensitive enough to study systems of 0.1 mm thickness such as sheets of various textiles.

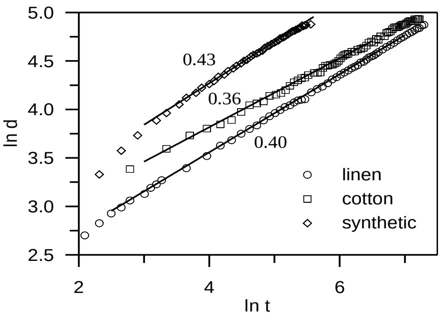

Fig. 1. Logarithmic plot of the wetting front distance from the water immersed end of a cotton fabric as a function of time. The numbers are the values of the α exponent.

The experiments were performed using the thermal neutron dynamic radiography facility at the MARIA reactor of NCBJ. The systems under study consisted of 20 mm wide and 130 mm long strips of fabric stretched on a vertical aluminum frame (Fig. 1) with its flat side parallel to the detector screen. In the wetting experiments the lower end of the sample was placed in a container which could be filled with water to wet that end of the sample. The drying process of the thin flat samples was studied with a water saturated sample placed in a vertical drying tunnel. The neutron images of the sample during wetting and drying were recorded on-line every 1.6 s by a dedicated computer system.

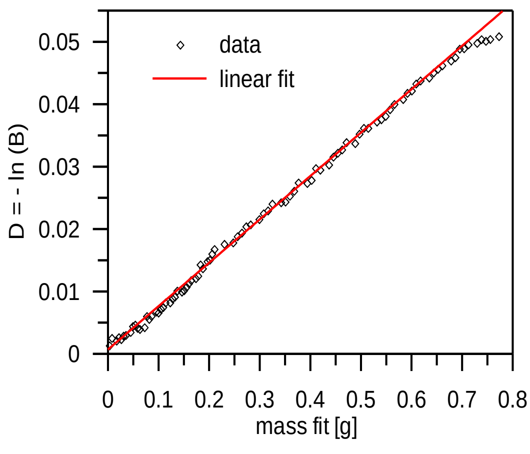

Fig. 2. The dependence of the average optical density in the image and the mass of the sample for the drying of linen.

The analysis of the drying experiments resulted in establishing a linear dependence between the average optical density in the image of the sample and the sample mass (Fig. 2). This property can be used to express the local surface density (*dm/dS*) of water mass in the sample in terms of the local optical density in the image of the sample.

It was found that the distribution of the optical density along the sample axis converges within experimental error to one curve when plotted versus the normalised variable $\varphi = x\ t^{-\alpha}$ where x denotes the position on the long axis of the sample (Fig. 3). The initial region of steep descent of the amount of water with the distance x from the water immersed end of the sample is due to a kind of meniscus formed at that end. Nevertheless, two regions with different slopes of the dependence of the amount of water on the variable φ were revealed for larger distances from the lower end of the sample.

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Although this universality is limited to samples with smooth surfaces the feature allows for calculation of the generalised diffusivity within the generalised diffusion equation approach.

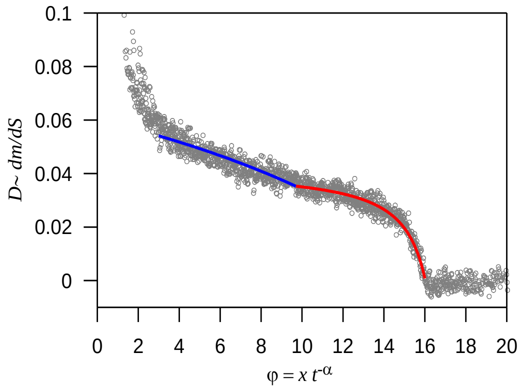

Fig. 3. The dependence of the average optical density and the generalised variable $\varphi = x\ t^{-\alpha}$ for wetting of synthetic fibre textile. The fits for two main regions of the sample are marked with blue and red curves

The influence of phase decomposition on phonon vibrations in $Mn_{0.3}Ni_{0.3}Cu_{0.4}$ alloy

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The possible influence of phase decomposition on the phonon dispersion relation in a sample of pseudo quasi-binary $Cu_{0.4}Mn_{0.3}Ni_{0.3}$ alloy was investigated for the initial stage of decomposition.

The $Cu_{1-2x}Mn_xNi_x$ alloys are known to harden as a result of phase decomposition which results in changes in atomic and magnetic ordering and the occurrence of tetragonal distortion in one of the phases. This alloy was the subject of our earlier studies on the magnetic and atomic ordering in the precipitated phase at the initial stage of decomposition [1]. The present problem of interest was the influence of the strain induced by decomposition on the phonon vibrations.

The phonons were investigated by means of the triple axis neutron spectrometer at the MARIA reactor in Świerk in a quenched (homogenised) sample and after short (20 min) thermal ageing at ~400°C. The low energy part of the dispersion relation was determined at room temperature for the [100] and [110] wave-vector directions (Fig. 1 and Fig. 2).

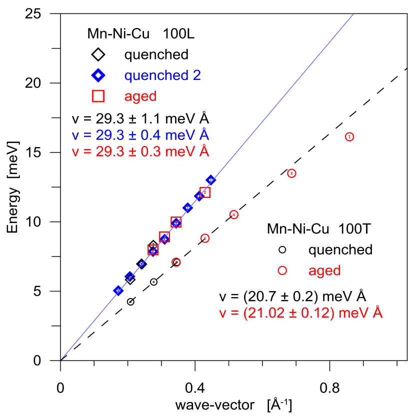

Fig. 1. The low energy part of the longitudinal and transverse phonon dispersion relation in the [100] direction investigated in a homogenised sample and after short ageing.

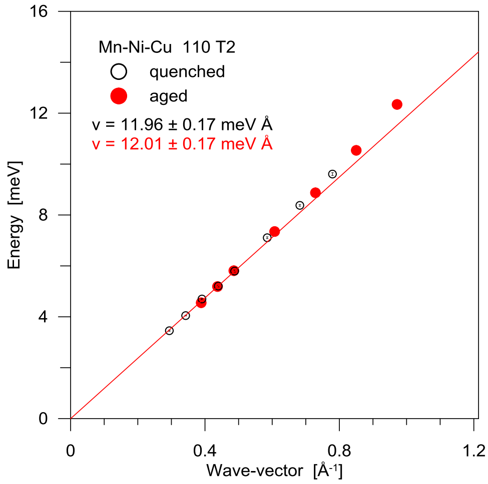

Fig. 2. The low energy part of the transverse T2 phonon dispersion relation in the [110] direction for a homogenised sample and after short ageing.

The elastic stiffness constants relevant to the FCC structure were obtained from the velocities of the longitudinal and transverse phonons for the above mentioned directions. The results are presented in the Table 1.

Table 1. The elastic stiffness constants of the $Cu_{0.4}Mn_{0.3}Ni_{0.3}$ alloy measured at room temperature for a homogenised sample and after short ageing.

Sample	*homogenised*	*aged*
Stiffness constants	$[10^{11}$ N $m^{-2}]$	
C_{11}	1.58(7)	1.58(7)
C_{12}	1.05(9)	1.04(10)
C_{44}	0.79(3)	0.82(3)
$(C_{11} - C_{12})/2$	0.264(13)	0.271(15)

Our results indicate that the values of the phonon velocities obtained and the resulting stiffness constants after short ageing do not differ within experimental errors from those for the homogenised sample.

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Library enlargement of atropisomeric compounds with implications for medicinal chemistry

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Atropisomerism is a kind of stereochemical phenomenon that arises from a hindered rotational barrier about a single bond, which behaves as an axis of chirality [1]. The term atropisomer is derived from the Greek *atropos*, meaning ‘not turning’. The name was coined by Kuhn in 1933 and it was first experimentally visualised by the resolution of enantiomers of 6,6’-dinitro-2,2’-diphenic acid by Christie in 1922 [2]. In biaryls the atropisomerism is generated by the presence of sterically demanding substituents placed at the *ortho*-position of the aryl moiety, thus causing restricted rotation around the pivotal bond. The physicochemistry of atropisomers may be studied using various analytical methods, including variable-temperature: NMR spectroscopy, dynamic GC, HPLC analysis and recently chiroptical methods such as electronic circular dichroism (ECD).

The role of atropisomerism in both chemistry and biology has already been well documented. As many biologically active compounds exist as pure atropisomers, this phenomenon has important implications in medicinal chemistry [3,4].

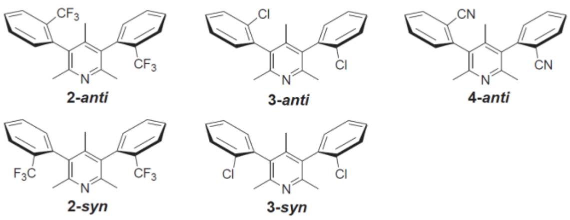

Fig. 1. *Examples* of studied atropisomers.

During our study on atropisomerism in aryl-pyridine derivatives we found that the Suzuki reaction of tribromo-2,6-lutidine with 2-methoxyphenylboronic acid gave 3,4,5-tri-(2-methoxyphenyl)-2,6-lutidine in the form of a mixture of three atropisomers stable at room temperature. Each of them was isolated and fully characterised, including their stereochemistry determination [5]. We have described [4] a further extension of the research to other derivatives of 3,5-diaryl substituted 2,4-, 2,6-lutidines and 2,4,6-collidines. We also expected that proper functionalisation at positions 2 and 4 of the pyridine ring would open the possibility for further transformation of the corresponding biaryls into other polyarylated heterocycles [4].

A separate subject was carrying out the Suzuki–Miyaura arylation of 4-amino-3,5-dibromo-2,6-lutidine with various *ortho*-substituted phenylboronic acids under the optimised conditions that were used for 3,4,5-tribromo-2,6-lutidine [5,6]. The coupling reaction was carried out in toluene with 2-dicyclohexylphosphino-2′,6′-dimethoxybiphenyl (S-Phos)/Pd(OAc)$_2$ as the catalyst and K_3PO_4 as the base.

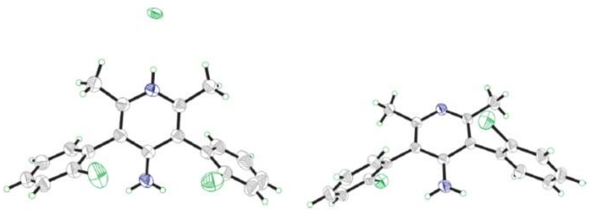

Fig. 2. Selected molecular structures derived from X-ray structural studies.

In summary, we prepared a library of compounds using the Suzuki-Miyaura reaction between 3,5-dibromo-2,4,6-collidine and bromo derivatives of 2,6- and 2,4-lutidine with a series of *ortho*-substituted boronic acids [4]. A series of mono- and diarylated pyridine derivatives were also prepared [6] by employing the Suzuki–Miyaura coupling reaction of 4-amino-3,5-dibromo-2,6-lutidine with various *ortho*-substituted phenylboronic acids. In some cases high thermal stability of the formed diastereomers was observed and allowed their separation by column chromatography (Fig. 1) and the absolute stereochemistry was determined by X-ray crystallography performed at NCBJ [4,6] (Fig. 2).

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Investigating a process for accelerating macroscopic objects in an eddy-current inductance coil magnetic field

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The subject of this paper is an analysis of the process of applying kinetic energy to a projectile made of non-magnetic electrically conductive material and located inside an induction coil live with alternating current, and a preliminary verification of the conclusion of this analysis. ICG ranged weapons (which do not employ explosive or combustion propellants) are currently the focus of study of many laboratories around the world [1–2].

In an ICG system which comprises a projectile with a coil, the axial component of the magnetic field generates a circulating eddy current which acts on the radial component of the same magnetic field and propels the projectile to translate it.

The energy input to affect the shot of this projectile has 8 outputs:

- generation of velocity of the projectile by the effect of the magnetic field radial component on the current induced in the projectile;
- generation of torque of the projectile by the effect of the magnetic field azimuthal component on the current induced in the projectile (and this effect is negligible in the ICG configurations used at the current stage of research);
- compression of the projectile by the effect of the magnetic field axial component on the current induced in the projectile;
- generation of oscillation of the inductance coil by the effect of the coil magnetic field on the coil current;
- resistive heating of the projectile material;
- loss of the power supply system;
- exchange of momentum with the accelerating coil mass;
- electromagnetic wave emission (from 5 to 10 kHz), which is negligible with the frequencies and geometrical dimensions of the ICG in question.

The design of the ICG and the technologies applied thereto must ensure optimisation of process 1 (and process 2, potentially) while minimizing the effects of processes 3 to 8.

Coupling the magnetic field with the eddy current resulted in a Lorentz force that acted on the projectile as follows:

$$F = I \times B$$

with a variety of components:
$F_z = B_r * I_\varphi$ – projectile acceleration,
$F_r = B_z * I_\varphi$ – projectile compression,
$F_\varphi = B_r * I_z$ – torque generation.

After some developments based on the theory of electrical circuits and Lorentz force formula, we obtain the epproximate expressions for a projectile output velocity v and an energy efficiency of the projectile acceleration η:

$$v \approx \frac{4h_r h_z k_{ef} \chi E_0}{m \cdot d \cdot \alpha} \qquad \eta \approx \frac{8h_r^2 \cdot h_z^2 \cdot k_{ef}^2 \cdot \chi^2 E_0}{m \cdot d^2 \alpha^2}$$

with:

- m – projectile mass,
- keff – projectile to coil coupling coefficient,
- hr – maximum relative value of the magnetic field radial component,
- hz – maximum relative value of the magnetic field axial component,
- d – coil inner diameter,
- χ – energy partition coefficient imposed by the balance of moments.

An energy loss due to coil vibrations and ohmic heating was as well as the effects of radial pressure causing the projectile deformation have also been estimated.

The estimations presented herein were verified in two stages. The first stage involved verification with a measurement system, comprising a power supply energy input bank with a capacity of C=25 μF, a self-inductance of 1.6 μH, and a series resistance of ca. 40 mΩ. This capacitor bank was charged to a voltage of 8–18 kV (i.e. an energy of 0.8–4 kJ). The second stage of verification included a similar measurement system with a capacity of C=12.5 μF, a self-inductance of 0.33 μH, and a series resistance of 40 mΩ. This capacitor bank was charged to a voltage of 15–30 kV (i.e. an energy of 1.4–5.6 kJ). Tests were performed on the process of accelerating cylindrical projectiles made of Duralumin PA6, 4–6 cm long, 2–3 mm in wall thickness, and 28–35 g in weight, and propelled with a coil with a length from 3 cm to 15 cm, made of Cu wire with a cross-sectional width of 2 or 3 mm, and built as a single or three-layer solenoid with 12 to 15 turns per layer. The projectile velocity was measured with a system comprising a LED and a phototransistor which measured the projectile flight time over a distance of ca. 50 cm. This test system is shown in Fig. 1

Fig. 1. Test system (see left) and an example of the test projectile (see right).

The aggregated measurement results of the system energy efficiency defined as the ratio of the projectile kinetic energy to the capacitor bank stored energy, and provided by both energy banks, are shown in Fig. 2.

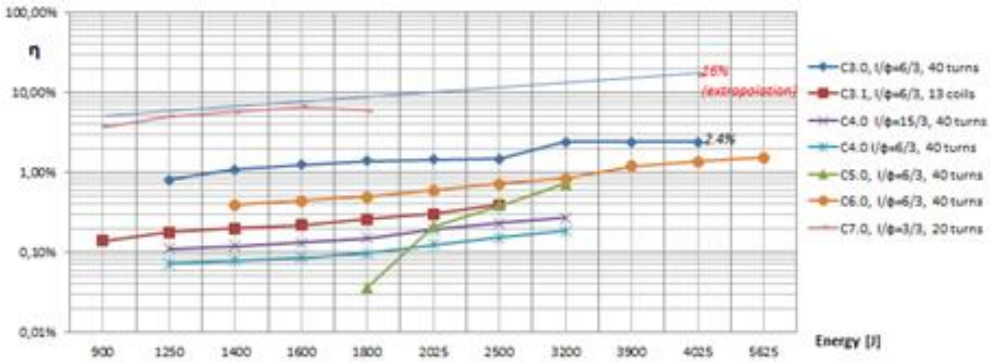

Fig. 2. Measurement results for the kinetic energy of various coil configurations and technologies vs. energy input.

The tests completed so far confirm that the initial evaluation of the power supply requirements, coil geometry, and processes of projectile acceleration were correct in general. The measurements confirmed virtually all analytical forecasts, both in qualitative and (partially) quantitative terms, including:

- the effects of the inductance coil form and dimensions (especially the length to diameter ratio);
- the influence of coil vibration on the acceleration energy efficiency;
- the significance of the balance of momenta of the coil and the projectile;
- the importance of the power supply energy input bank parameters (and especially its series inductance);
- the exposure of the projectile to compression.

These findings allow the technological and design requirements for future ICG (inductance coil guns) to be formulated.

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REACTOR PHYSICS, NUCLEAR TECHNOLOGY IN ENERGY GENERATION, MODELLING & CALCULATIONS

MARIA reactor operation

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The multipurpose high flux research reactor MARIA is a water and beryllium moderated reactor of a pool type with graphite reflector and pressurised channels containing concentric tube assemblies of fuel elements (Fig. 1, 2). It has been designed to provide a high degree of flexibility.

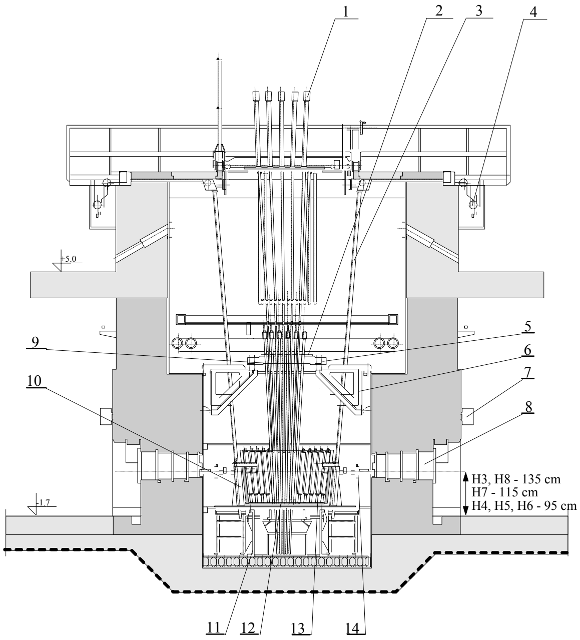

Fig. 1. Vertical section of the MARIA reactor. 1. control od drive mechanism, 2. mounting plate, 3. ionization chamber channel, 4. ionization chamber drive mechanism,5. fuel and loop channels support plate, 6. plate support console, 7. horizontal beam tube shutter drive mechanism, 8. beam tube shutter, 9. fuel channel, 10. ionization 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 and data of the MARIA reactor are as follows:

- nominal power 30 MW(th)
- thermal neutron flux density $2.5 \cdot 10^{14}$ 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 $3\text{-}5 \cdot 10^{9}$ 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.

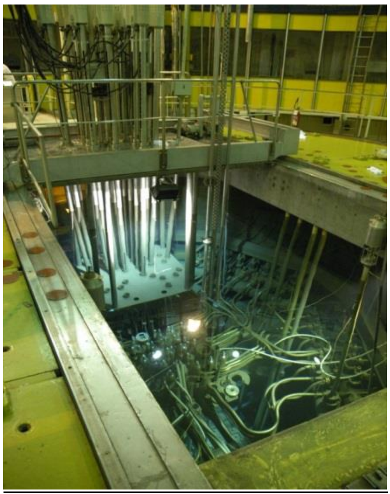

Fig. 2. The view of the reactor pool.

The main areas of reactor application 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 2016 the reactor completed 36 operational cycles at power levels from 30 kW to 25 MW (Fig. 3). The overall operation time was:4862 h.

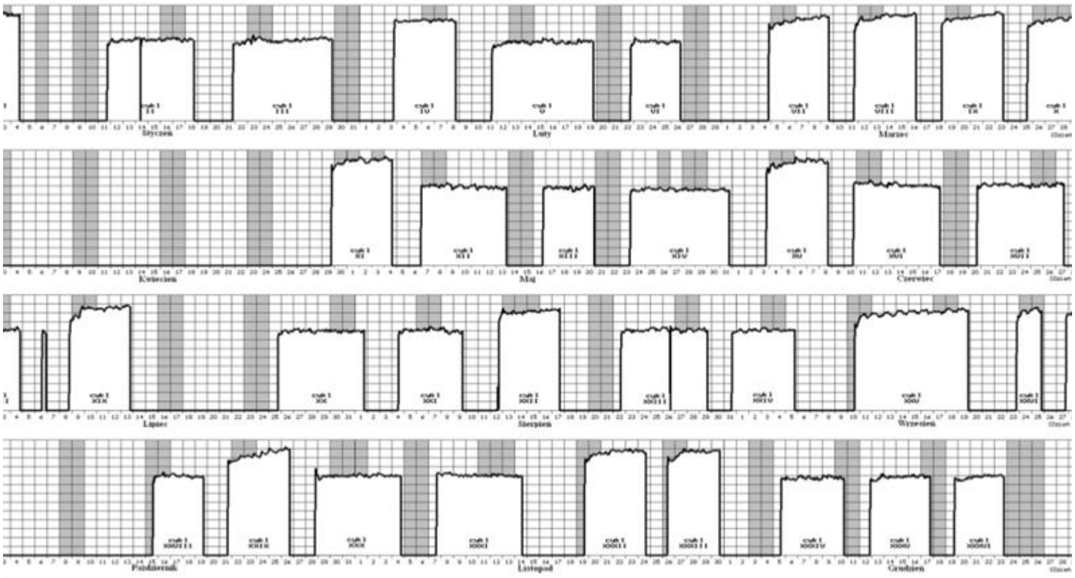

Fig. 3. Schedule of the MARIA reactor operation in 2016.

In the last year the return of highly enriched spent fuel to the Russian Federation was terminated. This process was performed under the programme of the Global Threat Reduction Initiative, initiated by the US government and the International Atomic Energy Agency. The last shipment in September consisted of 51 spent fuel elements.

In 2016, after having accomplished the conversion process of the Maria reactor core to low-enriched fuel with an enrichment of 19.75% in 235U, 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 2016 consisting of 26 fuel assemblies and 2 special channels for molybdenum ^{99}Mo production is presented in Fig. 4.

In 2016 the MARIA reactor was operated successfully. The reactor scram was activated 2 times for a very short time and it was not necessary to reduce the number of operation cycles.

Operational availability factors were as follows:

A1=OT/NH·100%=100%

A2=OT/8784·100%=55,3%

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 2016 the total emissions of radioactive materials to the environment were:

- inert gases (mainly ^{41}Ar): $8.9 \cdot 10^{12}$ Bq, i.e. 0.9% of the limit determined by the NAEA
- iodine: $2.6 \cdot 10^{7}$Bq, i.e. 0.5% of the limit determined by the NAEA

The yearly emissions of the noble gases and iodines are presented in Figs. 5 and 6.

In 2016 ninety-eight workers received measurable whole body doses from 0.1 to 2.33 mSv and 8 workers received skin doses from 1.28 to 3.12 mSv.

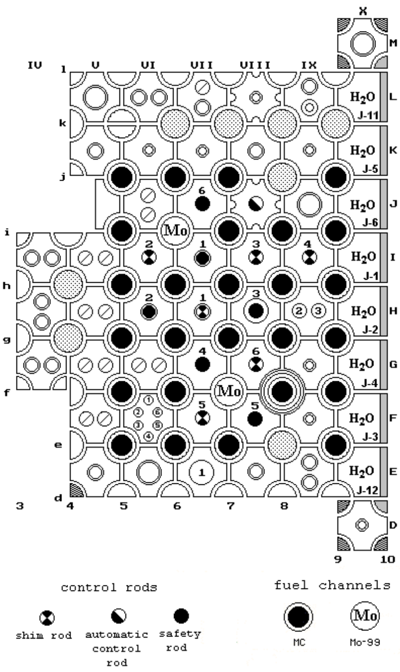

Fig. 4. Core configuration of December 2016.

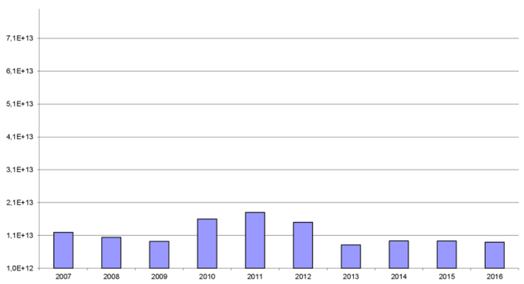

Fig. 5. Yearly emissions of noble gases in the last ten years.

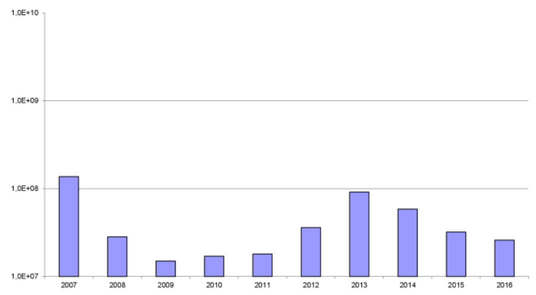

Fig. 6. Yearly iodines total emissions in the last ten years.

Neutron irradiation services

MARIA is one of the biggest research reactors in Europe. The neutron irradiation services provided at the MARIA research reactor include a wide range of radioisotope production, neutron activation analyses and biomedical technology. A particularly important service is the irradiation of uranium targets for 99Mo production. This kind of activity places MARIA, together with the HFR (Netherlands), BR2 (Belgium) and LVR14 (Czech Republic) reactors, in the top group of ^{99}Mo producers.

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 of the MARIA reactor, depending on the required neutron flux levels, irradiation times, target mass and geometry. Standard vertical in-core isotope channels as well as special ones equipped with a hydraulic transport system are in operation.

For domestic customers targets of S, TeO_2, Lu_2O_3, Yb_2O_3, Cu, Se, SmC_{l3} and KCl were irradiated (Fig. 7). Most of them were produced for the Radioisotope Centre POLATOM of the National Centre for Nuclear Research. Among them, irradiation of ^{192}Ir seeds used for Intravascular Radiation Therapy (IRT) and low activity ^{192}Ir source ribbon for Oncology applications, was continued. Total annual isotope production reached 1 242 TBq in 2016.

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

The standard irradiation services are widened by new possibilities. An example of such activity is the irradiation of metallic targets at the channel located under the safety rods as well the possibility for irradiation in the high fast neutron flux inside a specially constructed fuel element. The new experimental fuel element manufactured by the Russian company TVEL will be available for customers in the second half of 2017. The safety analyse are in the final stage of preparation and will be ready soon. One of the proposed targets will be $^{47}TiO_2$ to produce the very important for radiotherapy isotope ^{47}Sc.

Nuclear reactors remain a key component in the production of useful isotopes mainly for nuclear medicine treatments. A key medical isotope is ^{99}mTc, 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 diagnostic procedures.

The commercial irradiation of uranium plates for ^{99}Mo production was carried out at the MARIA reactor in 2016 during 13 reactor operation cycles. The targets were irradiated according to the 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. Average activity of ^{99}Mo at the end of irradiation (EOI) obtained from one irradiation channel was 260 TBq for loading 8 targets inside a channel and 360 TBq for a channel loaded with 12 uranium targets. Production of the radioisotope ^{99}Mo by irradiation of high-enriched uranium (HEU) targets reached 7 767 TBq in 2016.

Following the shortage of the key medical radioisotope ^{99}Mo and its daughter ^{99m}Tc related to long-term reliability the MARIA reactor has declared its readiness to irradiate newly designed LEU targets. One of the main producers of ^{99}Mo, who collaborates with the MARIA reactor, Mallinckrodt Pharmaceutical,s announced that from 2018 international regulations won't allow using high-enriched uranium targets (HEU) for ^{99}Mo production. In the last year the programme of certification of the new LEU targets (Low-Enriched Uranium) was successfully completed. The test irradiation performed in September 2016 confirmed the assumed parameters which were accepted by our partner Mallinckrodt Pharmaceuticals. This shows the readiness of the MARIA reactor to continue production of ^{99}Mo in the future.

The idea of the diversification of partners for ^{99}Mo production inclines us to collaborate with another partner: the Belgian company IRE as a second producer of ^{99}Mo in Europe. The numerical analyses and manufacture of the irradiation facility have been done. The new programme is dedicated to irradiation of HEU cylindrical type targets. Hot tests in the MARIA reactor core are foreseenfor the first part of 2017.

Based on the feasibility study and experience in irradiation of ^{235}U targets in the MARIA reactor, the project "Molybdenum Świerk Project" for production of ^{99}Mo was continued during 2016. The project of a production facility foresees the adoption of the existing infrastructure at the MARIA reactor and the infrastructure of POLATOM for ^{99}Mo/^{99m}Tc generator assembly.

A second programme dedicated to ^{99}Mo production provides good prospects. This programme, started in 2016, is carried out in collaboration with the company NorthWest Medical Isotopes (NWMI) from the USA.

The programme is focused on full technology of ^{99}Mo radioisotope production, starting from irradiation of the new type of targets in the MARIA reactor to extraction of the ^{99}Mo radioisotope as a product of radiochemistry processing. The advantage of the new technology is based on a new construction of the uranium targets. The targets are constructed using a special kind of microspheres including the UO_2 core. The targets prepared for the hot test are a result of a collaborationbetween 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 completed.

The first tests are planned for the first half of 2017 using the hot cell located the Radioactive Waste Management Plant (ZUOP) adopted to the project.

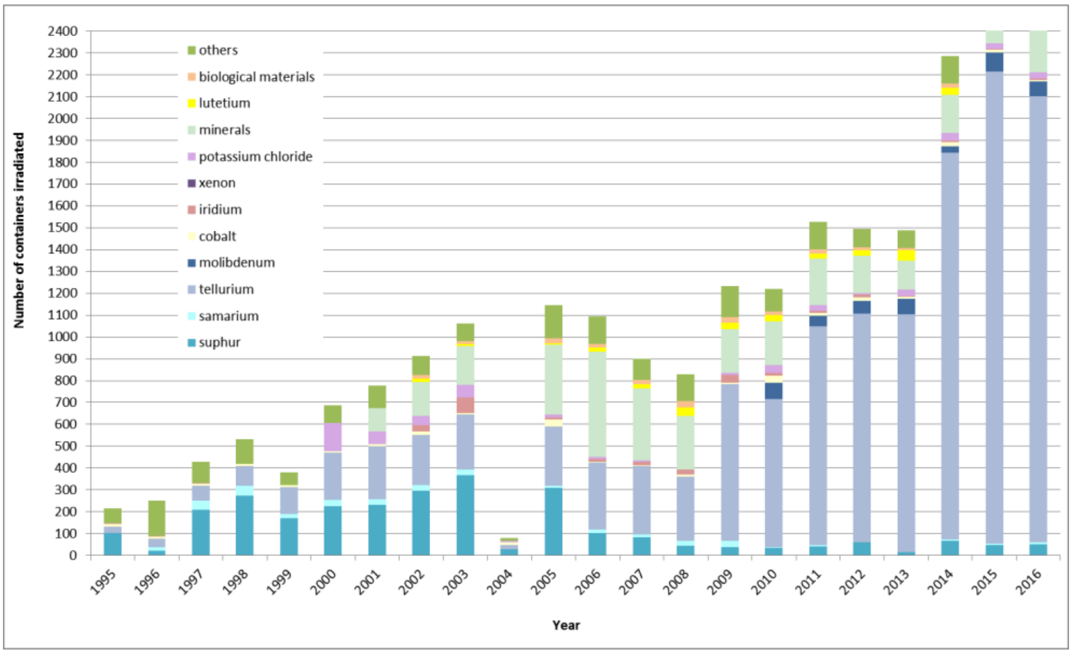

Fig. 7. Distribution of irradiated target materials.

Geometry of the MARIA reactor core

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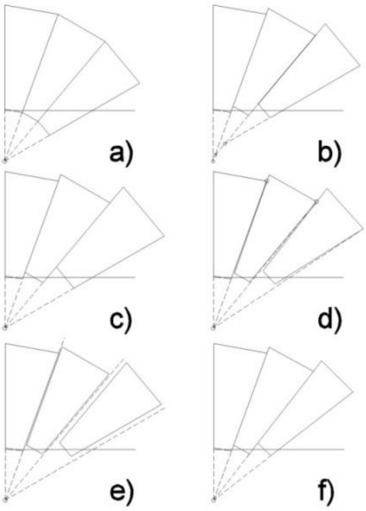
The aim of the investigation was to summarize the description of the MARIA reactor core geometry, as well as to develop a mathematical description of the main geometrical core structures and to generate surface equations describing them in the MCNP and TRIPOLI neutron computational codes input format. The unique MARIA core geometry was developed to meet some technical requirements, which makes, however, modelling the core much more complicated. One can describe the MARIA reactor core by phenomenological geometrical assumptions (see Fig. 1):

- the core consists of identical cells with constant angle of aperture,
- the cells are adjacent,
- the core geometry is conical,
- all the core cells (beryllium and graphite blocks) are fixed on the same level.

In fact the postulated conditions are contradictory, but the incompatibilities disappear in the manufacturing tolerances.



Case	Const. angle	Identical cells	Adjacent cella	Conical cells	Consr. level of the blocks
a	+	+	+	+	-
b	+	+	+	-	+
c	+	-	+	+	+
d	-	+	-	+	+
e	+	+	-	+	+
f	-	-	+	+	+

Fig. 1. The contradictory demands of the core geometry. The differences are in fact small enough to be negligible.

In the analysis the conical core geometry assumption was examined and the cone top position was determined. Further, an algorithm for determining core grid boundaries was developed. The algorithm was then applied to the design data on the core element angular deviations. It allowed us to discover a few mistakes among the data and to refine the remaining values.

In the report an innovative layer approach to modelling the main components of the core (beryllium and graphite blocks as well as fuel elements) was proposed. All the elements were simplified to sets of horizontal layers characterized by different material volumetric compositions, which were determined and provided. However, the more the elements of the core are depart from the core axis, the more tiled they are. Considering this fact, as well as the mathematical model as the direct equations of the layer shapes were developed for both hanging fuel elements and standing matrix blocks (see Fig. 2).

The vast part of the analysis provided the matrices for revolving and shifting the planes and cylinders in a form convenient to the application while creating cells of MARIA core elements. All the main elements as well as the isotopes channels, reactor core supporting structure and the water gaps were described and the equations for their boundaries were provided for the MCNP and TRIPOLI computational codes.

The report explains the mathematical background behind the transformations and surface equations, making it easily applicable, flexible and easy to check.

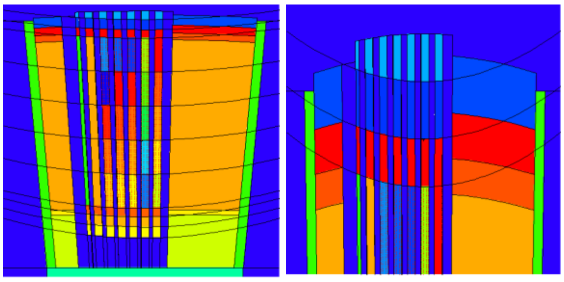


Fig. 2. Vertical cross-section of the MCNP core model, vertically contracted for demonstrating the layers. Convex – fuel element layers, concave – graphite matrix layers. Left – whole core height, right – focus on the top part.

Testing the accuracy of a rectangular diffusion model of the MARIA reactor

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The purpose of this work was to test the accuracy of the currently used diffusion theory computational model of the MARIA reactor, and possibly, improve it.

The beryllium blocks forming the core matrix of the MARIA reactor are wider at the higher end and narrower at the lower one [1]. On the other hand, the diffusion theory program REBUS [2], used for MARIA neutron physics analysis, is restricted to cuboidal geometry, which needs the geometry to be simplified, cf. Fig. 1 and 2.

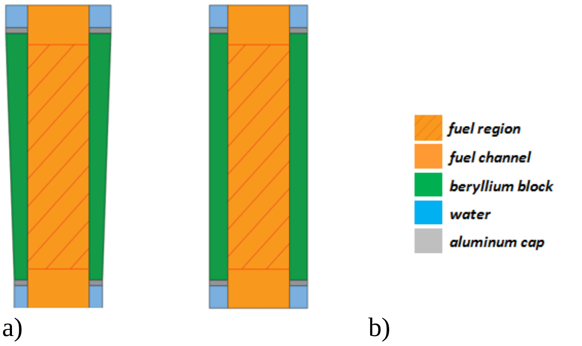

Fig. 1. Schematic vertical section of MARIA beryllium block with fuel element. (a - realistic, b - simplified).

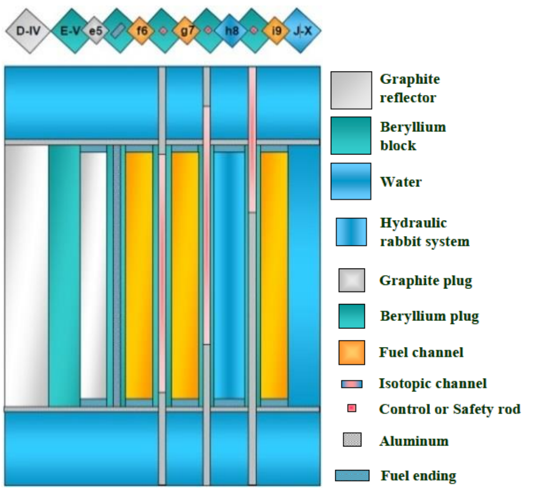

Fig. 2. Schematic vertical section of the MARIA core.

Reference calculations of a single fuel element with its surrounding beryllium were performed using the high fidelity Monte Carlo code MCNP [3], utilizing the models shown in Figs. 1a and 1b. The results of the calculations for realistic and simplified geometry are shown in Figs. 3 and 4. It may be noted that the fluxes for the simplified model are symmetric with regard to the fuel element half height. For the realistic model the fluxes are asymmetric and higher in the lower part of the element. The maximum difference in fluxes between the simplified and realistic models is 9% and 15%, in the fast and thermal energy groups, respectively.

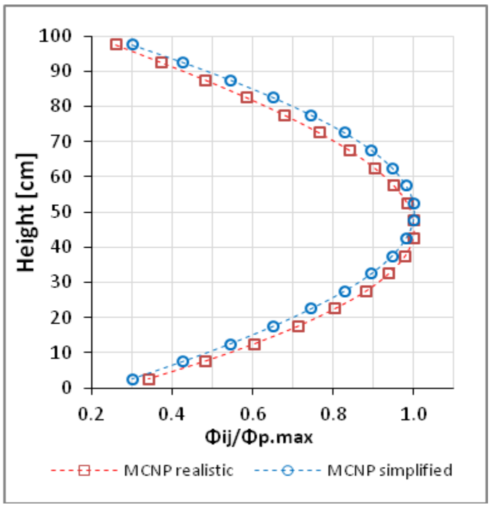

Fig. 3. Comparison of MCNP fast fluxes in fuel for realistic and simplified models.

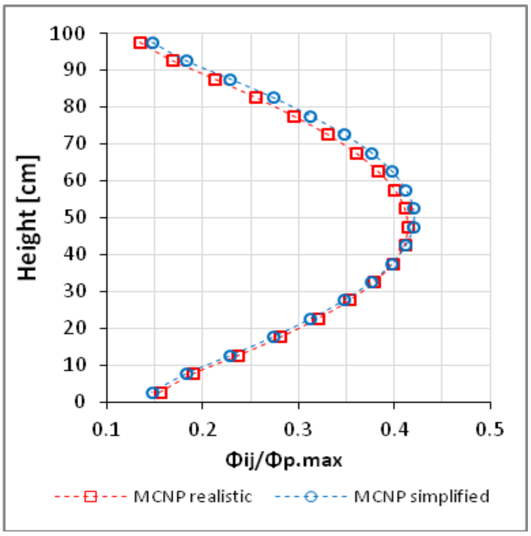

Fig. 4. Comparison of MCNP fast fluxes in fuel for realistic and simplified models.

In the presently used model the amount of beryllium surrounding the fuel element is constant with height which does not properly describe reality. As a consequence the cross sections used in the diffusion calculations were independent of height. In the improved model the amount of beryllium for a given computational layer corresponds the to average amount for a given height. In effect cross sections of different layers of the diffusion computational model were different. The layer cross sections were calculated using TRITON [4] code and the CITATION [5], a cuboidal geometry code, was used to perform the diffusion calculations. In order properly to use the cross sections calculated for different volume than used in CITATION it was necessary to re-normalize them to assure preservation of flux in all computational zones.

The results of the calculations with the improved model are shown in Figs. 5 and 6. It may be seen that the fast flux in both realistic and simplified models converges. The thermal flux is of analogous shape, but higher by 6.7%.

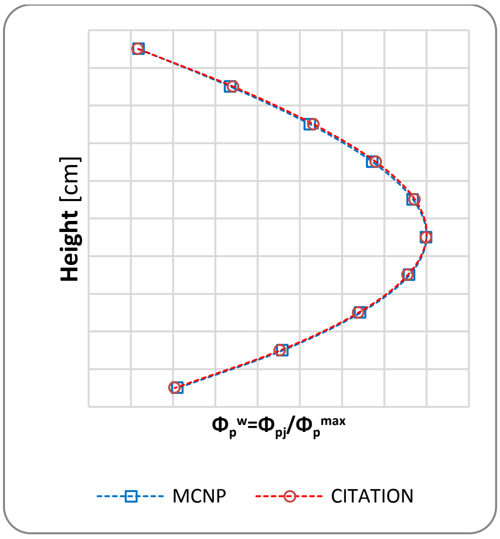

Fig. 5. Neutron flux distributions for MCNP and improved CITATION models, fast flux.

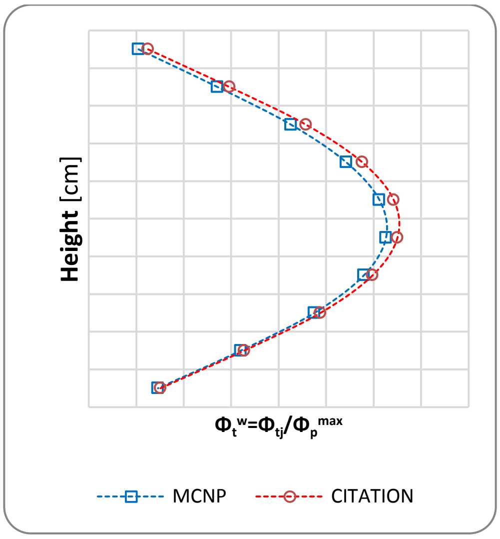

Fig. 6. Neutron flux distributions for MCNP and improved CITATION models thermal flux.

The effective neutron multiplication factors k-eff, the for presented models, are as follows:

- MCNP realistic model: 1.63811 ±0.00017
- MCNP simplified model: 1.63648 ±0.00017
- CITATION equivalent to realistic model: 1.65373
- CITATION equivalent to simplified model: 1.65383.

Explanation of these discrepancies should be a topic of further studies.

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Beryllium poisoning in the MARIA reactor calculated with the APOLLO2 and SERPENT2 codes

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The MARIA research reactor at the National Centre for Nuclear Research in Świerk, Poland operates using beryllium and water as moderators. Due to the isotopes generated in beryllium, some studies are being held in order to improve the modelling of the generation and distribution of these isotopes.

A new calculation scheme is under development in the French neutronic transport code APOLLO2 in order to create a more accurate tool than used previously. As a preliminary study, two solvers have been tested along with two energy group libraries. The collision probabilities method was compared with the method of characteristics. The benchmarking calculations were done for an elementary cell containing beryllium blocks with water gaps and a fuel element. The effect of energy mesh collapsing on the calculation accuracy was been tested by decreasing the number of groups to 69, 7 and 6. The data flow for one of the solvers is presented on Fig 1.

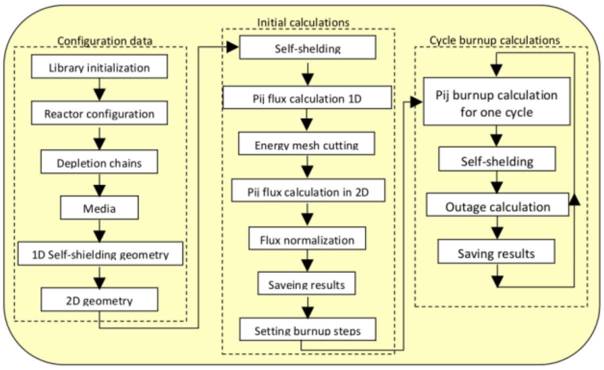

Fig. 1. Data flow for the Collision probabilities method in the APOLLO2 code.

The influence of self-shielding calculation method choice and the beryllium chain being introduced was also studied. Material compositions along with neutron fluxes and power distributions were compared in order to choose the most efficient scheme.

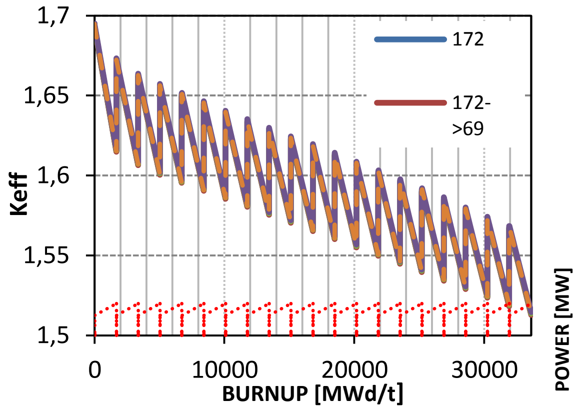

Fig. 2. Effective multiplication factor as a function of burnup. The effective multiplication factor comparison for the APOLLO2 calculations is presented in Fig. 2. Reactor cycles are presented with power changes.

Reference calculations were made using the SERPENT2 Monte Carlo code. Two libraries were considered: ENDFB7 and JEFF3.1.1. The discrepancies between SERPENT2 and APOLLO2 results are presented in Fig. 3.

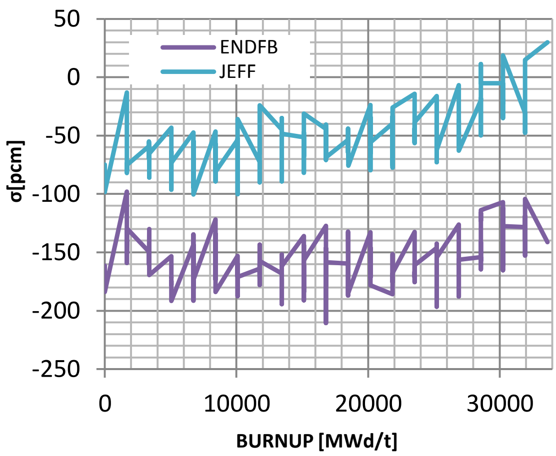

Fig. 3. Comparison of APOLLO2 and SERPENT2 results.

Conclusions

The analysis presented has shown that energy collapsing slightly affects the calculation results, without significant calculation time improvement. Both methods used in APOLLO2 give similar results. Comparison with SERPENT2 needs improvement due to errors in the libraries .

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Reactivity costs in the MARIA reactor

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The high-flux research reactor MARIA has operated in Poland since 1975. Maria supplies a neutron flux of $4x10^{14}$ n/cm^{2}s (thermal neutrons) and $2x10^{14}$ n/cm^{2}s (fast neutrons), which gives ample opportunity for producing radioisotopes. The reactor operates over 4000 hours annually, usually in hundred-hour cycles.

The major cost of reactor operation is the fuel elements. During exploitation these elements are supplemented, respectively, to the burn-up of the core. The power and the operating time of the reactor are factors, determining in a clear way, the disbursement of fuel. More precisely, a good measure of fuel burning is the product of power and operating time, which is equal to energy, released during operation. The correlation between energy released and fuel consumption is clearly noticeable.

Excess of reactivity is not directly correlated with core burn-up. We propose a methodology for quantifying the additional operating costs associated with the need to increase the excess of reactor core reactivity. We will identify them as reactivity costs.

Since the real excess of reactivity changes during reactor operation due to fuel burn, it is preferred to search for a correlation between the integral over time of the excess of reactivity and the integral over time of the power or the energy dissipated in the reactor, and thus the number of used fuel elements.

Changes in excess of reactivity are determined by two parameters: initial excess of reactivity, ρ_{ex} (0), for the cold core without poisons, calculated as the extrapolated value of reactivity excess at the beginning of a cycle and the slope of the tail of the reactivity excess curve, ρ'_{burn} (0), identified as the rate of decrease in reactivity due to burning (see Fig.1). The time integral of the real excess of reactivity (grey area in Fig. 1) is given by:

$$P \equiv \int_0^{t_c} \rho_{ex}(t)dt = t_c\left(\rho_{ex}(0) + \frac{1}{2}\rho'_{burn}t_c\right)$$

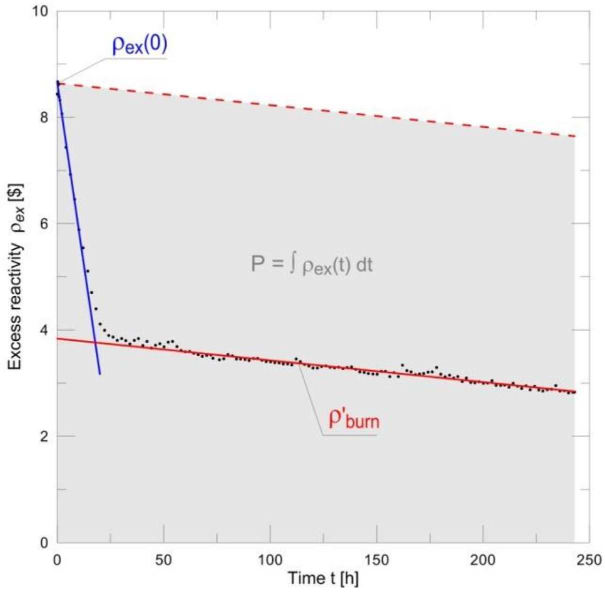

Fig. 1. Initial excess of reactivity and rate of decrease in reactivity, for one of the operating cycles of the MARIA reactor. The real excess of reactivity has been highlighted in grey.

The dependence of the number of spent fuel elements L on the time integral of the real reactivity excess:

$$\mathbf{L = \kappa P}$$

where the ratio κ is given by:

$$\kappa = (4.4 \pm 1.2) \cdot 10^{-4}\ [\text{f.a./\$h}]$$

This ratio, called the *reactivity price*, can be used to evaluate the reactivity costs (expressed as the number of fuel assemblies, f.a.) for different cases. For example, the reactivity cost of the introduction to the core of negative reactivity worth -1$ for a period of 100 hours can be calculated as $4.4 \cdot 10^{-4}\ [f.a./\$h] \cdot 1[\$] \cdot 100[h] = 4.4\%[f.a.]$. In other words, a 100-hour long operating cycle demanding an extra dollar of reactivity will spend anextra 4.4% of fuel elements.

A detailed analysis is described in [1].

Reference

[1] K. Pytel, Z. Marcinkowska, Reactivity costs in MARIA reactor, NCBJ report B 25/2015.

Calculation scheme for determining prompt and delayed nuclear heating in the MARIA reactor core

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In this investigation a calculation scheme for obtaining the prompt and delayed gamma flux distribution and nuclear heating power was proposed and tested. The proposed calculation scheme is a procedure involving various calculation techniques. The basis is a detailed model of the MARIA reactor core in the MCNP computational code, which simulates both particles generated in fission and their collisions. To validate the model activation experiment measurement data were used. The delayed radiation contribution was determined using the data on ionization chamber response for rapid reactor shut-down (SCRAM). The ionization chamber response to SCRAM was processed to separate the delayed nuclear heating contribution to the IC signal from the prompt radiation of the shutting-down reactor. To achieve that, the course of the reactor power was obtained by solving the inhour equation for the MARIA core as a response to the step reactivity drop during SCRAM.

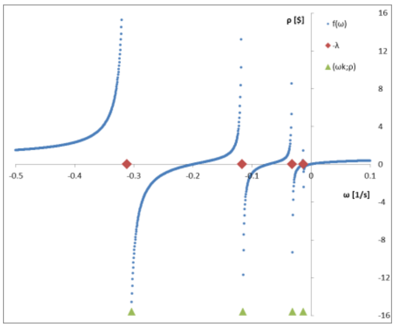

Fig. 1. The solution of the inhour for SCRAM.

This component, with an unknown share, was afterwards investigated in the ionization chamber response by signal analysis. In this way, the proportion between prompt and delayed signals and hence the delayed nuclear radiation contribution was obtained. To verify the calculation scheme, the ionization chamber in the reactor steady state was modelled and the computed response was rescaled using the delayed nuclear radiation share. The consistency between the computed results and the measured steady-state ionization chamber signal was examined. The proposed scheme properly simulates the flux density distribution for fast neutrons, which indicates proper modelling of the reactor core geometry. The model, however, underestimates the values for thermal neutrons by about 20%. This difference was probably caused by uncertainties in the beryllium matrix material composition, especially in the levels of neutron poisons (^{6}Li and ^{3}He). The obtained delayed nuclear heating share is claimed to be 38% of the total nuclear heating. The mass heating power computed using the calculation scheme is about 40% higher than that measured in the ionization chamber experiment, however it was shown that the ionization chamber is not an undisputed benchmark for nuclear heating calculations. A very small ionization chamber was used in the experiment, which increases the undesired exchange of secondary particles with the surroundings and affects the results. The nuclear heating computed by the MCNP code was overestimated. The most probable cause is inappropriate accounting of some components of the neutron heating in the collision point as the majority of them could neither remain in the IC nor be recorded by the IC because they did not cause ionization. Conclusions for future calculations and improvement of the scheme were drawn. It would be beneficial for the calculation scheme to track in the code all the particles which could be generated during neutron interaction with matter, especially recoil nuclei, by turning them on in the MODE card. All the dissipation events which do not cause ionization should be further subtracted from the neutron heating power for comparison to ionization chamber results. It would be also advisible to turn on the detailed physics treatment for neutrons on the PHYS card.

Table 1. The final results of the calculated and measured nuclear heating power in the active part of the ionization chamber.

energy deposition [W/g/MW]							C/E
neutrons	rescaled			total N+P+E	meas.		
	photons	electrons	sum P+E				
0.138	0.155	0.208	0.363	0.501	0.356		1.4

Table 1 depicts the final results for the computed total heating power and its comparison with experimental data, obtained for the active gas volume of the chamber. As was explained in the investigation, the energy deposited by electrons should be identified mainly with gamma radiation interaction with matter (photoelectric effect, Compton Effect and pair creation). Neutrons, on the contrary, distribute their energy mainly by direct collisions with atomic nuclei and by releasing binding energy during absorption. The heating power of gamma and electron radiation was rescaled according to the proposed calculation scheme to include the delayed radiation contribution. Neutron heating power does not need to be rescaled, because reactor power response for SCRAM computed using the inhour equation, called in the investigation the prompt component, includes delayed neutrons by definition. The total computed heating power, which is the sum of the computed neutron heating power and the rescaled gamma and electron heating power is greater than that obtained from the measurements. The calculated to experiment ratio has a value of 1.4.

Certification of low-enriched-uranium targets in the MARIA research reactor

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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 decisive factor determining its availability, despite its short life time, is the radioactive decay of ^{99}Mo into ^{99m}Tc. One possible source of molybdenum is the ^{235}U fission reaction. Extracting ^{99}Mo from the fission products is one of the most effective methods for obtaining this isotope. It enables us to obtain the isotope with high specific activity, which is a very important property from the viewpoint of the production of molybdenum-technetium generators commonly used in oncological diagnostics.

The ^{99}Mo deficit which occurred on the global market, and the pressure of international organizations for fuel conversion of nuclear reactors with highly enriched ^{235}U into low enriched (LEU) one, forced the development of new technology for the production of ^{99}Mo based on LEU targets. The primary intention was to remain independent of ^{99}Mo supply from unstable global markets.

Following the shortage of the key medical radioisotope ^{99}Mo and its daughter ^{99m}Tc related to long-term reliability the MARIA reactor has declared its readiness to irradiate newly designed LEU targets. The first step supporting such a conversion, is certification of the new LEU targets. The programme is being performed up collaboration with Mallinckrodt Pharmaceuticals (Netherlands / USA) and with the HFR (Netherlands) and BR-2 (Belgium)reactors. The programme includes safety analysis calculations, out-of reactor mechanical, hydraulic and vibration tests.

The technology proposed to irradiate uranium targets in the reactor in a relatively simple and at the same time very effective way utilizes both the structural possibilities of the MARIA reactor and the fundamental relationships between the fission power generated in the targets and the activity of the created ^{99}Mo as one of the ^{235}U fission products. The technology implemented in the MARIA reactor employs a specific construction of fuel channels with the cooling system, mechanical hardware and measuring system. Linked to the measuring system are the thermal-hydraulic parameters of the reactor fuel elements.

The ^{99}Mo isotope forms within the chain of β^- decays of consecutive fission fragments of short life originating from ^{99}Rb. The cumulated productivity of ^{99}Mo by one fission is γ=0.0611. Bearing in mind the longer half-life of ^{99}Mo one can assume that ^{99}Mo rises immediately as a product of ^{235}U fission. Under such an assumption the rate of build up of ^{99}Mo activity in a determined portion of fuel is proportional to the fission power released by that fuel portion. When assuming the energy released in one fission to be $E_f=3.244\cdot10^{-11}$ J (193 MeV) and the decay constant of ^{99}Mo to be $\lambda=2.9\cdot10^{-6}s^{-1}$ then the factor of proportionality between the build-up of ^{99}Mo activity and the fission power by singular fission is:

$$\alpha = \gamma\lambda / E_f = 5.47\cdot10^3\ Bq/Ws$$

In the course of uranium plate irradiation the ^{99}Mo activity changes over the exposure time in accordance with the equation:

$$\frac{dA(t)}{dt} = \alpha P_f(t) - \lambda A(t)$$

A(t) – activity of ^{99}Mo in the course of the irradiation
$P_f(t)$ – fission power generation by the uranium plate

Integrating the above equation within the limits over the plate irradiation time (0,t) we obtain a relation for the activity of ^{99}Mo formed from the fission power generation in the plate:

$$A(t) = \alpha\int_0^t P_f(\tau)\, e^{-\lambda(t-\tau)}\, d\tau$$

This relatively simple relation constitutes the basis for determining the quantity of ^{99}Mo to be generated by the irradiation of uranium plates in the reactor. It is the base for the development of the irradiation technology for uranium plates in the MARIA reactor.

The test irradiation of a set of 8 uranium targets of LEU (^{235}U <20%) inducing an average fission power of 165-175 kW over hours yields an activity of 5690 Ci (210.5 TBq) of ^{99}Mo at the end of irradiation. The highlighted technology to obtain ^{99}Mo in the MARIA reactor satisfics the procedure for determining and checking the activity of this isotope in the process of irradiation of uranium targets and creates unique manufacturing possibilities.

The activity of ^{99}Mo determined after radiochemical processing of the irradiated uranium targets related to the activity over the EOI time (End Of Irradiation) performed at the Petten Molybdenum Processing Facility (MPF / Netherlands) agreas with the prediction to within an error of 5%. One of the most important results of the new type LEU target certification is the acceptance of targets for routine irradiation by collaborateds in the project reactors: MARIA, HFR and BR2 to obtain ^{99}Mo for medical use.

Measurement of spent nuclear fuel burn-up spatial distribution

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Burn-up of nuclear fuel depends on the neutron flux density distribution during fuel operation in a nuclear reactor. A method for the measurement of the burn-up spatial distribution of spent nuclear fuel elements has been developed at the National Centre for Nuclear Research. The method is based on recording the neutron emission from the fuel element under investigation. Based on the performed analyses and calculations, a suitable measuring setup has been designed and constructed. The subjects of investigation were fuel elements used in the MARIA research reactor, operated by the National Centre for Nuclear Research in Świerk. The results of measurements made over a period of several years using the described method are presented.

Burn-up of nuclear fuel consists of decreasing the ^{235}U content due to neutron induced reactions in the reactor core. The burn-up quantity is often defined as the amount of energy generated during fission reactions in a mass unit of fuel or in a whole fuel element. Besides nuclear fission reactions, neutron radiative capture occurs in nuclear fuel during its operation. Both fission and radiative capture reactions lead to many nuclides, usually radioactive. Therefore, the burn-up value is directly connected with the activity of the nuclides accumulated in the fuel. This has a significant impact on the heat generation in spent fuel elements and accordingly their storage security. The spatial distribution of ^{235}U concentration in spent fuel elements also needs to be determined storage criticality safety.

In the described method the measurement of the burn-up distribution consists of recording the neutron emission from separate sections of a fuel element. The neutron emission is scaled down to the burn-up value of a particular section of the spent fuel element.

The only phenomenon occurring in spent nuclear fuel giving rise to neutron emission is spontaneous fission of nuclides accumulated in the fuel during its operation. Based on the cross-sections of particular nuclear reactions and the decay constants of their products, the main spontaneous fission neutron sources have been identified. They have been recognized as transuranic elements, which are formed in a series of nuclear reactions and transformations (mainly neutron activation and β^-–decay) of nuclides exposed to the high neutron flux in the reactor core. The series of these reactions and transformations is initiated by neutron reactions with ^{235}U and ^{238}U in the nuclear fuel.

The spatial distribution of the neutron emission rate from spontaneous fission of transuranic nuclides in spent nuclear fuel is strongly correlated with the local neutron fluence during the fuel operation and, therefore, with the fuel burn-up value. This relation is not trivial due to several factors which influence the neutron emission, e.g. operating conditions in the reactor, cooling time, initial uranium enrichment and initial uranium mass. Fluctuations of the vertical burn-up distribution in a fuel element are the result of the heterogeneous distribution of neutron flux density in the reactor core. They are influenced by the surrounding moderator, fuel elements, absorbing rods, irradiation targets etc.

A series of calculations have been performed in order to determine the inventory of neutron emitters in spent nuclear elements. The relative concentration of neutron emitters depends on the fuel burn-up and cooling time.

Measurement of the vertical burn-up distribution of a fuel assembly consists of counting the number of neutrons emitted in unit time from a particular section of the fuel assembly. The construction of the measuring stand allows the neutrons emitted from specified parts of fuel element to be counted separately. Measurements have been made at nine points along each fuel assembly. investigations were performed on 110 pcs of MR-6/80 fuel assemblies (80% enriched, used in the MARIA reactor until 1999) with total burn-up values varying from 40 MWd up to 127 MWd and cooling times from 5 to 27 years. The results are presented in fig. 1.

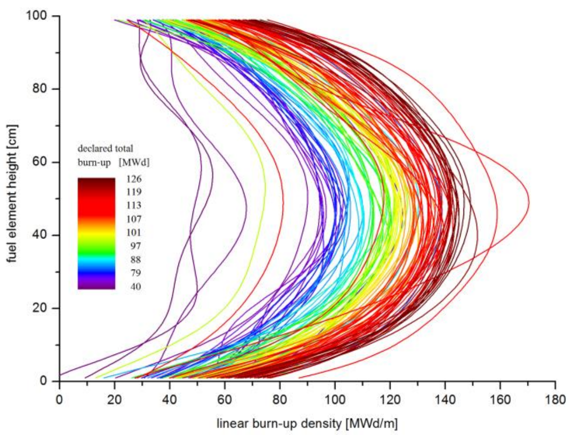

Fig. 1. Measured space distribution of burn-up of spent fuel assemblies; the warmer the colour, the higher the declared burn-up.

The collected data have been used to establish a universal relation for the relative linear burn-up distribution as a function of fuel height for a given total (or average) burn-up value. This relation is characteristic for a given reactor core – it depends on the neutron flux density distribution and does not depend on the fuel type. Therefore, it can be used in further analyses of the operation and storage of other types of fuel elements used in the MARIA reactor.

Encapsulation of MR type spent fuel for shipment in 2016

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National Centre for Nuclear Research, Otwock-Świerk

This report concerns spent fuel encapsulation *preparatory work for the last MR type spent fuel shipmen*t under the GTRI programme which was carried out in accordance with the procedure presented in [1]. The encapsulation operations took place in the disassembly cell of the MARIA reactor.

The most important moment of the encapsulation operation was the leak-tight closing of the spent fuel element in the capsule.

The capsule and its cover were earlier manufactured of certified materials and verified as regards the welding tightness by Russian specialists. The spent fuel assembly (SFA) was transferred from the storage pool into the disassembly cell (Fig.1) and next into the capsule thimble. This operation was recorded to identify the number on the capsule and the number of the fuel element (Fig.2). In the next operation the welding head was positioned onto the welding spot. Rotation of the chuck and the welding machine TIG were activated. A licensed welder completed the welding operation. On accomplishing the full rotation of the chuck, the welding machine was switched off (Fig. 3) and the tightness of the first weld was checked (Fig. 4).

Fig. 1.Operation of transferring the MR type SFA from the storage pool into the disassembly cell.

Fig. 2. Identifying the number on the capsule and the number of the SFA.

The SFA was dried by the vacuum method and the can was filled with helium. Next, the second weld was made and the tightness of the weld was also checked.

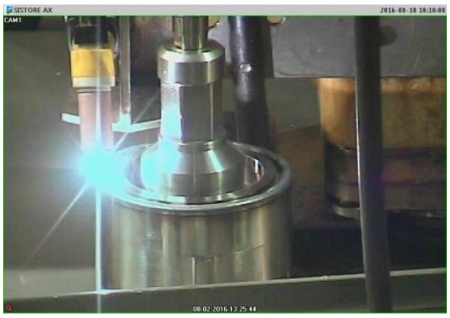

Fig. 3. Operation of the first weld in the disassembly cell.

Fig. 4. Operation of checking the tightness of the first weld.

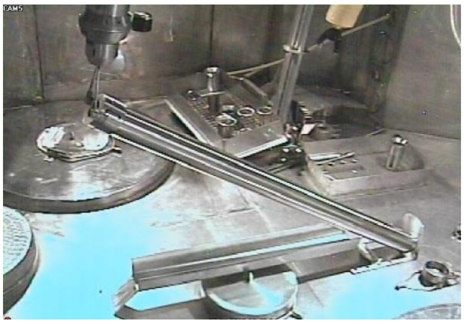

Fig. 5.Operaion of reversing the capsule on the cradle.

The capsule containing the SFA was moved using a the lifting magnet to the cradle. The capsule was reversed and after that put into the transport sleeve. Next, the capsule was transferred from the disassembly cell to the P-109 device and placed on the separator in the storage pool of the MARIA reactor.

The SFAs in the capsules were thenready for the last shipment to the Russian Federation.

Reference

[1] Borek-Kruszewska E., Piąstka J., Przybysz Z.,Wilczek I., Zawadka A.: Report No. C-11/2016: *Technology of MR Type Spent Fuel Encapsulation for Shipment in 2016.*

Shipment of MR type spent fuel from the Maria reactor to the Russian Federation in 2016

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This report concerns the last shipment of MR type spent fuel from the Republic of Poland to the Russian Federation under the Global Threat Reduction Initiative. The GTRI programme is intended to reduce global threats, consisting among others in financing the return of spent fuel coming from research reactors to the producer of the nuclear fuel. The first shipments took place in 2010.

With reference to the above, spent fuel of MR type enriched to 36% of U-235 from the Polish research reactor MARIA was returned to the Russian Federation for reprocessing. The high radioactive waste coming from the reprocessing of the fuel will stay in the Russian Federation.

The last shipment took place in September 2016 and included 51 pcs of encapsulated spent fuel elements loaded into 17 Russian transport containers of TUK-19 type.

The TUK-19 containes were delivered by rail and road to the forwarding point at the National Centre for Nuclear research in Świerk. Next, they were brought one by one (Fig.1) to the MARIA reactor facility where the spent fuel in cans was loaded into the containers.

The technological operations concerning loading the cans with spent fuel from the MARIA reactor storage pool into the TUK-19 containers were successfully performed according to the prepared plan [1].

Fig. 1. TUK-19 containers in the MARIA reactor decontamination hall.

The preparatory work for the shipment was carried out in accordance with the procedure for spent fuel encapsulation presented in [2].

The most important operations took place in the disassembly cell of the MARIA reactor (Fig.2). A TUK-19 container loaded with 3 pcs of spent fuel in cans was prepared for the final lock. Checking of the dose rate in the container and in the surrounding area was performed. The TUK-19 container left the reactor hall and ran into the decontamination hall in order to complete final operations associated with preparing for transport such as: screwing down the cover and checking the tightness of the container. The EUROATOM inspectors started their work of sealing the TUK-19 containers (Fig. 3).

Fig. 2. Handling operations in the disassembly cell.

Fig.3. Operation of sealing a TUK-19 container.

The secured and sealed TUK-19 containers loaded with spent fuel returned to the forwarding point, where they were put back into ISO type containers and they were then shipped back by air to the Russian Federation.

During the transport-handling operations conducted in the MARIA reactor facility neither abnormalities nor increased radiological threats were detected.

References

[1] Borek-Kruszewska E., Piąstka J., Z. Przybysz, M. Wierzchnicka, I. Wilczek, A. Zawadka.: Report No C-14/2016. Technology of MR type spent fuel shipment in 2016 from the MARIA reactor to the Russian Federation in TUK-19 cask.

[2] Borek-Kruszewska E., Piąstka J., Przybysz Z.,Wilczek.I., Zawadka A.:Report No. C-11/2016:Technology of MR Type Spent Fuel Encapsulation for Shipment in 2016.

Neutronic characteristics of a PWR core with SiC fuel cladding

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This analysis was to determine whether from the neutronic point of view the use of silicon carbide as a fuel cladding material will allow for safe operation of the reactor. The calculation model is based on the construction of the EPR [1-4]. For the calculations the Monte Carlo code MCNP5 / MCNPX was used [5-7]. Six PWR core configurations were taken into account, each based on the EPR core U. S. EPR Final Safety Analysis Report model. Designed configurations are constructed of five fuel assembly types with different amounts of U-235 enrichment (5.00%, 4.50%, 4.00%, 3.75%, 3.50%). All fuel assemblies are homogeneous. Borated water (moderator and coolant) contained 3565ppm of natural boron. It was assumed that the delayed neutron fraction was equal to 0.0074 [4]. The natural boron concentration level was adjusted to achieve a multiplication factor between <1, 1.0074>, to ensure controllability of the core. The control and safety rods were out (ARO- All Rods Out). The analysis was carried out for two core states: Cold Zero Power (CZP) and Hot Full Power (HFP). The CZP state assumes room temperature, instead of 295.23^{O}C for the HFP state [2-4]. The calculated multiplication factor of one of the designed TEPR cores for the CZP is 1.0041 and 0.9780 for the HFP. The quantity determining core reactivity behavior as a function of temperature is the temperature coefficient of reactivity. It can be defined for fuel, coolant and moderator. For a PWR core all three are negative. The fourth coefficient of reactivity was the void coefficient, describing the core reactivity behavior in the case of a coolant lack. It was calculated for 5%, 10%, 15% and 20% coolant lack (Tab 1)

Table 1. Reactivity temperature coefficients and void coefficients (state CZP and HFP).

CORE	Temperature coefficient for fuel α_{TF} [pcm/K]		Temperature coefficient for water α_{TW} [pcm/K]	
TEPR	-2.44		-7.01	
State CZP	Void coefficient α_V [pcm/%]			
CORE	5%	10%	15%	20%
TEPR	-55.90	-57.96	-65.03	-72.86
State HFP	Void coefficient α_V [pcm/%]			
CORE	5%	10%	15%	20%
TEPR	-100.23	-109.69	-112.66	-123.13

Negative values of reactivity coefficients guarantee reactivity decrease due to a rise in core temperature. During reactor operation reactivity changes are ever-present, whereas calculated values correspond to the core at the beginning of its life (BOL). Results correspond to literature data [8] and values from the U. S. EPR Final Safety Analysis Report [4]. Calculated reactivity coefficients prove safe TEPR core operation with SiC fuel cladding (Table 2).

Table 2. Comparison of the calculated reactivity coefficients of fuel and water with the literature data.

Parameter	TEPR	EPR	Literature data
α_{TF}[pcm/K]	-2.44	From -4.03 to -1.98	From -10 to -1
α_{TW}[pcm/K]	-7.01	≤ 0	From -100 to -10

The analyse carried out have shown that from the neutronic point of view the use of silicon carbide as a fuel cladding material allows safe operation of the reactor. However, based on a number of publications dealing with the advantages and disadvantages of silicon carbide resistance to radiation, which strongly depends on the production technology of the material, it should not be expected that this material will be used as fuel cladding in LWR reactors in the near future.

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Helium immobilization capability of a uo$_2$ surface using the "Ab Initio" method

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Many fission products (Xe, Kr, I, etc.) as well as α-particles (He) are produced during and after the irradiation of fuel in nuclear reactors. The presence of the fission products and He atoms can lead to the formation of bubbles and to a possible swelling of the fuel material. Due to their low solubility, they tend to precipitate or diffuse into the gap between the fuel grains, resulting in fuel swelling. As a result, their presence affects the mechanical properties of UO_2. The atomic transport processes of fission products and He in UO_2 are therefore of great interest for understanding the performance of UO_2 as a nuclear fuel. Despite intensive research, up to now it has been not explained why a noble gas such as helium is immobilized in the highly burned-up fuel up to a temperature of approx. 940 K, followed by an abrupt release.

We present the results of density functional theory calculations concerning uranium dioxide crystals with helium atoms incorporated in the octahedral sites on a nano superficial layer of UO_2 fuel element. In order to quantify the capability of helium immobilization we proposed a quantum model of adsorption and desorption which we compared with the classical model of Langmuir. Significant differences between the models are maintained over a wide temperature range including high temperatures of the order of 1000 K. By the proposed method of quantum isotherms it was established that the octahedral positions near the metal surface are good traps for helium atoms, while of a temperature close to 1089 K an intensive release of helium is predicted, which is consistent with the experimental results.

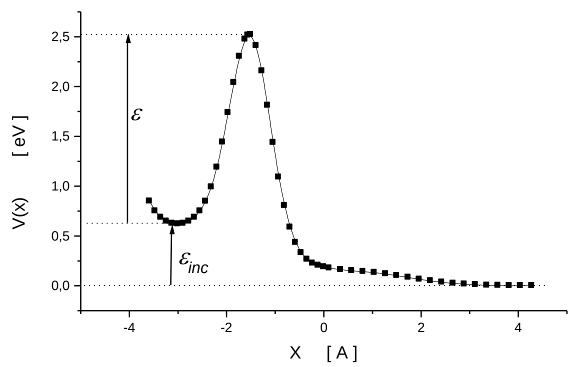

Fig. 1.The potential of the crystalline field, V(x) of He atoms versus distance from the surface, x.

For numerical calculations we chose a 25 atomic super-cell of dimensions 4axax, which we filled half with 8 uranium atoms, 16 oxygen atoms and a helium atom. The second half of the super-cell is a space free from oxygen and the uranium atoms. We considered U_8O_{16}+ He clusters in the octahedral site. In this configuration exists one minimum in the position octahedral site at a depth of approx. -3.01 Å, and the incorporation energy in this position is approx. εinc =+0.620 eV. The potential barrier however is high and equal to approx. ε =1.9 eV.

The process of helium release during annealing from the spent fuel was experimentally tested [2]. A similar process is observed in that at temperatures below 940 K there is no release of helium, and between 940 K and 1050 K, this process is particularly intense. In the temperature range between 1050 and 1380 K the release process is slowed down. Although our calculations relate to pure UO_2, and the experiment was carried out on spent fuel, the result obtained agrees well with our theoretical predictions.

Yet we know from experience that in the area of 1500 K the grain re-crystallization process starts. Therefore, the helium release in the interval 1380 -1580 K should be associated with the grain re-crystallization process in the deeper layers of the material.

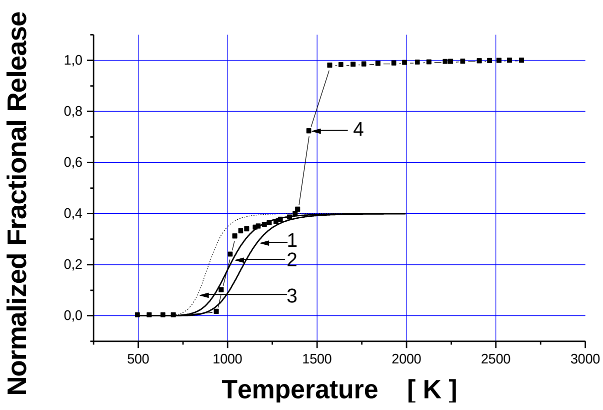

Fig. 2. Temperature dependences of helium release from the UO2 surface. The solid curves of the quantum variant are: 1: based on the "ab initio"calculation; 2: corrected, according to the best fit to the experimental data; 3: the dashed curve 3 is the classic variant. 4: experimental data from [2].

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Comparison of two fast neutron fluence measurement methods based on a Np-237 fission to capture ratio measurement (spectral index) and a reverse dark current measurement of a planar silicon detector

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The idea of the first method is to search the neutron energy for the ratio of fission cross section to capture cross section of the selected actinide isotope from the nuclear data base that is equal to the measured ratio of the fissioned and captured actinide isotope Np-237[1].

The idea of the second method is the measurement of the fast neutron irradiation induced reverse dark current increase of planar silicon detectors which is linearly proportional to neutron fluence [2].

Np-237 samples and planar silicon detectors were placed inside a subcritical assembly (the Quinta assembly at the Joint Institute for Nuclear Research, Russia) very close to each other, assuming that in both samples (detectors) the same neutron fluence wouldpass. (see Fig. 1).

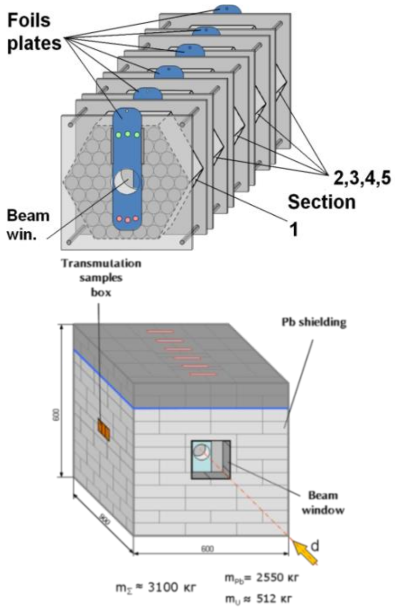

Fig. 1. Schematic of the Quinta assembly. Above view of the uranium target with supporting structures and plastics used for sample placement (detector plates). Below: view of the lead shielding encasing the target with the location in the shieldingof the transmutation samples box (window) for the actinide sample marked.

The mathematical construct of the equations describing the neutron fluence of the two methods is very alike. In both methods the values which are proportional to the neutron fluence depends on the cross section of neutron inducing damage in the silicon detector and the cross sections of neutron induced fission and capture on the Np-237 minor actinide (see Fig. 2).

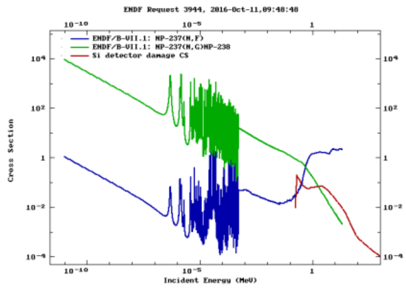

Fig. 2. Cross section of neutron inducing damage in the silicon detector (red curve) and cross sections of neutron induced fission and capture on the Np-237 minor actinide.

The damage done in the silicon lattice by the neutrons starts at the threshold energy above 100 keV [1, 2] (see Fig. 2). In the neutron energy range from 0.4 MeV to 4 MeV we can roughly assume that the damage cross section for silicon detectors is constant. Neutron damage in the silicon detector placed in a certain neutron spectrum collects the damage from the whole spectrum starting from the neutron energy at a threshold equal to 170 keV to very high energy, about 10 GeV (see Fig. 2) irrespective of its energy.

In the experiment, the fluence was estimated to be about 10^{13} n/cm^2 . The fluence measured by the silicon detector method was regularly (systematically) about 35% less than the fluence estimated by actinide methods. This could be expected because the silicon detector method effectively measures the fast neutrons of energy higher than 170 keV. So the difference of two fast neutron fluence measurements gives an estimation of the neutron fluence for neutron energies below 170 keV. This is an additional approach.

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(n,xn) cross section measurements for Y-89 foils used as detectors for high energy neutron measurements in the deeply subcritical assembly "QUINTA"

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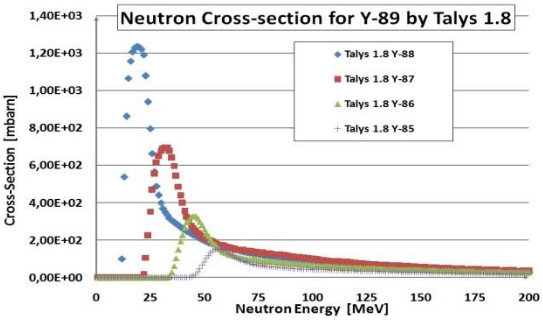
A "ready to use" assembly QUINTA, located at the Joint Institute for Nuclear Research (JINR), Dubna, Russia, has been used by the E&T RAW collaboration since 2010. Having determined production at specified positions in the QUINTA assembly of the three isotopes ^{88}Y, ^{87}Y and ^{86}Y, and knowing the energy thresholds for the respective (n,xn) reactions, we can estimate the average high-energy neutron flux in three energy ranges from 11 to 100 MeV at each ^{89}Y foil location [1].

In order to estimate the high energy neutron field, we need to know the microscopic cross sections for the ^{89}Y-(n,xn) reactions. We can retrieve some cross-section data for the reactions from the EXFOR data base [2]. Unfortunately, the volume of the available data is insufficient, except for the cross section of the ^{89}Y(n, 2n) reaction. We have not found sufficient data for the other reactions studied for neutron energies higher than 30-40 MeV. This is the reason why our cross sections were calculated using the TALYS code [3] (Fig. 1).



Rys.1 Microscopic cross sections calculated by the TALYS 1.8 code for the ^{89}Y(n, xn) reactions.

Yttrium foils have the following advantages: one stable isotope (^{89}Y), several threshold reaction channels, and several resulting isotopes with sufficiently long half-life time (longer than 12 hours). This was the motivation to make experiments to measure cross section values for these (n, xn) reactions. New experiments for the ^{89}Y cross section measurements were carried out at TSL in Uppsala [4] in 2015 (4 experiments at the quasi-monoenergetic neutron (QMN) with four different peak neutron energies). In this paper we present preliminary results for two of the four experiments, namely for those with proton energies of ≈38 and 50 MeV (Table 1). Neutrons were produced by a proton beam accelerated in the cyclotron, impinging on a ^{7}Li target. Protons that did not react with ^{7}Li nuclei were deflected by a magnetic field and guided to the dumping line, which ended at the beam dump far away from the experimental area. After passing the magnet area and the end-window of the vacuum system, a pure quasi-monochromatic neutron beam arrived at the ^{89}Y foils, located at a distance of 198 cm from the ^{7}Li target, at the so-called Close User Position (CUP) [4]. The procedure for determining the studied cross section was taken from [5]. For the calculation of the neutron number value we used our own MCNPX calculation for the simulation of conditions at the QMN facility at TSL (MCNPX ver. 2.7.0 with tabulated values of cross-section ENDF.80c and 3007.00h Los Alamos library (2000) for Li-7 proton reactions).

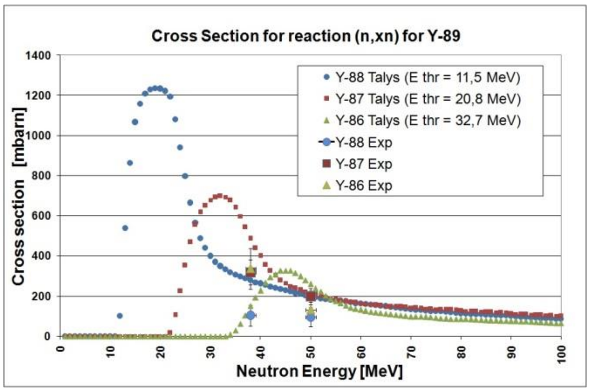


Fig.2 Comparison of ^{89}Y (n,xn) cross-section measurements and calculations. Our Uppsala experiments in 2015 are represented by the six bigger points. TALYS 1.8 [4] calculation results are represented by circles (^{88}Y), squares (^{87}Y) and triangles (^{86}Y).

Table 1. ^{89}Y (n,xn) cross-section measurement results

Proton Energy	38 MeV	50 MeV
Neutron Energy Peak (calc.)	35.5 MeV	47.5 MeV
^{89}Y(n,2n)^{88}Y	103 (31) mbarn	95 (28) mbarn
^{89}Y(n,3n)^{87}Y	319 (64) mbarn	198 (40) mbarn
^{89}Y(n,4n)^{86}Y	338 (68) mbarn	132 (26) mbarn

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Average fast neutron flux in three energy ranges in the Quinta assembly irradiated by two types of beams

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In order to measure the average high neutron flux density in three different energy ranges using deuteron and proton beams Ytrium 89 samples were located in the QUINTA assembly (see Fig. 1). The QUINTA assembly is composed of five sections, each separated by a 17 mm air gap which allows placement of samples mounted onto special plates. We have 6 plates (measurement positions) - 4 gaps between assembly sections and two positions in front and rear of the assembly.

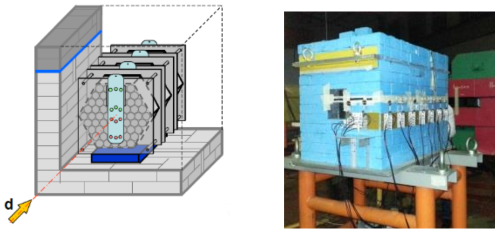

Fig. 1. The Quinta assembly (left) a cut-away view of the uranium target with supporting structures and plastics used for sample placement; (right) view of the lead shielding enclosing the target.

Up to now we concentrated on measurement of the neutron flux distribution in the deeply subcritical assembly Quinta versus the axis and radius of the assembly for neutron energies above 10 MeV, applying proton and deuteron beams of energies from 0.66 GeV to 6 GeV extracted from the Nuclotron and Phasotron accelerators.

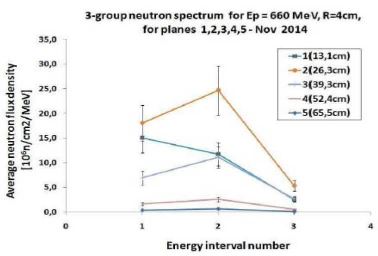

Fig. 2. Average neutron flux density versus three different energy ranges: 1-> (11,5-20,8 MeV), 2-> (20,8-32 MeV), 3-> (32-100MeV) for R=4 cm and five planes (number of successive planes 1,2, 3, 4 and 5); proton beam energy 0.66 GeV.

Recently we have applied a proton beam of energy 0.66 GeV extracted from the Phasotron accelerator. Nuclear data handling of the experimental session turned our attention to the neutron flux density measured on five foil plates in terms of three different neutron energies: 11.5– 20.8 MeV, 20.8-32.7 MeV and 32.7–100 MeV. It found that the neutron density flux for the range of neutron energies 20.8-32.7 MeV is higher than for the range of neutron energies 11.5–20.8 MeV an unexpected feature of the measurement. Repeating in the same way the data handling for the other planes, the in one figure it will be noted that the same effect is observed for planes 2–5 but not plane 1, which describes the average neutron flux density in the first section where the process of spallation begins. This unexpected feature of the measurement is presented in Fig. 2.

Since we found this unexpected feature of average neutron flux in the experiment with a proton beam of energy 0.66 GeV, we decided to make an overview of our experiments performed earlier for a deuteron beam of energy 1 – 6 GeV.

Repeating in the same way the data handling as in Fig. 2 for a deuteron beam of energy 2 GeV it will be noted (see Fig. 3) that the same effect is observed for planes 2, 4 and 5 but not planes 1 and 3, which describe the average neutron flux density in the first section and third section.

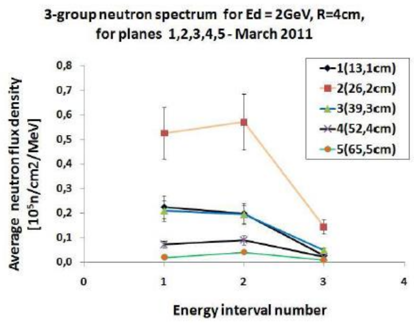

Fig. 3. Average neutron flux density versus three different energy ranges: 1- (11,5-20,8 MeV), 2- (20,8-32 MeV), 3- (32-100MeV) for R=4 cm and five planes (number of successive planes 1,2, 3, 4 and 5) ; deuteron beam energy 2 GeV;

However, the average neutron flux density versus three different energy ranges: 1- (11,5-20,8 MeV), 2- (20,8-32 MeV), 3- (32-100 MeV) for R=4 cm and five planes for deuteron beams of energy 4GeV and 6 GeV behave according to expectation.

The tendencies presented above are vague and need to be checked in further experiments because we do not clearly see this effect in all our experimental results Theoretical analysis carried out by the authors [1] using the MC method explains to some extent our experimental observation.

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Ion beam experimental optimization for the ADS-type setup QUINTA for actinide incineration purposes

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A series of experiments aimed at an investigation of actinide incineration was carried out on the ADS-type setup QUINTA at JINR DUBNA, Russia. Here ADS stands for Accelerator Driven System. The actinides are thought to become a problem for future nuclear power because they accumulate in present day power reactors. The most representative of the whole group of artificially produced actinides named minor actinides (MA) is Np-237. Its cross section (CS) for interaction with neutrons shown in Figure 1 explains its accumulation. Capture prevails over fission byabout 104 times in the thermal range then both come closer in the epithermal range until the fission CS becomes larger at energy about 0.8 MeV [1].

The only way to prevent this accumulation is to incinerate the actinides in a high energy neutron field.

JINR Dubna's spallation neutron source QUINTA consists of 510 kg of natural uranium core surrounded by a 10 cm lead shield. The spallation neutrons were produced by bombardment of the QUINTA uranium core by various ion beams - a 660 MeV proton beam 2, 4 and 8 GeV deuteron beams and a 24 GeV C6+ beam. The investigated Np-237 sample was irradiated in the middle of the core axis and about 22 cm to the side of the beam axis. For more irradiation details see table 1

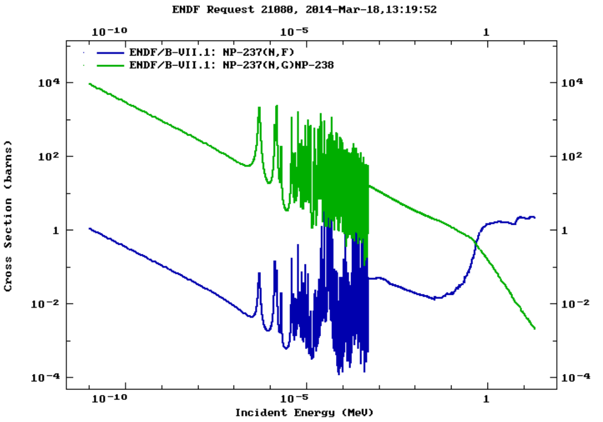

Fig. 1. Np-237 neutron induced fission (dark blue) and capture (green) cross section dependence on energy.

Table 1. Experiment data

Beam energy/particle*	0.66 GeV/ P	2 GeV/ d	4 GeV/ d	8 GeV/ d	24 GeV/ C6+
Date	08 Nov 2014	04 Dec 2012	13 Dec 2012	22 Dec 2012	18 Dec 2013
Irradiation time (h)	5.72	6.27	9.35	16.17	22.8
Beam integral (particles)	8.64 $\times10^{14}$	3.052 $\times10^{13}$	3.569 $\times10^{13}$	1.390 $\times10^{13}$	1.75 $\times10^{11}$

* particles – p-proton, d-deuteron, C6+ - ionized carbon

The measurement method was based on gamma-ray spectrometry. During the analysis of the spectra several fission products and one actinide were identified. Fission product activities gave the number of fissions. The activity of the actinide (Np-238), a result of neutron capture by Np-237, gave the number of captures.

The most appropriate parameter to characterize the ion incineration potential is the number of fissions per sample gram, per beam ion nucleon and per 1 GeV. As shown on Figure 2 the most effective ion been for Np-237 incineration is the proton. This result doesn't say what is the optimal proton beam energy. Nevertheless, the most widely accepted concept states that protons of energy 1-1.5 GeV are the most effective in actinide incineration. To confirm this statement two more experiments are needed – one with a 1 GeV proton beam and the other with 2 GeV.

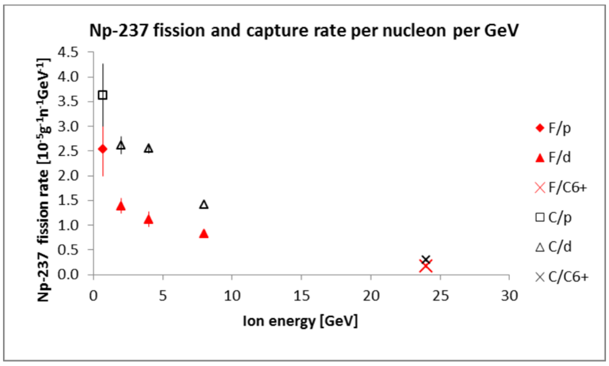

Fig. 2. Np-237 fission and capture rate per ion's nucleon for various ion beams. The symbols in the legend stand for fission (F) or capture (C) per beam ion (p, d, C6+)

Reference

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Validation of modified correlations for CHF prediction of the CATHARE-3 three-field with novel IEF correlation

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Prediction of critical heat flux is crucial for boiling system such as water cooled reactors. In the case of high steam qualities in the core, the occurrence of critical heat flux, also termed dryout, is usually associated with evaporation of a thin liquid film from the heated rods, thus leaving their cladding in direct contact with the vapour phase. Several phenomena require appropriate modelling in order accurately to estimate the occurrence of dryout and its location.

This work re-evaluates the model of the CATHARE-3 system code with an extended data base of adiabatic and diabatic tests in vertical pipes. Moreover, a model for the initial entrainment fraction is developed and validated.

Analysed phenomena

The following phenomena and their models have been analysed and modified accordingly to improve the results:

(1) Transition to annular flow

(2) Initial entrained fraction (IEF) – introduced in the recent study

(3) Entrainment and deposition mass transfer rates.

As far as point 1 is concerned, the current model for annular flow transition was developed by Kutateladze [1]. However, during the analysis, that model was replaced by the Wallis [2] quality transition criterion.

For point 2 there was no model for the initial condition at the onset of the annular flow. Within the recent work a correlation (eq. EQ_NR) was developed by the author of this paper, which was validated on broad experimental conditions – KTH Film flow experiment [3] and Wurtz Series 300 [4].

$IEF = 0.3$	for	$G < 500$
$IEF = \frac{0.1266461 \cdot G - 60.3850122}{G \cdot x_{tr}}$	for	$500 < G < 1800$
$IEF = 0.75$	for	$1800 < G$

Point 3. Current models for mass transfer rates between droplet and liquid field have been changed from the default correlations applied in the CATHARE-3 system code according to [5]

Additionally, terms which contributed to the droplet field due to numerous boiling effects [6,7] needed to be disabled. During the analysis of the KTH film flow experiment, described in detail in [8], it was proven that with a high heat flux these correlations tended drastically to overestimate the mass transfer from film to droplet field which resulted in dryout occurrence early in the flow.

Experimental Database

The models described herehave been tested on numerous adiabatic experiments – with pressures ranging from 2 bar up to 90 bar, and mass fluxes ranging from 300 kg/m2/s up to 3000 kg/m2/s and flow qualities from 8 to 80. For the adiabatic experiments, only outlet measurements weretaken into account.

The experiments with heat exchange covered pressures from 30 to 90 bar, mass fluxes from 500 to 3000. For the KTH film flow experiment several measurement points were available which allowed precise analysis of film flow in the CATHARE-3 code.

Comparison of the results

All the experiments were simulated using the CATHARE-3 three field code in two configurations. Configuration one represented the default state of the equations of the CATHARE-3 code, while configuration two represented the new correlation as well as the new phenomena introduced to the code.

In general configuration two (new) yielded more accurate results for adiabatic experiments. The adiabatic experiments' results prove that the Okawa correlation provides results characterised by lesser spread for high pressure cases only. However, for low pressure cases the results were much less accurate. All the high pressure results are depicted in Fig. 1.

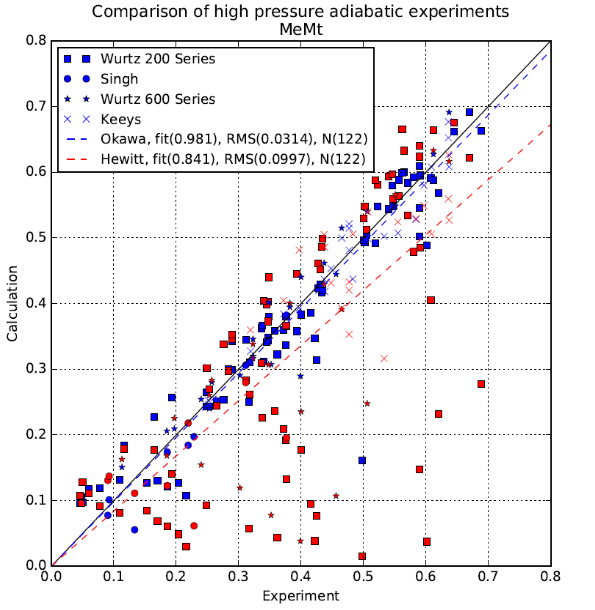

Fig. 1 Comparison of experimental and simulated data for adiabatic experiments.

The adiabatic results were the basis which allowed Okawa's correlation to be applied in diabatic experiments. With a new correlation for the transition criterion to annular flow and Spirzewski's correlation for the Initial Entrained Fraction it was possible to achieve exceptional results for the KTH film flow experiment as well as the Wurtz 300 series. The diabatic results comparison is depicted in Fig. 2.

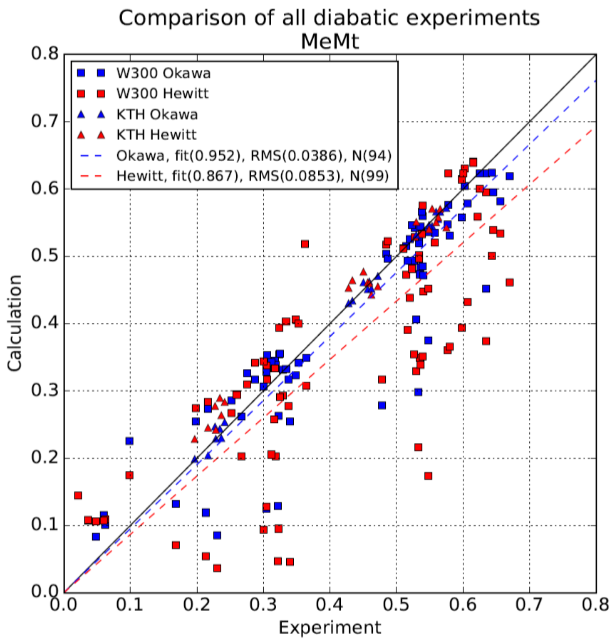

Fig. 2. Comparison of experimental and simulated data for diabatic experiments.

Error analysis

All data were analysed in order to find the weak-points of the current "modelling package" and which direction should be taken in order to advance in the computer simulation of the dryout phenomenon. The highest error is exhibited for the lowest values of M_eM_t (droplet flow to total flow ratio) and it tends to zero with increase of M_eM_t. For the vapour flux it was found that there is a noticeable break-point for G_v = 300 kg/m^{2}s where the error is the largest.

Conclusions

It was shown that configuration two with modified correlations and supplemented IEF model yields more accurate results with considerably lower spread both for adiabatic and diabatic experiments.

Additionally it was proven that IEF in conjunction with transition to annular flow criterion plays a major role in the estimation of droplet and film fields which is the essence of dryout modelling.

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The ALLEGRO demonstrator– the gas fast reactor fuel pin and fuel assembly neutronic benchmarks in the VINCO Project

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ALLEGRO, a demonstrator of a fast gas cooled reactor is being developed by four countries included in the Visegrad Initiative for Nuclear Cooperation: the Czech Republic, Slovakia, Hungary and Poland. The European Union Horizon2020 Project VINCO supports this activity. Since there are no available neutronic codes dedicated to helium coolant at the fast spectrum, benchmarking of existing codes was part of the Project. The neutronic benchmark in the framework of the VINCO Project was split into two parts. The first part of the VINCO Neutronic Methodological Benchmark focused on a pin cell with its environment. The second part, the VINCO Neutronic Assembly Oriented Benchmark, focused on the fuel assembly of a gas cooled fast reactor.

The first part, the simplest 2-D model of a heterogeneous unit of the reactor, a fuel pin surrounded by aa hexagonal cell was selected to avoid the user effect. A full set of geometrical and material data was supplied.

The benchmark was used to verify the effects of modelling of: 1. Nuclear data uncertainties, 2. Satisfactory energy discretization, 3. Resonance self-shielding in the energy region of the resolved and unresolved resonances, 4. anisotropy of the flux in the leakage calculation, 5. anisotropy of the scattering in the leakage calculation.

Calculations were to be performed for UOX and MOX fuel. Two options were considered: A – with the critical buckling iterated at each burnup step and B – with fixed buckling of B^2=2.7779e-03 1/cm^2. The base case temperature was 867°C, power density – 50 W/cm^3 and burnup had to be carried out up to 75 MWd/kg$_{HM}$. The volumetric power density corresponds to different power densities per gram of heavy metal for UOX and MOX fuels. To investigate the Doppler coefficient two additional calculations were to be performed: with pellet temperatures of 900K and 2100K without taking into account the thermal expansion of the pellet, which effect was investigated separately by performing calculations with thermal change of the pellet dimensions and number densities for these same temperatures, and without change of the pellet temperature. The linear expansion was calculated according to the formula set out in the benchmark specification, [1]. The participants were asked to provide the following results: for the base case: k-inf, k-eff at fixed buckling (option B), iterated critical buckling (option A), partial void effect on k-eff when the He-4 coolant number density is halved; for both options: number densities of the following isotopes U-235, U-236, U-238, Pu238, Pu-239, Pu-240, Pu241, Pu-242, Am-241 and Cm-242, k-eff for the fuel pellet temperature of the 900K and 2100K branches, and k-eff at pellet expansion at 900K and 2100K.

The second part concerned 2-D modelling of the ALLEGRO fuel assembly at an infinite lattice without fixed buckling and a critical spectrum for UOX and MOX fuel. The temperature distribution was more realistic than the uniform one in the first part. Pin geometry, materials data and power density were the same as in the first part. The assembly consisted of 8 concentric hexagonal rings of 169 fuel pins. The requested data were the same as in the first part, plus kinetic parameters such as the delayed neutron fraction β (and β_i at the delayed neutron group structure of the utilized code/library), prompt neutron lifetime, transport cross section at 8 selected collapsed groups.

The Polish group performed calculations for both parts of the benchmark using the control module TRITON of SCALE version 6.1.3 with the 238-group ENDF/B-VII.0 library and 6.2.1 with the same library and the 252-group ENDF/B-VII.1 library code system with ENDF. TRITON provides 2-D transport calculations in the NEWT and depletion calculations in the ORIGEN module.

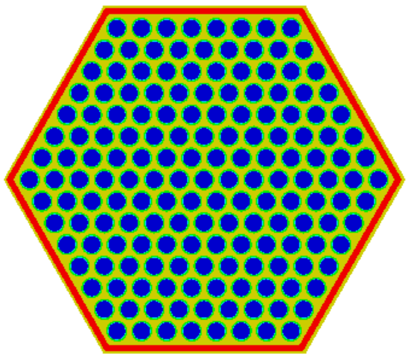

Fig. 1. ALLEGRO fuel assembly model in the SCALE6.2/TRITON.

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NUCLEAR TECHNIQUES IN HEALTH AND ENVIRONMENTAL PROTECTION, MANAGEMENT OF HAZARDS

In vitro evaluation of biological activity of radiopharmaceuticals

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Radiolabelled monoclonal antibodies (mAb) and peptides are powerful tools for tumour imaging or targeted radiotherapy. However, before they are used in humans it is of major importance to assess their biological activity and characterize their properties in pre- clinical testing. The immunoreactivity of mAbs or receptor binding affinity of peptides after the chelator is conjugated to them for radiometal labelling need to be assessed before in vivo studies.

In this work we evaluated the biological activity of antibodies and peptides that are under development at RC POLATOM using in vitro assays in dedicated cell lines.

Specific binding of ^{177}Lu-DOTA-Rituximab and ^{90}Y-DOTA-Rituximab (Fig. 1a) directed to CD20 antigen was evaluated by in vitro studies carried out on Raji cells. The IRF (Immunoreactivity Fraction Assay) was determined by the Lindmo et.al method [1].
The receptor binding affinity of the CP04 peptide radiolabelled with ^{177}Lu (Fig.1b) and ^{68}Ga towards CCK2R (gastrin/cholecystokinin receptor) was defined by an in vitro study according to the method of Kaloudi et. al [2], using A431(CCK2R(-)) cells and A431(CCK2R(+)) cells, which had been transfected with the plasmid pCR3.1.

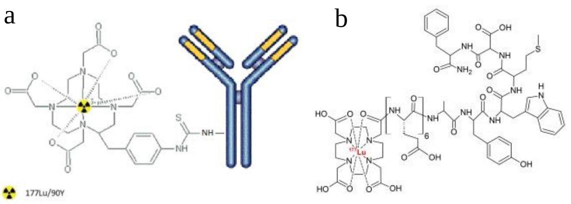

Fig. 1 Structure of radiolabelled monoclonal antibody (a) and ^{177}Lu- CP04 peptide(b).

All the studied radiopharmaceuticals were obtained with high radiolabelling yields of over 90%.

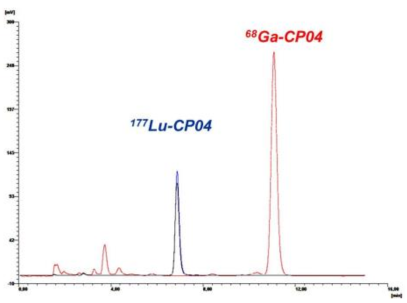

Fig.2. HPLC profile of radiollabeled ^{177}Lu-CP04 and ^{68}Ga –CP04 complexes.

Immunoreactivity Fraction Assay
Around 22% of ^{177}Lu-DOTA-Rituximab and 26% of ^{90}Y-DOTA-Rituximab was bound to the Raji cells. Very small differences wereobserved between IRFs of ^{177}Lu-DOTA-Rituximab and ^{90}Y-DOTA-Rituximab (Fig.3) and were not statistically significant.

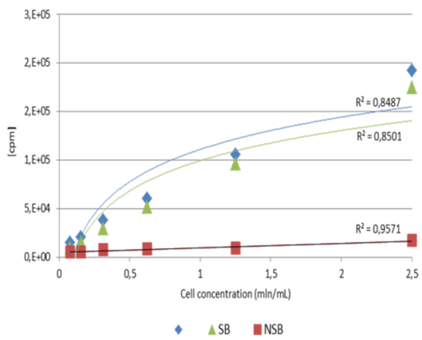

Fig. 3. Specific binding over total applied radioactivity of ^{177}Lu-DOTA-Rituximab (green) and ^{90}Y-DOTA-Rituximab (blue), as a function of increasing cell concentration (red –non-specific-binding, NSB).

The binding and internalization assay
^{177}Lu-CP04 and ^{68}Ga-CP04 showed a specific binding at the level of about 4% with a high internalization (over 70%) for both radiolabelled peptides, but no significant differences between them (tab.1).

Table. 1. Results of binding and internalization of radiolabelled CP04 complexes.

	177Lu-CP04 (n=6)	68Ga-CP04 (n=4)
total binding	5.83 +/- 1.46	5.00 +/- 1.10
total specific binding	4.10 +/- 0.91	3.63 +/- 0.78
internalization [%]	74.82 +/- 7.74	73.45 +/- 10.22

In vitro studies such as the immunoreactivity determination for monoclonal antibody-based tracers or binding and internalization for peptide-based radiopharmaceuticals are important tools for evaluation of potential drug candidates in the pre-clinical phase, giving an essential piece of information regarding their biological activity. The results of such studies are starting points for further comprehensive in vivo evaluation using specific animal models.

This study was presented as a poster at the 24th Young Research Fellow Meeting in Paris.

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Overview of activities in the research department of the Radioisotope Centre POLATOM

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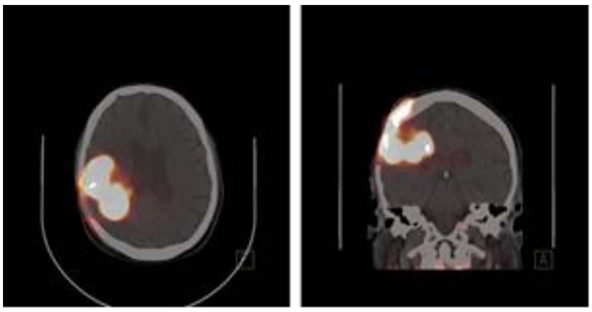
The R&D Department of the Radioisotope Centre POLATOM carries out research programmes related to the application of radioactive preparations and radiolabelled compounds in various fields of medicine, research and industry.

The results of our investigations are directly implemented in the technologies 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 2016 were:

- marketing authorization for Tektrotyd in several EU countries,
- permission from Polish, Austrian and Slovenian Authorities torecrui patients for a phase I clinical study for ^{111}In-CP04 preparation under the ERA-NET TRANSCAN project,
- development of a radiopharmaceutical kit for the preparation ^{68}Ga-PSMA – a radiopharmaceutical for PET diagnostics of prostate cancer.

Our colleague, Dariusz Pawlak, participated in a study on targeted alpha therapy of brain tumours headed by the Medical University of Warsaw.



PET/CT images after loco-regional co-injection of ^{68}Ga/^{213}Bi-Substance-P for targeted alpha therapy illustrating the distribution of the radiopharmaceuticals in the tumor.

The work "Secondary glioblastoma multiforme - local alpha emitters targeted therapy with ^{213}Bi-DOTA-substance P" presented at the EANM congress 2016 by the team: L. Królicki, A. Morgenstern, J. Kunikowska, H. Koziara, B. Królicki, M. Jakuciński, D. Pawlak, C. Apostolidis, F. Bruchertseifer representing the Medical University of Warsaw, European Commission, Joint Research Centre, Institute for Transuranium Elements, Institute of Psychiatry and Neurology, Brodnowski Hospital and the Radioisotope Centre POLATOM NCBJ was awarded the prestigious 2016 Marie Curie Award by the Scientific Committee of the European Association of Nuclear Medicine.

Currently, the R&D Department is involved in projects financed by the followingPolish funding institutions: the National Centre for Research and the Development and National Science Centre. The active projects are:

- 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).
- NCBiR Project No. PBS3/A9/28/2015 "Preparation of radiopharmaceuticals based on scandium radionuclides for positron emission tomography "PET-SKAND" (2015- 2017).
- 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 an acronym "BIOTECHNET" (2015-2018).
- The Operational Programme Smart Growth 2014-2020, Measure 1.2, Sectoral Programmes, Innomed Programme; Multivariate formulations of DOTATATE peptide as precursor for preparation of radiopharmaceuticals (MultiSom) (2016-2018).

The R&D Department in recent years has participated in and is currently active in the IAEA coordinated projects:

- IAEA No. 20496 "Therapeutic Radiopharmaceuticals Labelled with New Emerging

Radionuclides (^{67}Cu, ^{186}Re, ^{47}Sc) (F22053)" (2016-2019).
- IAEA No. 18475/RO "Nanosized delivery systems based radiopharmaceuticals in Poland" (2014-2017).
- In 2016 we contributed to COST (European Cooperation Programme of Scientific and Technical Cooperation):
- COST CM1105 - Functional metal complexes that bind to biomolecules (2012–2016).
- COST CM1207 – GLISTEN: GPCR-Ligand interactions, structures, and transmembrane signaling: a European Research Network.
- COST BM1403 - Native Mass Spectrometry and Related Methods for Structural Biology (2014-2018).

The Laboratory of Radioactivity Standards of the Radioisotope Centre POLATOM – overview of activities

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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 ɣ-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 Radionuclide Activity in Poland in 1999. The standard is stored and used in 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.

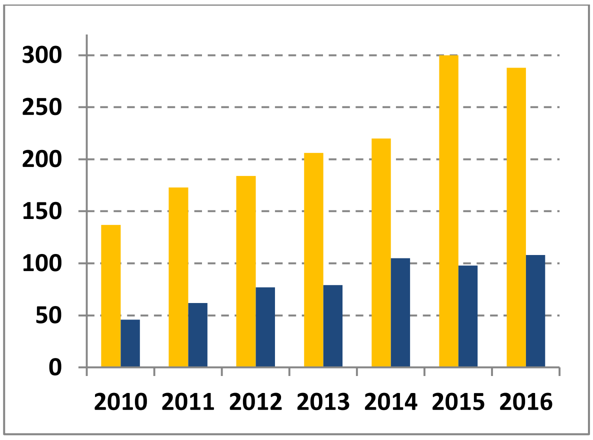

Fig. 1. Trend in customer requests for calibration of dose calibrators ■ and standard sources ■ in 2010-2016.

The Laboratory of Radioactivity Standards is the only Polish manufacturer of radioactive standard sources for customers in this country and abroad. The LRS is also the only calibration laboratory in Poland that fulfills the requirements of the Regulation of Health Ministry from 12th November 2015 on conditions of safety application of ionizing radiation in all kind of medical exposure (Dz. U. 2015, Item 2040) in the field of specialized technical tests for dose calibrators used by nuclear medicine departments.

During 2016 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 of 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 ISO/IEC 17025:2015 standard.

One of the main tasks performed by the LRS is the continuous improvement and expanding of measurement capabilities in the field of radionuclide metrology. Our primary goal is to ensure traceability with the 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).

The most important international comparison the LRS participated in during 2016 was connected with activity measurements of 3 short-lived radionuclides used in nuclear medicine: ^{18}F, ^{64}Cu and ^{99m}Tc.

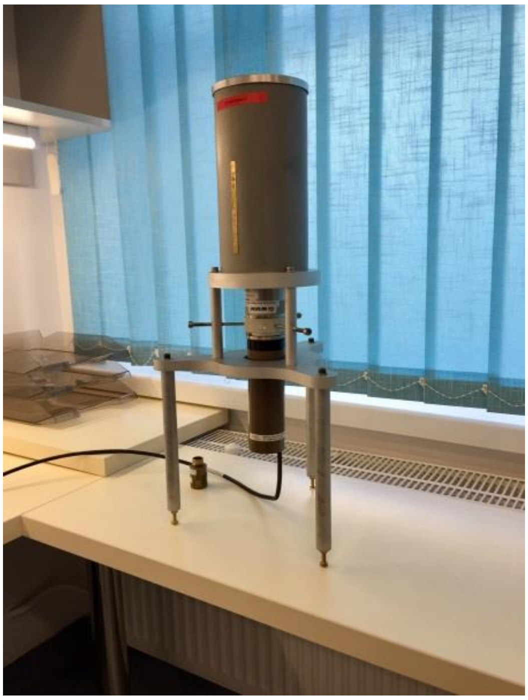

Fig. 2. SIRTI instrument used during the international comparison of short-lived radionuclide activity measurements.

Short-lived radionuclides are essential for nuclear medicine, particularly for imaging. The use of nuclear medicine is increasing with the accessibility of these radionuclides which are consequently of great interest to the National Metrology Institutes (NMIs) in terms of the standardization and traceability to the International System of Units. However, sending ampoules of short-lived radioactive material to the Bureau International des Poids et Mesures (BIPM) for measurement in the International Reference System (SIR) is only practicable for the NMIs that are based in Europe.

Consequently, to extend the utility of the SIR and enable other NMIs to participate, a transfer instrument (SIRTI) was developed at the BIPM with the support of the Consultative Committee for Ionizing Radiation CCRI(II) Transfer Instrument Working Group and has been in use since 2009. The SIRTI instrument, on which the BIPM ongoing comparison of activity measurements of short-lived radionuclides is based, is a 7.6 cm × 7.6 cm well-type NaI(Tl) crystal calibrated against the SIR. The system was moved to RC POLATOM in October 2016 in order to perform all necessary measurements. RC POLATOM was the second institution in the world (the first was NIST, USA) to participate in such a comparison for ^{64}Cu.

Master solutions of ^{18}F, ^{64}Cu and ^{99m}Tc have been standardized at RC POLATOM using primary activity measurement techniques based on 4π(LS)-γ coincidence and anti-coincidence counting and CIEMAT/NIST efficiency tracing with ^{3}H as a tracer.

The stability of the SIRTI system was monitored using a ^{94}Nb reference source ($T_{1/2}$ = 20 300 y; u = 1 600 y) from the Institute for Reference Materials and Measurements (IRMM, Geel), which also contains the ^{93m}Nb isotope. The prepared samples count rates above a low-energy threshold, defined by the ^{93m}Nb X-ray peak at 16.6 keV, were measured relative to the ^{94}Nb count rate above the same threshold. Once the threshold was set, a brass liner was placed in the well to suppress the ^{93m}Nb contribution to the ^{94}Nb stability measurements. It should be noted that the uncertainty associated with the ^{94}Nb decay correction is negligible. The SIR ampoule with a radioactive solution of a particular radionuclide was placed in the detector well with the brass liner. No extrapolation to zero energy was carried out as all the measurements are made with the same threshold setting. The life-time technique using the MTR2 module from the Laboratoire National d'Essais – Laboratoire National Henri Becquerel, France (LNE-LNHB) was used to correct for dead-time losses, taking into account the width of the oscillator pulses. The standard uncertainty associated with the life-time correction, due to the effect of finite frequency of the oscillator, is negligible.

Similar to the SIR, a SIRTI equivalent activity A_E is deduced from the particular radionuclide and ^{94}Nb counting results and the radionuclide activity measured by POLATOM: A_E corresponds to the inverse of the a detection efficiency, i.e. A_E is the activity of the source measured by the comparison participant divided by the radionuclide sample count rate in the SIRTI, expressed relative to the ^{94}Nb count rate. The possible presence of radionuclidic impurities in the solution was accounted using γ-spectrometry measurements carried out by the LRS. Final results were reported to BIPM. Data from this project are still under evaluation.

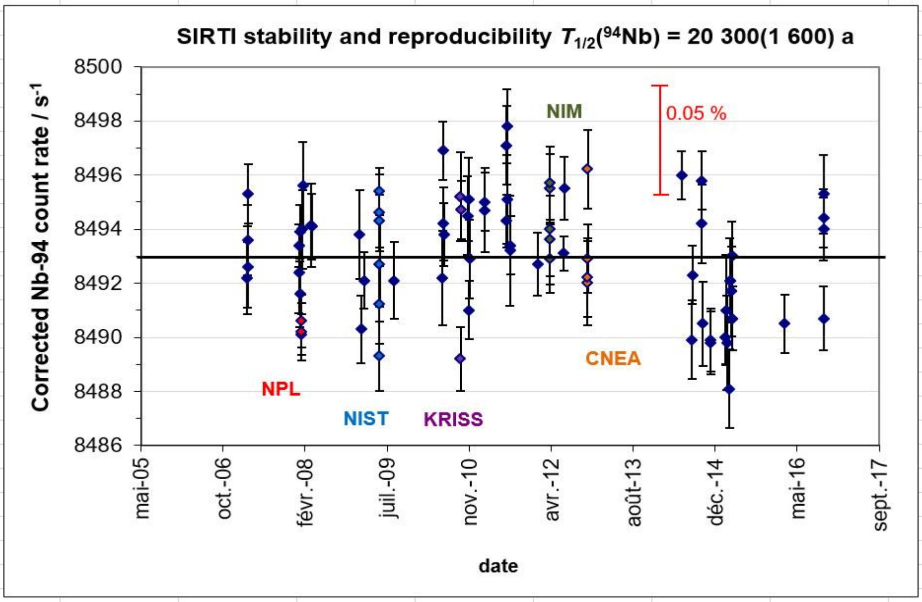

Fig. 3. Results of ^{94}Nb control source measurements in SIRTI. The most recent points on the graph represent measurements made at RC POLATOM.

Estimation of the low emissions from two housing estates in Pruszcz Gdański

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Low emissions consist of traffic emissions and emission of dust and harmful gases from local coal-fired boilers and domestic heating stoves where combustion of coal or wood takes place in an inefficient way using inexpensive low-grade coal with poor thermal characteristics and low heating capacity. A characteristic feature of low emission is that it is caused by multiple sources introducing small amounts of impurities into the air. In this case, the emitters (chimneys and other emission sources) are usually a max. 10 m high. This is why this phenomenon is so harmful, as impurities introduced into the air at this altitude gather around the point of origin and cause damage locally (usually in densely populated areas). Estimation of the low emissions from two housing estates in Pruszcz Gdański was the main goal of this paper. Two series of biweekly measurements of the PM10 mass concentration of suspended particulate matter in the air of two housing estates in Pruszcz Gdański were conducted using the NCBJ mobile laboratory for environmental measurements (in short: mobile laboratory). The study was conducted in the housing estates of Wschód and Nad Radunią in Pruszcz Gdański. The first series of measurements was carried out in the full heating season (November/December 2015), when household stoves usually work with full thermal load. The mobile laboratory was placed in the Wschód estate from 28-th November to 11-th December and in the Nad Radunią estate from 14-th to 27-th December 2015. The second series was conducted in the summer of 2016 (June/July) when the household stoves were not in operation, in Wschód from 15-th to 28-th June and in Nad Radunią from 2-nd to 15-th July 2016. The size of the low emissions was determined on the basis of comparison of the diurnal PM10 mass concentrations in both series The low emission is the difference between the summarized PM10 concentration during fourteen days in the heating and out of heating seasons. Figures 1 and 2 present the one-day PM10 mass fraction values recorded during two measuring periods: heating season and out of heating season at both housing estates [1, 2]. In the Wschód housing estate in the heating season the one-day PM10 value once excess over of the maximum permissible one-day PM10 concentration (in short: limit value-50 µg/m3) was recorded. The low emission from this residential quarter comprised 26,1% of the emissions during the heating season. In the Nad Radunią housing estate in the heating season the one-day PM10 values twice exceed the limit value. The low emission from this residential quarter comprised 44.4% of the PM10 emissions during the heating season.

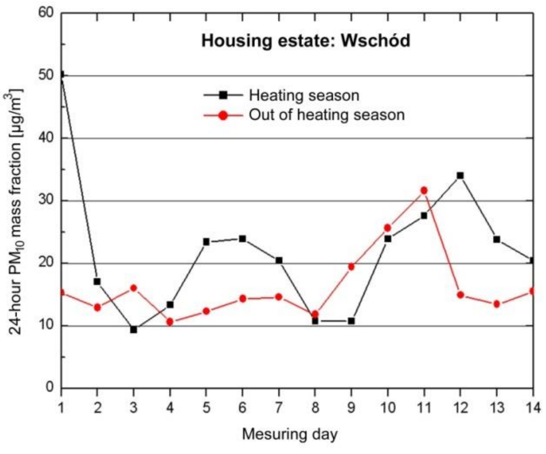

Fig. 1. The one-day PM10 mass fraction values recorded during two measuring periods: heating season and out of heating season at the Wschód housing estate.

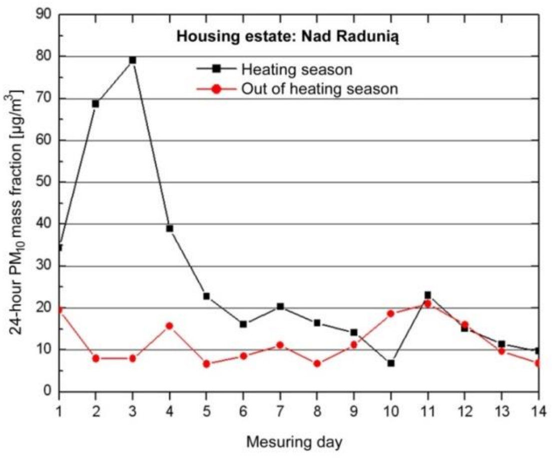

Fig. 2. The one-day PM_{10} mass fraction values recorded during two measuring periods: heating season and out of heating season at the Nad Radunią housing estate.

References

[1] Raport z pomiarów stężeń masowych frakcji PM_{10} i $PM_{2,5}$ pyłu zawieszonego w powietrzu na osiedlach mieszkaniowych Wschód i Nad Radunią w Pruszczu Gdańskim w sezonie grzewczym.

[2] Raport z pomiarów stężeń masowych frakcji PM_{10} i $PM_{2,5}$ pyłu zawieszonego w powietrzu na osiedlach mieszkaniowych Wschód i Nad Radunią w Pruszczu Gdańskim po sezonie grzewczym

Modelling of severe accident in-vessel progression issues – Bali Metal experiment calculations

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The In Vessel Melt Retention strategy is a severe accident management strategy that incorporates internal or external vessel flooding to remove the heat from the in-vessel molten pool material. In this method the heat is transferred from the molten pool to the external environment (atmosphere or coolant) through the vessel wall. This impacts highly the structure of the vessel due to the high temperature and the interaction between the corium and the steel walls (ablation). The IVMR strategy is considered feasible for small power reactors and the aim of this study is to consider from the safety point of view its applicability to high power reactors with power of about 1000MWe or more.

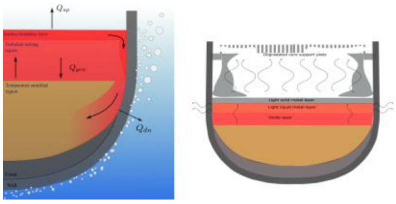

Fig. 1. Heat transfer during the IVMR strategy. Focusing effect.

In this part of the work the focus is on the liquid phase of the metallic layer during a severe accident for studies investigating the heat transfer regimes in the metallic layer - the time delay of the establishment of convection and the description of the thermalhydraulics in the metallic layer.

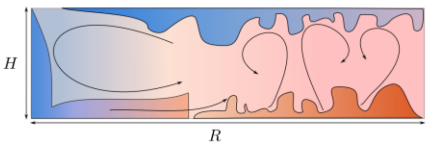

Fig. 2. Convection in a thin Metal Layer –cold tongue effect.

The analysis was performed in several steps. First, using nondimensional analysis of the conservation equations and boundary conditions, the dominance and time span of the heat transfer regimes was studied. The next step was a stability analysis to estimate the surface deformation of the steel layer at the free surface boundary. For that purpose we used BALI metal experiment data and performed CFD calculation in order to build a simplified model [1].

The experiments simulated by the CFD software focus on the metallic layer created on the top of the corium pool, for various layer heights. The meshing and geometry are based on available data from partners, based on the experiment documentation, with the stress on the most interesting boundary wall – thee lateral direction, where the focusing effect takes place. The main results show the behaviour of the fluid during the transient simulations – creation of the different flow patterns, characteristic temperatures for selected cross sections, power split and nondimensionalized numbers characterizing the heat exchange. The second part of this project produced simulations for prototypical calculations of the metallic layer with the metal fluid in a sector of the cylindrical layer geometry. The results for the U4 test of the BALI Metal calculations are in agreement with the CFD simulations, with the more correct results for the DNS calculations, but with k-ω results that are not disqualified.

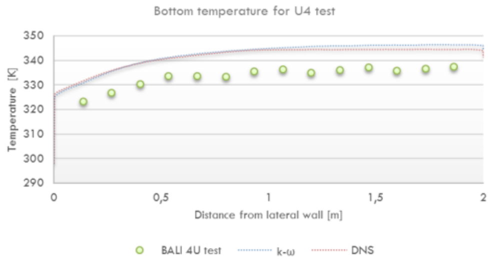

Fig. 3. Time averaged bottom temperature profile for CFD calculations (DNS and k-ω).

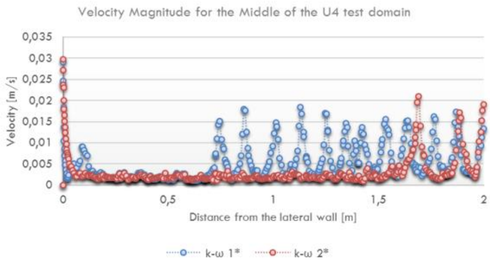

Fig. 4. Velocity evolution for U4 test, for 1 - 175s and 2* - 1600s.*

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The NCBJ contribution to the blind CFD benchmark exercise - GEMIX

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The use of Computational Fluid Dynamics (CFD) in nuclear engineering is becoming widespread for modelling physical situations, especially when mass and heat are transferred with strong 3D effects, such as mixing of hot and cold water in the case of a Loss of Coolant Accident or Pressurized Thermal Shock scenarios. Density differences and associated buoyancy effects may play a significant role in the flow structure, leading to complex modes of turbulent transport of momentum and thermal energy. The 3-D nature of the liquid flow generated in such situations invites the use of CFD simulations, but such applications in safety demonstration are often difficult due to the lack of an uncertainty evaluation.

Discrepancies between experimental data and numerical simulations are due to, on the one hand, the experience and computational capabilities of the CFD code user, who often has to decide on simplifications and assumptions, but on the other hand and most importantly, discrepancies come from uncertainties due to inaccuracies in measurement methods, on the basis of which the CFD results are compered.

The GEneric MIxing eXperiment (GEMIX) benchmark international activity hosted by the Paul Scherer Institute (PSI – Switzerland) and sponsored by the OECD/NEA, was to provide invaluable data in the quest to improve the acceptability of CFD simulations for such safety issues. In essence, the aim of the exercise was to compare and evaluate different Uncertainty Quantification (UQ) methodologies, currently used to assess the reliability of CFD simulations in the presence of several sources of uncertainties.

The confined wake flow water mixing experiments in the GEMIX facility focus on the basic turbulent mixing mechanisms for un-stratified and stably stratified conditions. A simplified schematic of the test rig is shown in Fig. 1. The inlet section comprises the lower and upper legs, where the two co-flowing water streams are initially separated by the splitter plate. The participants of this benchmark were free to choose the uncertainty sources (e.g. boundary conditions, turbulence model coefficients and numerical errors) and the methodology to compute uncertainty bands. The selection of numerical schemes, turbulence models and computational mesh were also left to participants' decision.

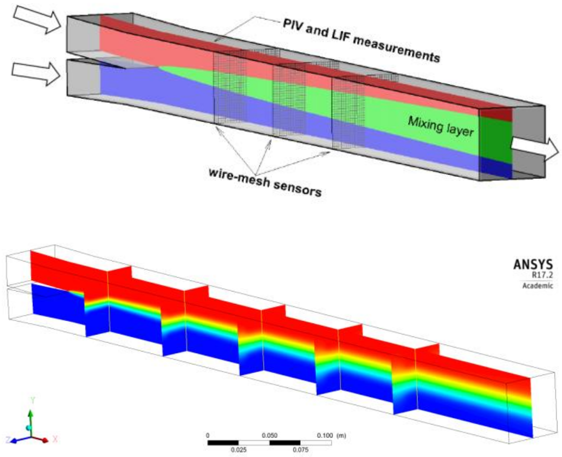

Fig. 1. Upper: general geometry. Lower: concentration profile.

In the benchmark data from 3 tests were open to allow some calibration of the computational setup. The data from fourth test was closed and was used in order to verify the results of a 'blind' benchmark exercises. All the participants were requested to provide mean velocity, turbulence kinetic energy, concentration profiles and thickness of the mixing layer with the uncertainty band along the domain at selected locations inside the mixing section.

The CFD Analysis Group at NCBJ, based on its own best practices, started the work (in 2015) evaluating the uncertainty due to mesh resolution and turbulence model applied first. Then the uncertainty due to fuzzy input data has been applied, evaluated and concluded as the most impacting factor to the discrepancies between simulation and reality.

It is worth to mention, that from all declared participants only half of them provided final results. The NCBJ fulfilled all the requirements as one of few nuclear-related CFD teams and has been classified, however specific conclusions cannot be presented here as the final public OECD report is supposed to be issued in third/fourth quarter of the 2017.

Assessment of external event risks resulting from man-made hazards for the location of nuclear facilities

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The ASAMPSA_E (Advanced Safety Assessment Methodologies: extended PSA) project aims at examining in detail how far the PSA (Probabilistic Safety Assessment) methodology is able to identify any major risk induced by the interaction between a NPP and its environment, and to derive some technical recommendations for PSA developers and users. During the ASAMPSA_E End-Users workshop held in Uppsala, 10 important external hazards were identified as the minimum required to be addressed by the project. These hazards are the following: earthquake, external flooding, extreme air temperatures, snow packs, lightning, storm, strong wind, biological infestation, aircraft crash, external fire and external explosion. Consequently, it was decided to focus on these external hazards for developing guidance and that different reports would be prepared according to the hazards considered.

One of the developed guidelines is focused specifically on man-made hazards and implementation in extended PSA [1]. The following issues are addressed in the guidance document:

- Hazard assessment methodologies;
- Issues related to considering hazard combinations;
- Multi-unit PSA challenges.

The main sources for man-made hazards are external fires, explosions and toxic releases. In principle, they can be divided into stationary and mobile, as follows:

- Stationary sources in the vicinity of the plant under consideration such as oil refineries, chemical plants, mines, forests, storage facilities, other nuclear facilities, high energy rotating equipment, military facilities, and pipelines;
- Mobile sources such as railway trains, road vehicles, ships, and aircraft (civil, military, and agricultural, if needed).

According to this division the appropriate data have to be used in the hazard analysis. Identification of parameters important for making frequency assessment and consequence analysis including uncertainty consideration plays an important role in the whole PSA analysis. In principle this step can be based on a kind of risk assessment, like QRA (Quantitative Risk Analysis), which is a typical tool for the analysis of man-made hazards like fires, explosions and releases of toxic substances, performed for chemical processing plants. Methodologies for the assessment of man-made hazards have to take into account a number of various factors and usually utilize different approaches and methods in order to make a full image of the real processes. In general, man-made hazards are related to the physical properties of the material and these properties determine the inherent risk and the potential consequences in the case of an accident with the release of dangerous substances.

The transformation process of risks related to fires, explosions and toxic releases into initiating events is strictly related to the following issues:

- Methodological issues (involving the use of existing internal events, SSC (System, Structure, Component) in fault tree modelling and human aspects);
- Analysis of the response from mobile equipment, help from outside, special provisions that can be made available and taking preventive measures;
- Limitations in the methodology and open points that should be addressed during modelling (for example screening criteria to be used during initiating the event due to man-made hazard analysis).

External man-made hazards are generally characterized by a relatively large number of cross-correlated phenomena and can simultaneously affect all the units at a site. This requires appropriate interface arrangements to deal with it as well as with the potential domino effects. The initiating events can create the potential for similar accident sequences and for common cause failure of identical components across units or inter-unit common cause failures. A single-unit event can also trigger a cascade sequence to impact the other units, particularly for those with shared or connected structures.

Therefore, both hazard combinations and multi-unit PSA challenges need special attention to address cross-cutting issues.

In the report [1] a number of open issues, where further research might be needed in order to perform PSA studies, are also presented. There is still many limitations and gaps in the methodologies, nevertheless the basic methods are described in [1].

Reference

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Application of Approximate Bayesian Computation methods in the stochastic estimation of atmospheric contamination parameters for mobile sources

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The Bayesian methodology, known as Approximate Bayesian Computation [1] (ABC), was applied to the problem of atmospheric contamination source identification. The algorithm input data are concentrations of the released substance registered by the distributed sensors network and arriving online. In [2] we presented in detail the Sequential ABC algorithm and tested its efficiency in the estimation of probabilistic distributions of atmospheric release parameters of a mobile contamination source. The developed algorithms were tested using data from the Over-Land Atmospheric Diffusion [3] (OLAD) field tracer experiment (see fig.1). We demonstrated the estimation of seven parameters characterizing the contamination source, i.e.: contamination source starting position (x,y), the direction of motion of the source (d), its velocity (v), release rate (q), start time of release (ts) and duration (td) (see fig. 2 and [3]). The new online-arriving concentrations dynamically update the probability distributions of the search parameters. The Second-order Closure Integrated PUFF [4] (SCIPUFF) Model was used as the atmospheric dispersion forward model to predict the concentrations at the sensor locations.

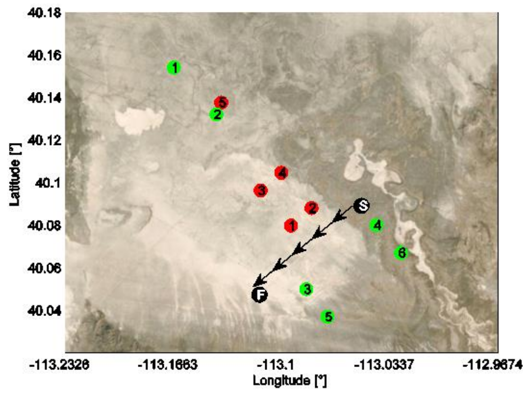

Fig. 1. Topographic map of the OLAD Trial-252-2 experiment. The black dots mark the starting (S) and final (F) points of the release; The sampling points are indicated with red dots and the weather stations with green squares. (39.9800N,113.2 W).

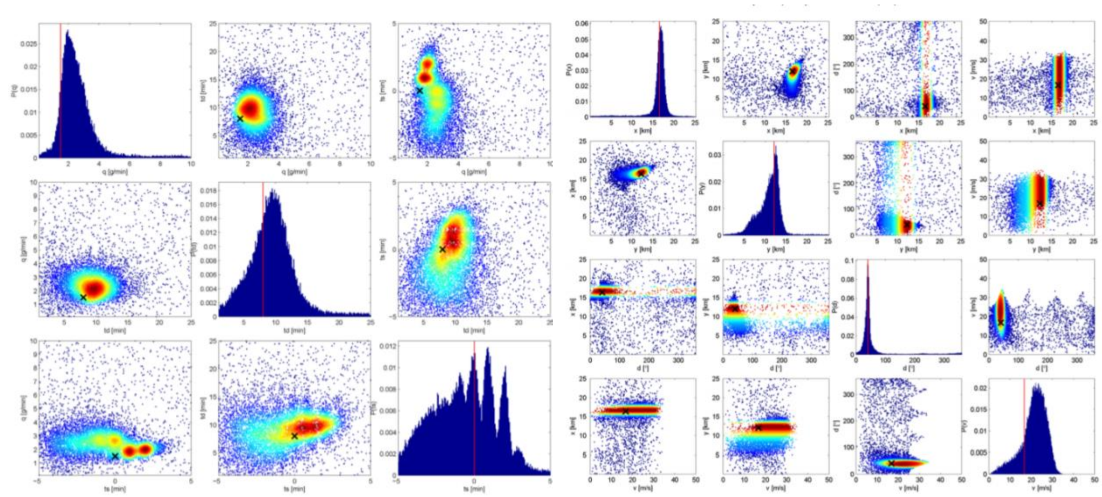

Fig. 2. Bivariate and marginal posterior distributions for searched parameters θ ≡ *(*x,y,d,v,q,td,ts*). Probability density colours the plot, the more red the region, the higher its probability. The vertical red lines in the diagonal plots and the black crosses in the bivariate probability distributions mark the target values of the parameters.*

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[3] Kopka, P., Wawrzynczak, A., & Borysiewicz, M. (2016). Application of the Approximate Bayesian Computation methods in the stochastic estimation of atmospheric contamination parameters for mobile sources. Atmospheric Environment, 145, 201-212

[4] Sykes, R. I., Henn, D. S., & Parker, S. F. (2000). Pc-scipuff Version 1.3 ARAP Report

A system for risk assessment of a major accident in an industrial installation with potential off-site hazards

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The main purpose of the national project EVARIS is to develop a program for assessing the risk in industrial plant, which pose a threat outside their premises. The aim is to be achieved by applying the methods of risk analysis, emergency scenarios and assessment of potential effects of industrial accidents.

In particular the following aspects are to be taken into consideration:

- Analysis and development of a methodology of risk assessment in industrial facilities.
- Development of assumptions for creating representative accident scenarios related to industrial infrastructure.
- Development of algorithms and numerical models enabling estimation of the scope of the consequences of the potential release of dangerous substance into the environment.
- Development of IT tools enabling effective determination of safety zones important for land-use planning.

The basic concept of the system is based on the following assumptions:

1. Determination of different types of risk: local risk: frequency of the reference damages (e.g. mortality) due to an accident in the selected area. Presentation of the results can be made in the form of risk contours and histograms showing the contribution to the risk from different sources.

- individual risk: similar to the local, but additional elements for risk assessment are taken into account like: mean exposition time or sheltering possibilities. Apart from risk contours special places of high vulnerability can also be considered – this concerns hospitals, schools, etc.
- social risk: the number of probably exposed people is also taken into account. The presentation is typically in the form of an F-N curve i.e. graph with cumulated frequency from all the sources and the number of people exposed.

2. The estimation of risk is made for:
- Substances or groups of substances e.g. flammable, explosive, toxic.
- Sources (single plant or groups of plants of the type of activities, for example petrochemical or fuel storages).

Types of possible consequences.

3. The user should have the possibility to filter the results by choosing:

- substance or type of substance,
- type of accident,
- type of consequences,
- type of source (plant).

4. It should be possible to add fictitious facilities in order to estimate the risk from planned installations.

A general basic algorithm for the determination of risk in industrial areas can be described as follows:

- For each plant within the area considered, it is first checked whether this plant should be included in the calculation of risk i.e. whether it could be the source of a risk of the considered type.
- If for a given installation (plant) there are scenarios already prepared then the risk is calculated based on these scenarios.
- If there are no dedicated scenarios for the considered installation, then generic scenarios should be taken into account, and the risk should to be estimated on such a basis.
- Depending on the scenario the appropriate computing model is selected (which can be either an internal module or an external program) for risk calculation in the area of interest.
- The most important scenarios that have to be analyzed are the following:
  Evaporation of toxic substances from a pool;
- Fire pool;
- BLEVE – Boiling Liquid Evaporation Explosion;
- Flash fire;
- Vapour Cloud Expansion;
- Jet fire;
- Dispersion of toxic substance.

Apart from the computing models implemented directly in the system, it is assumed that it will also be possible to use the results of external computer programs via a well-defined interface. This will allow for usage of more advanced models like CFD (Computational Fluid Dynamic) packages for very special cases – for example FDS (Fire Development System) for fire simulations or FLACS (©Gexcon) for explosions and dispersion of gases in industrial facilities.

The whole system will be implemented in the form of a Web application with many embedded GIS (Geographical Information System) features. Implementation of the system will contribute to the effective identification of hazards which arise from the use of dangerous substances in industrial facilities, early identification and assessment of the risks "in situ" and it can also strengthen the cooperation between employers and local authorities and their subordinate service units.

Developing a computerized tool will make it possible to calculate the scope of the effects of industrial accidents, including the possibility of determining a safe distance, as well as developing legal recommendations regarding land-use planning.

NEOBOR – European/international scientific network for BNCT research and medical training at the MARIA reactor

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[3]*Institute of Medical Biology Polish Academy of Sciences, Łódź, Poland*

A BNCT facility at the MARIA reactor based on a uranium fission converter is under construction. Selected subsystems of the research-training neutron station have already been constructed. It is expected to run a neutron beam with an intensity of 10^9 n cm^{-2} s^{-1} for the first time just after the arrival of the ordered uranium plates for the converter from the TVEL Fuel Company. Based on the MARIA facility the scientific network NEOBOR is forming. Several Polish and several European research institutions have already signed the Letter of Intent for collaboration in BNCT research. Work Packages were defined for the years 2016/2017. The four most important of them concern irradiation technology (tech), dosimetry (dosi), chemistry (chem) and biology (biol). Tte technology package coordinated by NCBJ contains: intelligent converter for beam intensity modulation, adjustable filter-moderator system for energy spectrum change, Pg-SPECT, collimator, beam shutter, beam stopper, beam dosimetry, room shielding and radiation protection system. Dosimetry package: the station will be equipped with unique recombination detectors and methods developed in Poland for determining the four components of the therapeutic dose. The set of four recombination detectors fulfils the needs of four dose determination for medical protocols in BNCT: (1) hydrogen free to measure external gamma radiation and from the capture reaction $^{1}H(n,\gamma)^{2}D$, (2) tissue-equivalent to distinguish gamma and total neutron dose, (3) nitrogen to detect protons from the $^{14}N(n,p)$ reaction and to extract thermal neutrons and finally (4) boron fluoride for boron dose determination from the $^{10}B(n,\alpha)^{7}Li$ reaction. Chemistry package: though two boron carriers, BSH and BPA, have been successfully used in BNCT for many years, broader use of BNCT as a clinically useful modality requires the development of new boron target compounds and complementary delivery methods. Through the now 50-year course of BNCT an array of potential boron carriers have been synthesized but none was investigated using actual BNCT experiments. Borated nucleosides are one of the best characterized and promising boron carriers for BNCT waiting in the pipeline for further development. The great advantage of this class of boron carriers, in addition to other properties useful in BNCT, is that nucleoside derivatives have been in clinical use for several decades and have become cornerstones of treatment for patients with cancer or viral infections. The knowledge accumulated on their medicinal chemistry, pharmacology and biology can be used to facilitate and accelerate the development of this class of boron carriers for BNCT. Development of innovative nucleoside boron carriers for BNCT is one of the NEOBOR network's targets. Biology package: research on boron carriers will include the synthesis and investigation of the properties of boron cluster conjugates with macromolecular carriers and small molecules. One aim is to impair the biological activity of the T-regulatory lymphocytes by boron cluster antibody conjugates, thereby enhancing the cytotoxic T-cells. In addition, it is planned to use phagocytic cells as carriers of insoluble boron derivatives (boron carbide, boron nitride) to deliver and deposit them in tumour tissues. NEOBOR also intends to investigate BNCT for the treatment of certain autoimmune disorders.

Main NEOBOR scientific network partners:

- National Centre for Nuclear Research,
- Institute of Medical Biology,
- Ludwik Hirszfeld Institute of Immunology and Experimental Therapy,
- Jan Długosz University,
- Università di Pavia,
- University of Tsakuba,
- National Research Nuclear University "MEPhI"

- Blokhin Russian Cancer Research Centre,
- VTT Technical Research Centre of Finland Ltd.

Reference

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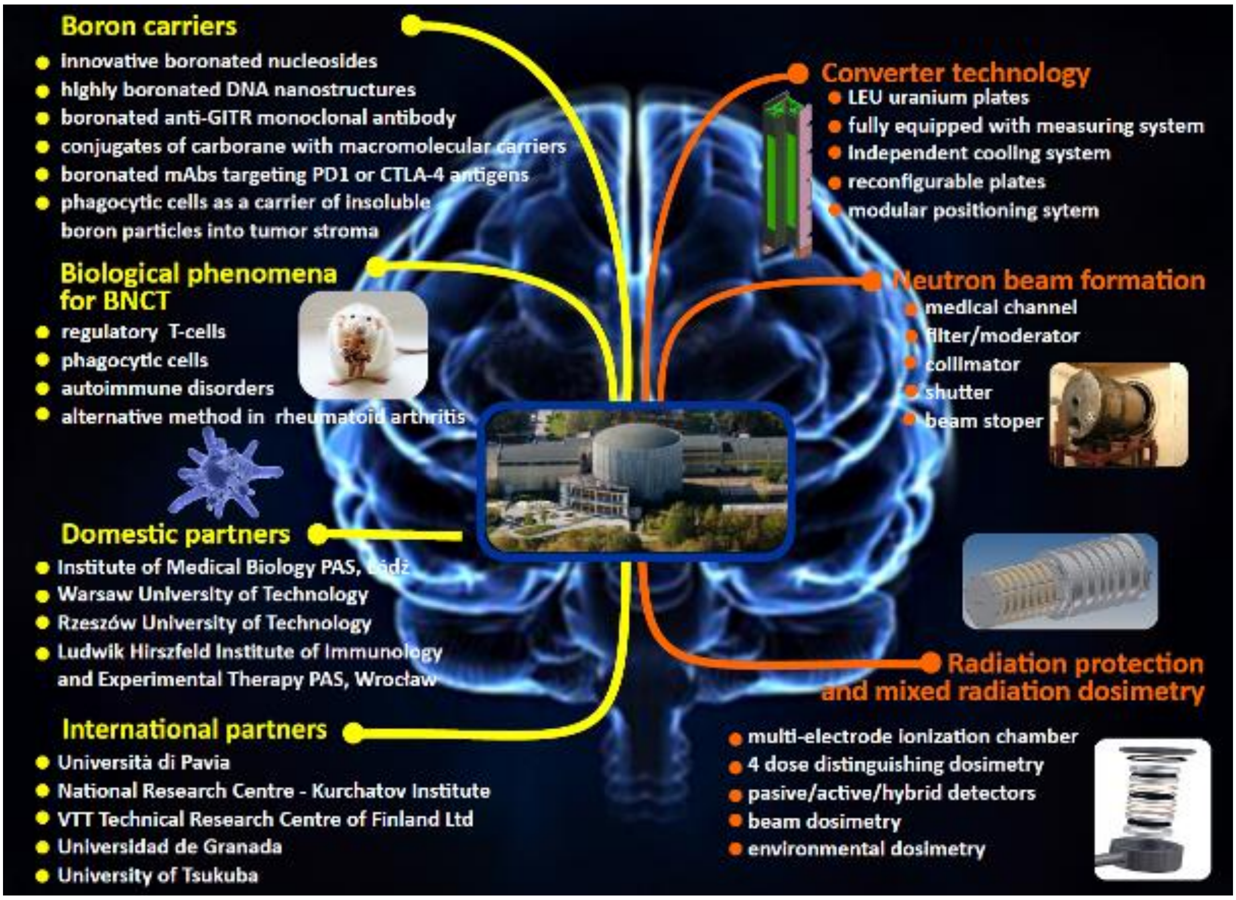

Experimental investigation of radiation shielding properties of concrete

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This paper presents the set of procedures developed in Radiation Protection Measurements Laboratory at National Centre for Nuclear Research for evaluation of the shielding properties of high performance concrete. The purpose of such a procedure is to characterize the material behavior against gamma and neutron radiation. Tests were performed on 40 cm × 40 cm × 5 cm slabs with density approx. 3000 kg·cm-3. Units were exposed to gamma radiation (^{60}Co, ^{137}Cs) and neutron radiation (^{239}Pu-Be) under controlled conditions.

Gamma sources were exposed with a Tema Synergie irradiator. The device produces a collimated beam directed through a bench for precise positioning of radiation detectors. The neutron source was exposed in free field geometry, directly from the specially designed container for storing high activity isotopic sources. During the exposure the sources were placed in the axis of the calibration bench, 100 cm over the floor.

To estimate the parameters of neutron radiation passing through concrete, two recombination chambers REM-2 and GW2 were used alternatively. REM-2 № 8 chamber [1] is a high pressure recombination chamber, filled with tissue equivalent gas containing 11 % of hydrogen. It has a similar sensitivity for neutron and gamma radiation. The second chamber, GW2 has a similar construction [2], but it is filled with CO_2. Hydrogen free filling assures weak sensitivity for neutron radiation.

The measurements were conducted for various thicknesses of each concrete. The slabs were set on a steel frame, strong enough to carry at least ten concrete plates with a total mass up to 300 kg. The distance between the source and the detector was set to 132,8 cm. The scattered fraction of neutrons was measured using on shadow cone [3] and estimated as 8,73±8.7 µGy h-1.

The final result of the study for each concrete, are the values of HVL and TVL determined on the basis of attenuation curves. The resulting values are presented on the Fig. 1. We can clearly state that the density of the shield is an important factor in attenuation. Hence reduction of high specific gravity enhance the attenuation performance of concretes.

In contrast to this figure is an attempt to search for a similar dependence for neutron radiation. As one can see in the graph in Fig. 2 for this particular problem it is hard to find a simple relation between the applied aggregate and shielding parameters for this studied concrete mixtures

Finally we decided to present our results [4] in the form of the nomograms allowing the determination of the attenuation coefficients in the radiation field.

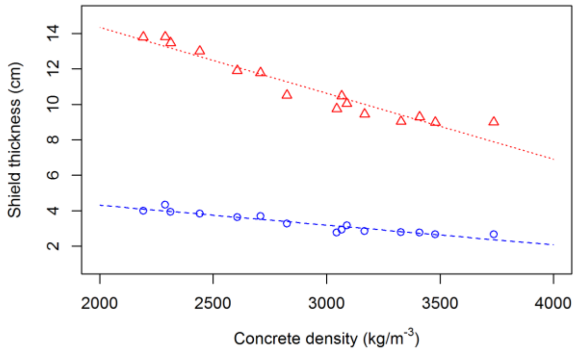

Fig. 1. Variation of HVL and TVL values, gamma attenuation estimators, as a function of the density of different concretes for a ^{137}Cs source.

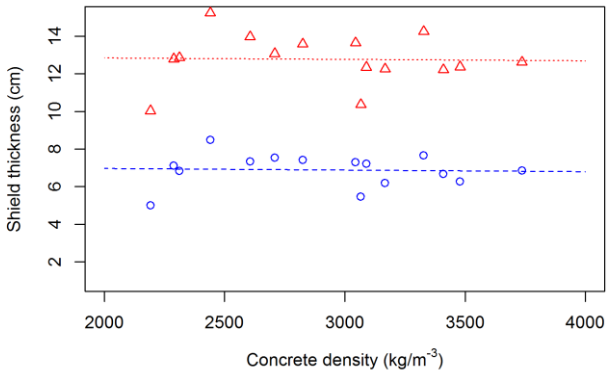

Fig. 2 .Measured values of 1.HVLn (circles) and 1.HVLn+2.HVLn (triangles) for various types of high performance concretes. Measured results do not show any correlation to concrete density.

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CAThyMARA – Child and Adult Thyroid Monitoring After a Reactor Accident

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The aim of the CAThyMARA (Child And Adult Thyroid Monitoring After Reactor Accident) project is to develop the monitoring strategies for the evaluation of absorbed dose resulting from internal exposures. The project focuses on post-accidental ^{131}I measurement in the thyroid, particularly for children. This project is realized in the frame of the Open Project for the European Radiation Research Area OPERRA 2014 by an international consortium of 15 institutes from 12 European countries.

Project is has taken place from December 2015 to May 2017.

The project
Project includes 7 workpackages:
WP1. Coordination,
WP2. Review of existing plans and means,
WP3. Measurement inter-comparison and harmonization for mobile units,
WP4. Measurement inter-comparison and harmonization for trained responders,
WP5. Monte Carlo calculations,
WP6. Criteria for screening and dose estimates for protective actions,
WP7. Guidelines and dissemination of knowledge.

NCBJ participates in the realization of WP4, WP5 and WP7.

The aim of WP4 is to organize the interlaboratory comparison in the field of iodine in thyroid measurements with radiometers, dosemeters and gamma-camera, i.e. non spectroscopic devices. Each participant of this study received a cylindrical neck phantom (made by SCK-CEN, Belgium) with sources of unknown activity (Ba-133 and Cs-137 as I-131 substitute) simulating thyroid glands of different sizes (5, 10, and adult) (fig. 1).

12 labs from 7 countries (Belgium, Czech Republic, Germany, Italy, Poland, Spain and Sweden) participated in the intercomparison.

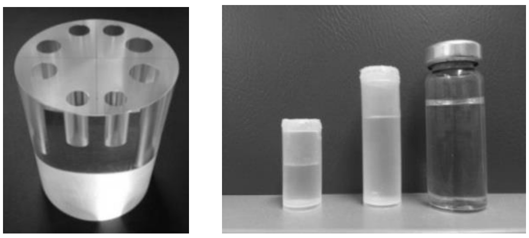

Fig. 1. SCK-CEN thyroid phantom, neck (left) three various thyroid glands (5y, 10y, adult) (right).

WP5 conducts calculations focused on modeling of detector responses to ^{131}I accumulated in a thyroid, using voxel models of humans of various age (a size) and gender and models of a few types of detectors (fig. 2). The calculations investigate the influence of geometry – the size of thyroid, type and shape of the detector, the measurement distance – as well as the influence of the ^{131}I isotope accumulated in other organs.

Fig. 2. Voxel model of a 5 years old child's and <nazwa> detector owned by NCBJ.

The aim of WP7 is to prepare technical guidelines. This work will start at January 2017

Conclusion
The expected result of the program will be the issue of guidelines and recommendations. These guidelines will include description of suitable calibration procedures for children and tabulated age dependent correction factors for common instruments. It also establishes recommendations and caveats regarding the internal dose calculations based on iodine measurement only, including the case of iodine prophylaxis. These guidelines will be useful for the technical staff performing the measurements. Moreover, the guidelines will include recommendations to decision makers, based on identified gaps in the monitoring strategies and its current implementation

Radiological measurements of soils from polar regions

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The aim of our research was to determinate which radioactive isotopes and in what quantities are present in soils from the North and South Poles. It is known that radionuclides in the soil have an influence on the electrical parameters of the atmosphere what is the main purpose of this analysis. For this purpose gamma radiation analysis was used. Due to the location of the station in a place away from sources of industrial pollution and traffic, the above issues may be successfully analyzed. Until now only artificial radionuclides were analyzed in the soils from polar regions [1]. Studies of radionuclides in Arctic sea ice have also been carried out [2].

The soil samples were taken from the area of the Stanisław Siedlecki Polish Polar Station in Hornsund (Fig. 1), managed by the Institute of Geophysics, Polish Academy of Sciences, for the North Pole (77° 00,23' N, 15° 32,14' E) at the beginning of June 2016 and the Henryk Arctowski Polish Antarctic Station on King George Island (Fig. 2), managed by Institute of Biochemistry and Biophysics, Polish Academy of Sciences**,** for the South Pole (62° 09.5814' S, 58° 28.6133' W) at the end of July 2016. Sampling depth was about 10cm. All the material was transported to the spectrometric laboratory at the National Center For Nuclear Research (Otwock-Świerk). Soil was purified from organic the elements but was not sieved so small stones could occur.

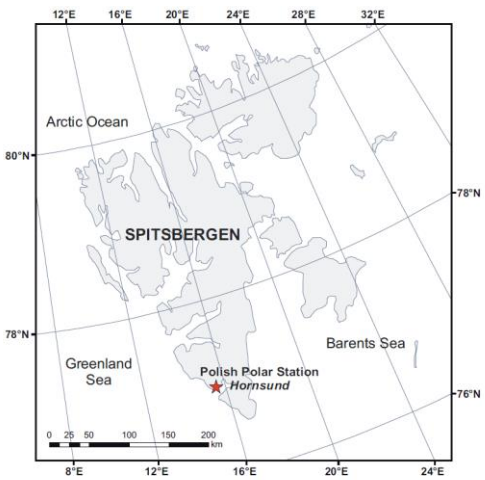

Fig. 1. Stanisław Siedlecki Polish Polar Station in Hornsund.

Each soil sample was dried at room temperature then transferred to a 1dm^3 marinelli container and measured using a Canberra gamma detector. The mass of each sample was exactly: 1938,6g (for the North Pole) and 1891.3g (for the South Pole). The measurement live time for both samples was 80 000 s and 500 000 s (the same time was used for background measurements). The background spectrum was removed from all spectra then we proceeded to analyze the spectra using a spreadsheet specially created for the purpose.

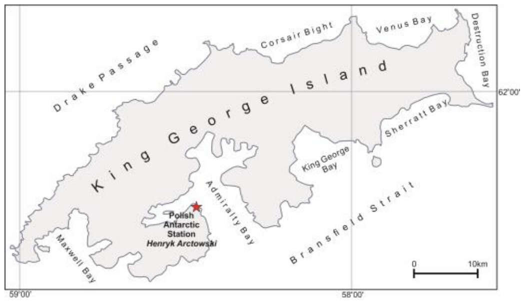

Fig. 2. Henryk Arctowski Polish Antarctic Station on the King George Island.

The main lines located in the spectra were from natural decay chains, especially from the thorium series and the uranium series. The most common isotopes in this region of the Earth are ^{214}Bi (uranium series) and ^{228}Th (thorium series). There were also several another lines such as ^{226}Ra, ^{212}Pb, ^{212}Bi and ^{208}Tl. In addition to isotopes from natural decay chains typical background lines like ^{40}K and ^{137}Cs (which come from the Chernobyl disaster and ground nuclear test explosions and is artificial) were also recorded.

In the region of the South Pole the same lines as in the region of the North Pole were recorded but in some varying quantities, excluding ^{137}Cs. This is probably caused by the low position of the South Pole where radioactive cloud did not reach after the Chernobyl disaster and ground nuclear test explosions. To confirm this thesis it is necessary to study more samples from different places in the region of the Polish stations.

Acknowledgments
This study were made courtesy of the Stanisław Siedlecki Polish Polar Station in Hornsund (Institute of Geophysics, Polish Academy of Sciences) and Henryk Arctowski Polish Antarctic Station on the King George Island (Institute of Biochemistry and Biophysics, Polish Academy of Sciences), which provided samples of soils.

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LIST OFPUBLICATIONS

PUBLICATIONS IN PEER-REVIEWED JOURNALS

1. Analysis of the elemental composition of the artefacts from the Kosewo archaeological site
A. Gójska, **E. Miśta**
Acta Phys. Pol. A Vol. 130 No 6 (2016) 1415

2. Dynamics of Users Activity on Web-Blogs
Z. Kozioł
Acta Phys. Pol. A Vol. 129 (2016) 1060-1063

3. Beam profile investigation of the new collimator system for the J-PET detector
E. Kubicz, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
Acta Phys. Pol. B Vol. 47 (2016) 537

4. Determination of impact parameters in aligned breakup of projectile-like fragments in ^{197}Au + ^{197}Au collisions at 23A MeV
T. Cap, ... , **J. Wilczyński**, **E. Piasecki**, ... et al.
Acta Phys. Pol. B Vol. 47 No 3 (2016) 983

5. Determination of the 3gamma fraction from positron annihilation in mesoporous materials for symmetry violation experiment with J-PET scanner
B. Jasińska, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
Acta Phys. Pol. B Vol. 47 (2016) 453

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P. Adrich, **A. Zając**, P. Wilk, M. Chorowski, J. Poliński, P. Bogdan
Acta Phys. Pol. B Vol. 47 No 2 (2016) 267

7. First Tests of Superthin, Ion-implanted Silicon Strip Detectors Produced by Low-temperature Technique
A.J. Kordyasz, ... , **P. Sibczyński**, ... et al.
Acta Phys. Pol. B Vol. 47 No 3 (2016) 797

8. Heavy Ion Results of the CMS Experiment
B. Boimska
Acta Phys. Pol. B Vol. 47 No 6 (2016) 1397

9. Investigation of the Freeze-Out Configuration in the Au-197+Au-197 Reaction at 23 a MeV
R. Najman, ... , **E. Piasecki**, **J. Wilczyński**, ... et al.
Acta Phys. Pol. B Vol. 47 No 3 (2016) 975

10. Investigation of γ-ray emission in heavy ion induced fission during the cyclotron beam-on periods
J. Kownacki, ... , **M. Kisieliński**, **E. Ruchowska**, **W. Czarnacki**, **A. Korman**, **P. Sibczyński**, ... et al.
Acta Phys. Pol. B Vol. 47 (2016) 723

11. Overview of the software architecture and data flow for the J-PET tomography device
W. Krzemień, ... , **P. Kowalski**, **L. Raczyński**, **W. Wiślicki**, ... et al.
Acta Phys. Pol. B Vol. 47 (2016) 561

12. Population of Levels in ^{15}O up to 15 MeV in Excitation by the ^{14}N(^{3}He, d) Reaction
C.E. Mertin, ... , **N. Keeley**, ... et al.
Acta Phys. Pol. B Vol. 47 (2016) 815

13. Potential of the J-PET detector for studies of discrete symmetries in decays of positronium atom - a purely leptonic system
P. Moskal, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
Acta Phys. Pol. B Vol. 47 (2016) 509

14. Sampling FEE and Trigger-less DAQ for the J-PET Scanner
G. Korcyl, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
Acta Phys. Pol. B Vol. 47 (2016) 491

15. Scatter fraction of the J-PET tomography scanner
P. Kowalski, ... , **W. Wiślicki**, **L. Raczyński**, **W. Krzemień**, ... et al.
Acta Phys. Pol. B Vol. 27 (2016) 549

16. Study of the Near-barrier Scattering of ^{8}He on ^{208}Pb
G. Marquinez-Duran, ... , **N. Keeley**, **L. Standylo**, **I. Strojek**, ... et al.
Acta Phys. Pol. B Vol. 47 (2016) 841

17. SUSY searches at the CMS
M. Kazana
Acta Phys. Pol. B Vol. 47 No 6 (2016) 1489

18. Upper Limits for the Production of the ηη-mesic Helium in the dd→3dd→3Henπ0nπ0 and dd→3dd→3Hepπ−pπ−Reactions
M. Skurzok, **W. Krzemień**, O. Rundel, P. Moskal
Acta Phys. Pol. B Vol. 47 (2016) 503

19. Pomiary ^{60}Co w obiektach z żelazną matrycą.
Z. Tymiński, ... , **T. Dziel**, **P. Saganowski**, **E. Kołakowska**, **A. Listkowska**, **K. Tymińska**, ... et al.
Acta Soci Metheor Polonorum Vol. 7 (2016) 144-150

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A.V. Kuchuk, ... , **R. Ratajczak**, ... et al.
Adv. Condensed Matter Phys. Vol. 2016 (2016) 26

21. X-ray and neutron radiography studies of archeological objects
E. Miśta, **J.J. Milczarek**, P. Tulik, **I. Fijał-Kirejczyk**
Advanced Mechatronics Solutions (Advances in Intelligent Systems and Computing) No 393 (2016) 187-192

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B. Sartowska, W. Starosta, **M. Barlak**, L. Waliś
AMSE Vol. 77 (2016) 53-57

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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
Annalen Phys. Vol. 1 (2016) 1

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A. Chartier, C. Onofri, L. VanBrutzel, C. Sabathier, **O. Dorosh**, **J. Jagielski**
Appl. Phys. Lett. Vol. 109 (2016) 181902

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F. Tzika, ... , **Z. Tymiński**, ... et al.
Appl. Radiat. Isot. Vol. 114 (2016) 167

26. A new 4∏(LS)-γ coincidence counter at NCBJ RC POLATOM with TDCR detector in the beta channel
T. Ziemek, **A. Jęczmieniowski**, **D. Cacko**, **R. Broda**, **E. Lech**
Appl. Radiat. Isot. No 109 (2016) 290-295

27. Application of Analig resin for ^{99m}Tc separation from ^{100}Mo target irradiated in cyclotron
D. Pawlak, **W. Wojdowska**, **J.L. Parus**, **R. Mikołajczak**
Appl. Radiat. Isot. Vol. 113 (2016) 75-78

28. Radionuclidic purity tests in ^{18}F radiopharmaceuticals production process
T. Dziel, **Z. Tymiński**, K. Sobczyk, A. Walęcka-Mazur, P. Kozanecki
Appl. Radiat. Isot. Vol. 109 (2016) 242-246

29. Standardisation and half-life measurements of ^{111}In
T. Dziel, **A. Listkowska**, **Z. Tymiński**
Appl. Radiat. Isot. Vol. 109 (2016) 345-348

30. Effect of the star formation histories on the SFR-M_* relation at $z \geq 2$
L.P. Cassarà, ... , **A. Durkalec**, ... et al.
Astron. Astrophys. Vol. 593 (2016) 9

31. Machine-learning identification of galaxies in the WISE x SuperCOSMOS all-sky catalogue
T. Krakowski, **K. Małek**, M. Bilicki, **A. Pollo**, M. Krupa, A. Kurcz
Astron. Astrophys. Vol. 596 (2016) A39

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A. Grazian, ... , **A. Durkalec**, ... et al.
Astron. Astrophys. Vol. 585 (2016) 48

33. The VIMOS Public Extragalactic Redshift Survey (VIPERS): On the correct recovery of the count-in-cell probability distribution function
J. Bel, ... , **K. Małek**, **A. Pollo**, ... et al.
Astron. Astrophys. Vol. 588 (2016) 15

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I. Davidzon, ... , **K. Małek**, ... et al.
Astron. Astrophys. Vol. 586 (2016) 21

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C. DiPorto, ... , **K. Małek**, **A. Pollo**, ... et al.
Astron. Astrophys. Vol. 594 (2016) 22

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N.P. Hathi, ... , **A. Durkalec**, ... et al.
Astron. Astrophys. Vol. 588 (2016) 26

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A. Solarz, T.T. Takeuchi, **A. Pollo**
Astron. Astrophys. Vol. 592 (2016) A155

38. Towards automatic classification of all WISE sources
A. Kurcz, M. Bilicki, **A. Solarz**, M. Krupa, **A. Pollo**, **K. Małek**
Astron. Astrophys. Vol. 592 No A25 (2016) 18

39. A crosstalk and non-uniformity correction method for the space-borne Compton polarimeter POLAR
H. Xiao, ... , **T. Batsch**, **D. Rybka**, **J. Szabelski**, **A. Zwolińska**, ... et al.
Astropart. Phys. Vol. 83 (2016) 6-12

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W.D. Apel, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Astropart. Phys. Vol. 77 (2016) 21

41. Improved absolute calibration of LOPES measurements and its impact on the comparison with REAS 3.11 and COREAS simulations
W.D. Apel, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Astropart. Phys. Vol. 75 (2016) 72-74

42. Real-Time Supernova Neutrino Burst Monitor at Super-Kamiokande
K. Abe, ... , **P. Mijakowski**, ... et al.
Astropart. Phys. Vol. 81 (2016) 39-48

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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
Astroph.J. Vol. 818 (2016) L22

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B.P. Abbott, ... , **A. Ćwiek**, **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
Astroph.J. Vol. 826 No 1 (2016) L13

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K. Abe, ... , **P. Mijakowski**, **K. Frankiewicz**, ... et al.
Astroph.J. Vol. 830 No 1 (2016) L11

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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
Astroph.J. Vol. 833 (2016) L1

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M. Bilicki, ... , **A. Solarz**, ... et al.
Astroph.J. Vol. 225 No 1 (2016) 5

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B.P. Abbott, ... , **A. Ćwiek**, **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
Astrophys J Suppl S Vol. 225 No 1 (2016) 8

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P. Kopka, A. Wawrzyńczak-Szaban, **M. Borysiewicz**
Atmos. Environ. Vol. 145 (2016) 201-212

50. Legal obstacles to the construction of high-temperature reactors for heat generation on the example of Polish regulations
J. Szczurek, **Ł. Koszuk**, **M. Klisińska**, **K. Andrzejewski**
ATW-INT J Nucl Power Vol. 7 (2016) 455

51. Ryzyko zdrowotne związane z niskimi dawkami promieniowania
L. Dobrzyński, K.W. Fornalski, **J. Reszczyńska**
Bezpieczeństwo jądrowe i ochrona radiologiczna Vol. 1 (2016) 42

52. Fabrication and characterization of superhard tungsten boride layers deposited by radio frequency magnetron sputtering
J. Chrzanowska, **Ł. Kurpaska**, M. Giżyński, **J. Hoffman**, Z. Szymański, T. Mościcki
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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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E. Łukowska-Chojnacka, M. Staniszewska, M. Bondaryk, **J.K. Maurin**, M. Bretner
Chirality Vol. 28 (2016) 347

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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
Class. Quantum Grav. Vol. 33 (2016) 134001

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M. Chmielewski, Sz. Nosewicz, **Ł. Kurpaska**, B. Romelczyk
COMPOS Part B-Eng Vol. 98 (2016) 88-96

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A. Burakowska, **M. Maciak**, **Ł. Murawski**, **S. Domański**, **M.A. Gryziński**
Czasopismo Inżynierii Lądowej Vol. XXXIII No 63 (2016) 87-96

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J. Kunikowska, ... , **D. Pawlak**, **R. Mikołajczak**, ... et al.
Endokrynologia Polska Vol. 67 No 1 (2016) 68-71

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M.P. Dąbrowski, H. Gohar, V. Salzano
Entropy Vol. 18 (2016) 60

60. Numerical simulation of stratified flow around a tall building of a complex shape
M. Korycki, L. Łobocki, A. Wyszogrodzki
Environ Fluid Mech Vol. 16 No 6 (2016) 1143

61. Abilities of helium immobilization by the UO_2 surface using the ab initio method
L. Dąbrowski, **M. Szuta**
Epl-Europhys Lett Vol. 115 No 62001 (2016) 62001-p1

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D. Pawlak, ... , **P. Garnuszek**, **M. Maurin**, **R. Mikołajczak**, ... et al.
Eur J Pharm Sci Vol. 85 (2016) 1-9

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T. Mainaa, ... , **P. Garnuszek**, **R. Mikołajczak**, ... et al.
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Z. Sosin, **J. Błocki**, J. Kallunkathariyil, J. Lukasik, P. Pawłowski
Eur. Phys. J. A Vol. 52 No 120 (2016) 4

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J. Rożynek, **G. Wilk**
Eur. Phys. J. A Vol. 52 (2016) 294

66. Conceptual design of the early implementation of the Neutron Detector Array (NEDA) with AGATA
T. Huyuk, ... , **M. Moszyński**, ... et al.
Eur. Phys. J. A Vol. 32 No 3 (2016) 55

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B. Singh, ... , **A. Chłopik**, **G. Kęsik**, **D. Melnychuk**, **B. Słowiński**, **A. Trzciński**, **M. Wojciechowski**, **S. Wronka**, **B. Zwięgliński**, ... et al.
Eur. Phys. J. A Vol. 52 (2016) 325

68. Measurement of the ~np → $d\pi^0\pi^0$ Reaction with Polarized Beam in the Region of the $d^*(2380)$ Resonance
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.
Eur. Phys. J. A Vol. 52 (2016) 147

69. New results from isochronous mass measurements of neutron-rich uranium fission fragments with the FRS-ESR-facility at GSI
R. Knoebel, ... , **Z. Patyk**, ... et al.
Eur. Phys. J. A Vol. 52 (2016) 138

70. Nonextensive Nambu Jona-Lasinio Model of QCD matter
J. Rożynek, **G. Wilk**
Eur. Phys. J. A Vol. 52 (2016) 13

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H. Mach, ... , **E. Ruchowska**, ... et al.
Eur. Phys. J. A Vol. 52 (2016) 172

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P. Gasik, ... , **M. Kirejczyk**, ... et al.
Eur. Phys. J. A Vol. 52 (2016) 177

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P. Gasik, ... , **M. Kirejczyk**, ... et al.
Eur. Phys. J. A Vol. 52 (2016) 177

74. A feasibility study of ortho-positronium decays measurement with the J-PET scanner based on plastic scintillators
D. Kamińska, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
Eur. Phys. J. C Vol. 76 No 8 (2016) 445

75. A precise measurement of the B^0 meson oscillation frequency
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. 76 (2016) 412

76. Centrality dependence of charged jet production in p-Pb collisions at $\sqrt{s_{NN}}$= 5.02 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. C Vol. 76 (2016) 271

77. Event generator tunes obtained from underlying event and multiparton scattering measurements
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. 76 (2016) 155

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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. 76 (2016) 325

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J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. C Vol. 76 (2016) 184

80. Measurement of differential cross sections for Higgs boson production in the diphoton decay channel 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.
Eur. Phys. J. C Vol. 76 (2016) 13

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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. 76 (2016) 536

82. Measurement of inclusive jet production and nuclear modifications in 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.
Eur. Phys. J. C Vol. 76 (2016) 372

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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. Traczyk**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 76 (2016) 469

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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. 76 (2016) 451

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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. 76 (2016) 265

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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. 76 (2016) 128

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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. 76 (2016) 401

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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. 76 (2016) 379

89. Measurements of $\pi^{\pm}$ differential yields from the surface of the T2K replica target for incoming 31 GeV/c protons with the NA61/SHINE spectrometer at the CERN SPS
N. Abgrall, ... , **K. Kowalik**, **E. Rondio**, **J. Stepaniak**, ... et al.
Eur. Phys. J. C Vol. 76 No 11 (2016) 1-27

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N. Abgrall, ... , **K. Kowalik**, **E. Rondio**, **J. Stepaniak**, ... et al.
Eur. Phys. J. C Vol. 76 No 2 (2016) 84

91. Multiplicity and transverse momentum evolution of charge-dependent correlations in pp, p–Pb, and Pb–Pb collisions at the LHC
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. C Vol. 76 (2016) 86

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A. Aduszkiewicz, ... , **K. Kowalik**, **E. Rondio**, **J. Stepaniak**, ... et al.
Eur. Phys. J. C Vol. 76 (2016) 635

93. New tests of the variability of the speed of light
M.P. Dąbrowski, V. Salzano, A. Balcerzak, R. Lazkoz
Eur. Phys. J. C Vol. 126 (2016) 04012

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H. Abramowicz, ... , **M. Adamus**, **T. Tymieniecka**, ... et al.
Eur. Phys. J. C No 76 (2016) 1

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J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. C Vol. 76 (2016) 245

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A. Aduszkiewicz, ... , **K. Kowalik**, **E. Rondio**, **J. Stepaniak**, ... et al.
Eur. Phys. J. C Vol. 76 No 4 (2016) 198

97. Search for direct pair production of supersymmetric top quarks decaying to all-hadronic final states 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.
Eur. Phys. J. C Vol. 76 (2016) 460

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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. Traczyk**, **P. Zalewski**, ... et al.
Eur. Phys. J. C Vol. 76 (2016) 371

99. Search for Higgs-like bosons decaying into long-lived exotic particles
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. 76 (2016) 664

100. Search for lepton flavour violating decays of heavy resonances and quantum black holes to an eμ pair 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.
Eur. Phys. J. C Vol. 76 (2016) 317

101. Search for massive WH resonances decaying into the lνbbbar final state 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.
Eur. Phys. J. C Vol. 76 (2016) 237

102. Search for new physics in same-sign dilepton events in proton–proton collisions at $\sqrt{s}$= 13TeV
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. 76 (2016) 439

103. Stopping and straggling of H and He in ZnO
R. Fadanelli, ... , **A. Turos**, ... et al.
Eur. Phys. J. D Vol. 70 (2016) 178

104. Particle identification in ALICE: a Bayesian approach
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Eur. Phys. J. Plus Vol. 131 (2016) 168

105. Atropoisomerism in mono- and di-arylsubstituted 4-Amino-2,6-lutidines
P. Roszkowski, D. Błachut, **J.K. Maurin**, **A. Budzianowski**, M. Górecki, J. Frelek, Z. Czarnocki
European Journal of Organic Chemistry Vol. 2016 No 17 (2016) 2966-2971

106. Pilot plant for electron beam treatment of flue gases from heavy fuel oil fired boiler
A. Pawelec, A.G. Chmielewski, **J. Licki**, B. Han, J. Kim, N. Kunnummal, O.I. Fageeha
Fuel Process Technol Vol. 145 (2016) 123-129

107. 68Ga-DOTATATE PET in juvenile angiofibroma
Z. Gronkiewicz, W. Kukwa, L. Krolicki, A. Cyran-Clebicka, **D. Pawlak**, C. Stankiewicz
Future Oncol Vol. 12 (2016) 1483-1491

108. The K x-ray line structures of the 3d-transition metals in warm dense plasma
E. Szymańska, Ł. Syrocki, K. Słabkowska, M. Polasik, **J. Rzadkiewicz**
H. En. Den. Phys. Vol. 20 (2016) 29

109. Commissioning and Field Tests of a Van-Mounted System for the Detection of Radioactive Sources and Special Nuclear Material
D. Chester, ... , **J. Iwanowska-Hanke**, **P. Sibczyński**, **M. Moszyński**, **Ł. Świderski**, ... et al.
IEEE Trans. Nucl. Sci. Vol. 63 No 2 (2016) 1314-1322

110. Digital Approach To High Count Rate Gamma-Ray Spectrometry
S. Korolczuk, **S. Mianowski**, **J. Rzadkiewicz**, **P. Sibczyński**, **Ł. Świderski**, **I. Zychor**
IEEE Trans. Nucl. Sci. Vol. 63 No 3 (2016) 1668

111. Energy Resolution and Slow Components in Undoped CsI Crystals
M. Moszyński, ... , **A. Syntfeld-Każuch**, **Ł. Świderski**, **P. Sibczyński**, **M. Grodzicka**, **T. Szczęśniak**, ... et al.
IEEE Trans. Nucl. Sci. Vol. 63 No 2 (2016) 459

112. Photomultipliers with the Screening Grid at Anode for the TOF PET Block Detectors
M. Moszyński, **T. Szczęśniak**, **M. Grodzicka**, R. Leclercq, A. West, **M. Kapusta**
IEEE Trans. Nucl. Sci. Vol. 63 No 6 (2016) 100

113. Responses of single-cell and differential calorimeters: from out-of-pile callibration to irradiation campaigns
J. Brun, ... , **M. Tarchalski**, **K. Pytel**, **J. Jagielski**, ... et al.
IEEE Trans. Nucl. Sci. Vol. 63 No 3 (2016) 1630

114. Odtwarzanie jednostki aktywności radionuklidów za pomocą techniki ciekłych scyntylatorów (LSC)-Realisation of radionuclides activity unit using the liquid scintillation counting (LSC)
R. Broda, **T. Dziel**, **A. Listkowska**, **T. Ziemek**
Informatyka, Automatyka, Pomiary w gospodarce i ochronie środowiska No 3 (2016) 28

115. Structural and Thermoelectric Properties of Polycrystallinep-Type Mg2-xLixSi
P. Nieroda, A. Kolezynski, M. Oszajca, **J.J. Milczarek**, K.T. Wojciechowski
J Electron Mater Vol. 45 No 7 (2016) 3418

116. A one-step automated synthesis of the dopamine transporter ligand [^{18}F]FECNT from the chlorinated precursor
J. Pijarowska-Kruszyna, **A. Jaroń**, A. Kachniarz, B. Małkowski, **P. Garnuszek**, **R. Mikołajczak**
J Labelled Comp Radiopharm Vol. 59 (2016) 82-86

117. Stability of ion acoustic nonlinear waves and solitons in magnetized plasmas
P. Goldstein, **E. Infeld**
J Plasma Phys Vol. 82 No 6 (2016) 905820603

118. Measurement and comparison of individual external doses of high-school students living in Japan, France, Poland and Belarus—the D-shuttle project—
N. Adachi, ... , **L. Dobrzyński**, **M. Sadowski**, ... et al.
J Radiol Prot Vol. 36 (2016) 49

119. Electron-beam pulse annealed Ti-implanted GaP
Z. Werner, **M. Barlak**, **R. Ratajczak**, P. Konarski, A.M. Markov, R. Heller
J. Appl. Phys. Vol. 120 (2016) 085103-1

120. No need for dark matter in galaxy clusters within Galileon theory
V. Salzano, D.F. Mota, **M.P. Dąbrowski**, S. Capozziello
J. Cosm. Astroparticle Phys. Vol. 10 (2016) 033

121. Reconstructing WIMP properties through an interplay of signal measurements in direct detection, Fermi-LAT, and CTA searches for dark matter
L. Roszkowski, **E. Sessolo**, **S. Trojanowski**, **A.J. Williams**
J. Cosm. Astroparticle Phys. Vol. 1608 No 08 (2016) 033

122. Study of cosmic ray events with high muon multiplicity using the ALICE detector at the CERN Large Hadron Collider
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
J. Cosm. Astroparticle Phys. Vol. 01 (2016) 032

123. $Ca_{10}Li(VO_4)_7:Nd^{3+}$, a promising laser material: growth, structure and spectral characteristics of a Czochralski-grown single crystal
M.B. Kosmyna, ... , **K. Wieteska**, ... et al.
J. Crystal Growth Vol. 445 (2016) 101

124. Angular analysis of the $B^0 \rightarrow K^{*0}\mu^+\mu^-$ decay
V. Batozskaya, ... , **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 02 (2016) 104

125. Azimuthal decorrelation of jets widely separated in rapidity in pp collisions at $\sqrt{s}$ =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. 08 (2016) 139

126. Centrality dependence of ψ(2S) suppression in p-Pb collisions at $\sqrt{s_{NN=}}$ 5.02 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
J. High Energy Phys. Vol. 06 (2016) 050

127. Cornering diphoton resonance models at the LHC
M. Backovic, S. Kulkarni, A. Mariotti, **E. Sessolo**, M. Spannowsky
J. High Energy Phys. Vol. 1608 (2016) 018

128. Correlations between jets and charged particles in PbPb and pp 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.
J. High Energy Phys. Vol. 02 (2016) 156

129. Decomposing transverse momentum balance contributions for quenched jets 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.
J. High Energy Phys. Vol. 11 (2016) 55

130. Differential branching fraction and angular moments analysis of the decay B0->K+π−μ+μ− in the K∗0,2(1430)0 region
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. 12 (2016) 065

131. Differential studies of inclusive J/Ψ and Ψ(2S) production at forward rapidity in Pb–Pb collisions at $\sqrt{s_{NN}}$= 2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
J. High Energy Phys. Vol. 05 (2016) 179

132. Elliptic flow of electrons from heavy-flavour hadron decays at mid-rapidity 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.
J. High Energy Phys. Vol. 09 (2016) 028

133. Evidence for exclusive $\gamma\gamma\rightarrow W^+W^-$ production and constraints on anomalous quartic gauge couplings in pp collisions at $\sqrt{s}$=7 and 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Frueboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Traczyk**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 08 (2016) 119

134. Finite-temperature modification of heavy particle decay and dark matter annihilation
M. Beneke, F. Dighera, **A.J. Hryczuk**
J. High Energy Phys. Vol. 1609 (2016) 31

135. First observation of the decay $B^0_s\rightarrow K^0_S K^*(892)^0$
V. Batozskaya, ... , **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 01 (2016) 012

136. Higher harmonic flow coefficients of identified hadrons in Pb–Pbcollisions at $\sqrt{s_{NN}}$= 2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
J. High Energy Phys. Vol. 09 (2016) 164

137. Less-simplified models of dark matter for direct detection and the LHC
A. Choudhury, **K. Kowalska**, **L. Roszkowski**, **E. Sessolo**, **A.J. Williams**
J. High Energy Phys. Vol. 1604 (2016) 182

138. Measurement of D-meson production versus multiplicity in p-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.
J. High Energy Phys. Vol. 08 (2016) 078

139. Measurement of D^+_s production and nuclear modification factor in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
J. High Energy Phys. Vol. 03 (2016) 082

140. Measurement of differential and integrated fiducial cross sections for Higgs boson production in the four-lepton decay channel in pp collisions at $\sqrt{s}$=7 and 8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Frueboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 04 (2016) 005

141. Measurement of electroweak production of a W boson and two forward jets in proton-proton collisions at $\sqrt{s}$=8 TeV
V. Khachatryan, ... , **H. Białkowska**, **M. Bluj**, **B. Boimska**, **T. Frueboes**, **M. Górski**, **M. Kazana**, **K. Nawrocki**, **K. Romanowska-Rybińska**, **M. Szleper**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 11 (2016) 147

142. Measurement of forward W and Z boson production in association with jets in proton-proton collisions at $\sqrt{s}$=8 TeV
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 (2016) 131

143. Measurement of forward W and Z boson production in pp collisions at √s=8TeV
V. Batozskaya, ... , **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 01 (2016) 155

144. Measurement of forward $W \to e\nu$ production in pp collisions at √s=8TeV
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. 10 (2016) 030

145. Measurement of the CKM angle γ using $B^0 \to DK^{*0}$ with $D \to K^0{}_S\pi^+\pi^-$ decays
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. 08 (2016) 137

146. Measurement of the forward Z boson production cross-section in pp collisions at √s=13 TeV
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. 09 (2016) 136

147. Measurement of the mass of the top quark in decays with a J/ψ meson in pp collisions at 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. 12 (2016) 123

148. Measurement of the properties of the $\Xi^{*0}{}_b$ baryon
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 (2016) 161

149. Measurement of the ratio of branching fractions $B(B^+{}_c \to J/\psi K^+)/B(B^+{}_c \to J/\psi\pi_+)$
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. 09 (2016) 153

150. Measurement of the t-tbar production cross section in the e-mu channel in proton-proton 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. Traczyk**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 08 (2016) 029

151. Measurement of top quark polarisation in t-channel single top quark production
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 (2016) 073

152. Measurement of transverse momentum relative to dijet systems in PbPb and pp 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.
J. High Energy Phys. Vol. 01 (2016) 006

153. Measurements of prompt charm production cross-sections in pp collisions at √s = 13 TeV
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. 03 (2016) 159

154. Measurements of the Higgs boson production and decay rates and constraints on its couplings from a combined ATLAS and CMS analysis of the LHC pp collision data at √s=7 and 8 TeV
G. Aad, ... , **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 (2016) 045

155. Measurements of the S-wave fraction in $B^0 \to K^+\pi^-\mu^+\mu^-$ decays and the $B^0 \to K^*(892)^0\mu^+\mu^-$ differential branching fraction
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 (2016) 047

156. Model-independent measurement of mixing parameters in $D^0 \to K^0_S\pi^+\pi^-$ decays
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. 04 (2016) 033

157. Model-independent measurement of the CKM angle γ using $B^0 \to DK^{*0}$ decays with $D \to K^0_S\pi^+\pi^-$ and $K^0_SK^+K^-$
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. 06 (2016) 131

158. Observation of the $B^0_s \to J/\psi\phi\phi$ decay
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. 03 (2016) 040

159. Observation of top quark pairs produced in association with a vector boson 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. 01 (2016) 096

160. Observation of $\Lambda^0_b \to \psi(2S)pK^-$ and $\Lambda^0_b \to J/\psi\pi^+\pi^-pK^-$ decays and a measurement of the Λ^0_b baryon mass
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 (2016) 132

161. Observations of $\Lambda^0_b \to \Lambda K^+\pi^-$ and $\Lambda^0_b \to \Lambda K^+K^-$ decays and searches for other Λ^0_b and Ξ^0_b decays to $\Lambda h^+h'^-$ final states
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. 1605 (2016) 081

162. On the one loop gamma^* --> q anti-q impact factor and the exclusive diffractive cross sections for the production of two or three jets
R. Boussarie, A.V. Grabovsky, **L. Szymanowski**, S. Wallon
J. High Energy Phys. Vol. 11 (2016) 149

163. Phenomenological MSSM interpretation of CMS searches 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. Traczyk**, **P. Zalewski**, ... et al.
J. High Energy Phys. Vol. 10 (2016) 129

164. Precision measurement of the η→π+π−π0 Dalitz plot distribution with the KLOE detector
A. Anastasi, ... , **M. Berłowski**, **W. Krzemień**, **A. Kupść**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 1605 (2016) 019

165. Production of associated Y and open charm hadrons in pp collisions at √s=7 and 8 TeV via double parton scattering
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. 1607 (2016) 052

166. Relic density of wino-like dark matter in the MSSM
M. Beneke, A. Bharucha, F. Dighera, C. Hellmann, **A.J. Hryczuk**, S. Recksiegel, P. Ruiz-Femenia
J. High Energy Phys. Vol. 1603 (2016) 119

167. Search for a massive resonance decaying into a Higgs boson and a W or Z boson in hadronic 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.
J. High Energy Phys. Vol. 02 (2016) 145

168. Search for a very light NMSSM Higgs boson produced in decays of the 125 GeV scalar boson and decaying into τ leptons 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. 01 (2016) 079

169. Search for anomalous single top quark production in association with a photon 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 (2016) 035

170. Search for dark matter in proton-proton collisions at 8 TeV with missing transverse momentum and vector boson tagged jets
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. 12 (2016) 83

171. Search for dark matter particles in proton-proton collisions at √s=8 TeV using the razor variables
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. 12 (2016) 088

172. Search for direct pair production of scalar top quarks in the single- and dilepton channels 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. 07 (2016) 027

173. Search for excited leptons 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 (2016) 125

174. Search for heavy Majorana neutrinos in $e^{\pm}e^{\pm}$+jets and $e^{\pm}$ $\mu^{\pm}$+jets events 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. 04 (2016) 169

175. Search for Higgs boson off-shell production in proton-proton collisions at 7 and 8 TeV and derivation of constraints on its total decay width
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. 09 (2016) 051

176. Search for new physics in final states with two opposite-sign, same-flavor leptons, jets, and missing transverse momentum 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.
J. High Energy Phys. Vol. 12 (2016) 013

177. Search for new physics with the M_{T2} variable in all-jets final states produced 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.
J. High Energy Phys. Vol. 10 (2016) 006

178. Search for s 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. 09 (2016) 027

179. Search for supersymmetry in pp collisions at √s=13 TeV in the single-lepton final state using the sum of masses of large-radius jets
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. 08 (2016) 122

180. Search for the associated production of a Higgs boson with a single top quark 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. 06 (2016) 177

181. Search for the production of an excited bottom quark decaying to tW 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. 01 (2016) 166

182. Search for W′→tb 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. 02 (2016) 122

183. Study of $D^{(*)+}_{sJ}$ mesons decaying to $D^{*+}K^0_S$ and $D^{*0}K^+$ final states
V. Batozskaya, ... , **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. High Energy Phys. Vol. 02 (2016) 133

184. Study of ψ(2S) production and cold nuclear matter effects in pPb collisions at $\sqrt{s_{NN}}$=5 TeV
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. 03 (2016) 133

185. Sudakov Resummations in Mueller-Navelet Dijet Production
A.H. Mueller, **L. Szymanowski**, S. Wallon, B.W. Xiao, F. Yuan
J. High Energy Phys. Vol. 03 (2016) 096

186. Transverse momentum dependence of D-meson production in Pb–Pb collisions at $\sqrt{s_{NN}}$ =2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
J. High Energy Phys. Vol. 03 (2016) 081

187. A new algorithm for identifying the flavour of B^0_s mesons at LHCb
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
J. Instrum. Vol. 11 No 5 (2016) P05010

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M. Rosiński, ... , **A. Szydłowski**, **A. Malinowska**, ... et al.
J. Instrum. No 11 (2016) CO5017

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S. Korolczuk, M. Linczuk, R. Romaniuk, **I. Zychor**
J. Instrum. Vol. 11 (2016) C09013

190. Performance of the EUSO-Balloon electronics
P. Barrillon, ... , **J. Karczmarczyk**, **J. Szabelski**, ... et al.
J. Instrum. Vol. 11 (2016) C01075

191. Reconstruction and identification of τ lepton decays to hadrons and ν_τ at CMS
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. Instrum. Vol. 11 (2016) P01019

192. Effect of hybrid oxidation on the titanium oxide layer\\\'s properties investigated by spectroscopic methods
J.J. Jasinski, **Ł. Kurpaska**, M. Lubas, M. Lesniak, J. Jasinski, M. Sitarz
J. Mol. Struct. Vol. 1126 (2016) 165

193. Influence of Ar-irradiation on structural and nanomechanical properties of purezirconium measured by means of GIXRD and nanoindentation techniques
Ł. Kurpaska, ... , **K. Nowakowska-Langier**, **J. Jagielski**, ... et al.
J. Mol. Struct. Vol. 1126 (2016) 226

194. Shift in low-frequency vibrational spectra measured in-situ at 600 C by Raman spectroscopy of zirconia developed on pure zirconium and Zr-1%Nb alloy
Ł. Kurpaska, M. Lesniak, R. Jadach, M. Sitarz, J.J. Jasinski, J.-L. Grosseau-Poussard
J. Mol. Struct. Vol. 1126 (2016) 186

195. Study of sub-oxide phases at the metal-oxide interface in oxidized pure zirconium and Zr-1.0% Nb alloy by using SEM/FIB/EBSD and EDS techniques
Ł. Kurpaska, I. Jóźwik, **J. Jagielski**
J. Nucl. Mater. Vol. 476 No 1 (2016) 56-62

196. Latest (Anti) Neutrino Oscillation Results from T2K
J. Zalipska
J. of Phys. Conf. S. Vol. 770 (2016) 012022

197. Indirect searches for dark matter particles at Super-Kamiokande
P. Mijakowski
J. Phys. Conf. Ser. Vol. 718 No 4 (2016) 042040

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S. Adrian-Martinez, ... , **P. Mijakowski**, ... et al.
J. Phys. G: Nucl. Part. Phys. Vol. 43 No 8 (2016) 084001

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K. Akiba, ... , **L. Szymanowski**, ... et al.
J. Phys. G: Nucl. Part. Phys. Vol. 43 (2016) 110201

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A. Sobiczewski
J. Phys. G: Nucl. Part. Phys. Vol. 43 (2016) 095108

201. CFD modelling of low-emission pulverized coal swirl burner
J. Polewka, P. Krawczyk, **P. Prusiński**
J. Power Technol. Vol. 96 No 5 (2016) 313-320

202. Impact of the DBA Blocks Alignment on the Beam Dynamics of the Storage Ring in Solaris
J.J. Wiechecki, ... , **R. Nietubyć**, ... et al.
JACoW (2016)

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A.I. Wawrzyniak, ... , **R. Nietubyć**, ... et al.
JACoW (2016)

204. Prospects for Localization of Gravitational Wave Transients by the Advanced LIGO and Advanced Virgo Observatories
J. Aasi, ... , **A. Królak**, **A. Zadrożny**, ... et al.
Living Rev Relativ Vol. 19 (2016) 1

205. ^{90}Y microspheres prepared by sol-gel method, promising medical material for radioembolization of liver malignancies
W. Łada, **E. Iller**, D. Wawszczak, **M. Konior**, **T. Dziel**
Mat. Sci. Eng. C Vol. 67 (2016) 629–635

206. Re-melting technique with high intense pulsed plasma beams applied for surface modification of steel. Own investigations
B. Sartowska, **M. Barlak**, L. Waliś, W. Starosta
Mat. Sci. Forum Vol. 879 (2016) 1668-1674

207. Novel GIMS technique for deposition of coloured Ti/TiO2 coatings in industrial scale
KrzysztofZdunek, ... , **K. Nowakowska-Langier**, ... et al.
Materials Science-Poland Vol. 34 No 1 (2016) x

208. The application of magnetic self-filter to optimization of AlN film growth process during the impulse plasma deposition synthesis
R. Chodun, **K. Nowakowska-Langier**, S. Okrasa, K. Zdunek
Materials Science-Poland Vol. 34 No 1 (2016) 126-131

209. Titanium nitride coatings synthesized by IPD method with eliminated current oscillations
R. Chodun, **K. Nowakowska-Langier**, K. Zdunek
Materials Science-Poland Vol. 3 (2016) 523-528

210. A method of measuring the neutron energy spectrum by activation detectors
A. Wojciechowski, Y.C. Lim, V. Stepanenko, S. Tiutiunnikov, A. Khilmanovich, B. Martsynkevich
MEASUREMENT Vol. 90 No 90 (2016) 118-126

211. Co-60 Isotope Content in Iron Meteorites
Z. Tymiński, **A. Burakowska**, **K. Tymińska**, M. Stolarz, A. Olech, P. Żołądek, M. Wiśniewski
Meteoritics & Planetary Science Vol. 51 (2016) 634

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A. Olech, ... , **Z. Tymiński**, ... et al.
Mon. Not. R. Astron. Soc. Vol. 461 (2016) 674-683

213. Clustering-based redshift estimation: application to VIPERS/CFHTLS
V. Scottez, ... , **K. Małek**, **A. Pollo**, ... et al.
Mon. Not. R. Astron. Soc. Vol. 462 (2016) 1683-1696

214. Cyclic multiverses
K. Marosek, **M.P. Dąbrowski**, A. Balcerzak
Mon. Not. R. Astron. Soc. Vol. 461 (2016) 2777-2788

215. Magnetoelectric effect in ceramics based on bismuth ferrite
E. Jartych, T. Pikula, **K. Kowal**, J. Dzik, P. Guzdek, D. Czekaj
Nanoscale Research Letters Vol. 11 (2016) 234

216. Editorial. Special issue: Somatostatin Receptor Scintigprahy in NEN
R. Mikołajczak, GrzegorzKamiński
Nucl Med Rev Vol. 19 No 2 (2016) 1

217. Influence of PET/CT ^{68}Ga somatostatin receptor imaging on proceeding with patients, who were previously diagnosed with ^{99m}Tc-EDDA/HYNIC-TOC SPECT
D. Mądrzak, **R. Mikołajczak**, G. Kamiński
Nucl Med Rev Vol. 19 No 2 (2016) 88-92

218. Oxidation of methionine — is it limiting the diagnostic properties of ^{99m}Tc-labeled Exendin-4, a Glucagon-Like Peptide-1 receptor agonist?
B. Janota, **U. Karczmarczyk**, **E. Laszuk**, **P. Garnuszek**, **R. Mikołajczak**
Nucl Med Rev Vol. 19 No 2 (2016) 104-110

219. Radiopharmaceuticals for somatostatin receptor imaging
R. Mikołajczak, H.R. Maecke
Nucl Med Rev Vol. 19 No 2 (2016) 126-132

220. Diagnostics and control for the steady state and pulsed tokamak DEMO
F.P. Orsitto, ... , **J. Rzadkiewicz**, ... et al.
Nucl. Fusion Vol. 56 (2016) 026009

221. Hydrogen release from irradiated elastomers measured by Nuclear Reaction Analysis
J. Jagielski, ... , **A. Kosińska**, ... et al.
Nucl. Instr. and Meth. B Vol. 371 (2016) 216-219

222. Mechanical properties of irradiated $Gd_2Zr_2O_7$ pyrochlores as studied by nanoindentation technique – effect of grains and grain boundaries.
Ł. Kurpaska, **J. Jagielski**
Nucl. Instr. and Meth. B Vol. 379 No 15 (2016) 107-111

223. Nanoindentation study of irradiation and temperature effectsin yttria-stabilized zirconia
Ł. Kurpaska, **J. Jagielski**, **K. Nowakowska-Langier**
Nucl. Instr. and Meth. B Vol. 379 (2016) 112-115

224. A new method for designing dual foil electron beam forming systems. I. Introduction, concept of the method
P. Adrich
Nucl. Instr. Meth. A Vol. 817 (2016) 93–99

225. A new method for designing dual foil electron beam forming systems. II. Feasibility of practical implementation of the method
P. Adrich
Nucl. Instr. Meth. A Vol. 817 (2016) 100–108

226. Determination of nuclear fuel burn-up axial profile by neutron emission measurement
R. Prokopowicz, **K. Pytel**
Nucl. Instr. Meth. A Vol. 838 (2016) 18-23

227. Energy resolution of scintillation detectors
M. Moszyński, **A. Syntfeld-Każuch**, **Ł. Świderski**, **M. Grodzicka**, **J. Iwanowska-Hanke**, **P. Sibczyński**, **T. Szczęśniak**
Nucl. Instr. Meth. A Vol. A805 (2016) 25-35

228. EUSO-Balloon: The first flight
V. Scotti, ... , **T. Batsch**, **J. Karczmarczyk**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Nucl. Instr. Meth. A Vol. 824 (2016) 655

229. EUSO-TA prototype telescope
F. Bisconti, ... , **T. Batsch**, **J. Karczmarczyk**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Nucl. Instr. Meth. A Vol. 824 (2016) 603

230. SWAN - Detection of explosives by means of fast neutron activation analysis
M. Gierlik, ... , **S. Borsuk**, **Z. Guzik**, **J. Iwanowska-Hanke**, **Ł. Kaźmierczak**, **S. Korolczuk**, **T. Kozłowski**, **T. Krakowski**, **R. Marcinkowski**, **Ł. Świderski**, **M. Szeptycka**, **J. Szewiński**, **A. Urban**, ... et al.
Nucl. Instr. Meth. A Vol. 834 (2016) 16-23

231. The First Level Trigger of JEM-EUSO: Concept and tests
M. Bertaina, ... , **T. Batsch**, **J. Karczmarczyk**, **Z. Plebaniak**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Nucl. Instr. Meth. A Vol. 824 (2016) 253

232. Trilateration-based reconstruction of ortho-positronium decays into three photons with the J-PET detector
A. Gajos, ... , **P. Kowalski**, **W. Krzemień**, **L. Raczyński**, **W. Wiślicki**, ... et al.
Nucl. Instr. Meth. A Vol. 819 (2016) 54

233. (Anti-)deuteron production and anisotropic flow measured with ALICE at the LHC
R. Lea, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 264-267

234. Azimuthal anisotropy of charged jet production in $\sqrt{s_{NN}}$=2.76 TeV Pb–Pb collisions: Quark Matter 2015
R.A. Bertens, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 629-632

235. Charged-Particle Multiplicity Distributions over a Wide Pseudorapidity Range in Proton–Proton Collisions with ALICE
V. Zaccolo, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 529-532

236. Charmonium production in Pb–Pb collisions with ALICE at the LHC
H. Pereira~Da~Costa, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 689-692

237. Direct photon measurement in Pb–Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV with ALICE
B. Sahlmülle, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 421-424

238. Event-by-Event Identified Particle Ratio Fluctuations in Pb–Pb Collisions with ALICE using the Identity Method
M. Arslandok, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 870-873

239. Femtoscopy of identified particles in Pb–Pb collisions with ALICE at the LHC
L.V. Malinina, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 373–376

240. Heavy-flavor correlations and multiplicity dependence in pp and p–Pb collisions with ALICE
F. Colamaria, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 497-500

241. Higher harmonic anisotropic flow of identified particles in Pb–Pb collisions with the ALICE detector
N. Mohammadi, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 304-307

242. Inclusive J/ψ and ψ(2S) production in p–Pb collisions with ALICE at the LHC
M. Leoncino, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 689-692

243. Jet shapes in pp and Pb–Pb collisions at ALICE
L. Cunqueiro, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 593-596

244. Light flavor results in p–Pb collisions with ALICE
A. Ortiz, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 757-760

245. Longitudinal Asymmetry and its Measurable Effects in Pb–Pb Collisions at 2.76 TeV
R. Raniwala, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 324-327

246. Low-Mass Dielectron Production in pp, p–Pb and Pb–Pb Collisions with ALICE
P. Reichelt, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 433-436

247. Measurement of neutral mesons in pp and Pb–Pb collisions at mid-rapidity with ALICE
A. Morreale, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 645-648

248. Measurements of correlations of anisotropic flow harmonics in Pb–Pb Collisions with ALICE
Y. Zhou, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 296-299

249. Measurements of heavy-flavour nuclear modification factor and elliptic flow in Pb–Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV with ALICE
A. Dubla, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A No 956 (2016) 477-480

250. Measurements of heavy-flavour production in p–Pb collisions with ALICE: Quark Matter 2015
J. Wilkinson, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 493-496

251. On the K-4He-> Lambda pi 3He resonant and nonresonant processes
K. Pisciccia, **S. Wycech**, C. Curceanu
Nucl. Phys. A Vol. 92 (2016) 75

252. Overview of recent ALICE results
TakuGunji, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 11-18

253. Results from (anti-)(hyper-)nuclei production and searches for exotic bound states with ALICE at the LHC
N. Sharma, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 461-464

254. Strangeness production as a function of charged particle multiplicity in proton–proton collisions
L. Bianchi, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 777-780

255. Study of doubly strange systems using stored antiprotons
A. Chłopik, ... , **G. Kęsik**, **D. Melnychuk**, **B. Słowiński**, **A. Trzciński**, **M. Wojciechowski**, **S. Wronka**, **B. Zwięgliński**, ... et al.
Nucl. Phys. A Vol. 954 (2016) 323-340

256. Upgrade of the ALICE Inner Tracking System
P. Riedler, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 866-869

257. Υ production measurements in pp, p–Pb and Pb–Pb collisions with ALICE
I. Das, **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**
Nucl. Phys. A Vol. 956 (2016) 709-712

258. ϕ production at forward rapidity in pp, p–Pb and Pb–Pb collisions with ALICE
A. DeFalco, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Nucl. Phys. A Vol. 956 (2016) 453-456

259. Measurement of the cross-section ratio sigma_{psi(2S)}/sigma_{J/psi(1S)} in deep inelastic exclusive ep scattering at HERA
H. Abramowicz, ... , **M. Adamus**, **T. Tymieniecka**, ... et al.
Nucl. Phys. B No 909 (2016) 934

260. KASCADE-Grande experiment measurements of the cosmic ray spectrum and large scale anisotropy
A. Chiavassa, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Nuclear and Particle Physics Proceedings No 279-281 (2016) 56-62

261. Ambient dose equivalent measurements in secondary radiation fields at proton therapy facility CCB IFJ PAN in Krakow using recombination chambers
E.A. Jakubowska, ... , **M.A. Gryziński**, ... et al.
Nukleonika Vol. 1 No 61 (2016) 23–28

262. Application of the compress sensing theory for improvement of the TOF resolution in a novel J-PET instrument
L. Raczyński, ... , **P. Kowalski**, **W. Wiślicki**, ... et al.
Nukleonika Vol. 61 (2016) 35

263. Measurements of fast electron beams and soft X-ray emission from plasma-focus experiments
W. Surała, **M.J. Sadowski**, **R. Kwiatkowski**, **L. Jakubowski**, **J. Żebrowski**
Nukleonika Vol. 61 No 2 (2016) 161-167

264. Numerical model of thyroid counter
M. Szuchta, **J. Ośko**
Nukleonika Vol. 61 No 1 (2016) 45-47

265. Research on interactions of plasma streams with CFC targets in the rod plasma injector facility
D. Załoga, **R. Kwiatkowski**, **E. Składnik-Sadowska**, **M.J. Sadowski**, **K. Nowakowska-Langier**
Nukleonika Vol. 61 No 2 (2016) 179-183

266. Studies of plasma interactions with tungsten targets in PF-1000U facility
M.S. Ladygina, ... , **E. Składnik-Sadowska**, **D. Załoga**, **M.J. Sadowski**, ... et al.
Nukleonika Vol. 61 No 2 (2016) 149-153

267. The IOERT IntraLine accelerator – the development, current state, and future plans
P. Adrich, ... , **R. Hanke**, **E. Kulczycka**, **K. Kosiński**, **B. Meglicki**, **A. Misiarz**, **E. Pławski**, **M. Staszczak**, **K. Swat**, **A. Syntfeld-Każuch**, **M. Wójtowicz**, **A. Wysocka-Rabin**, ... et al.
Nukleonika Vol. 61 No 1 (2016) 3-9

268. The role of magnetic energy on glow discharge localization under reduced pressure
R. Chodun, **K. Nowakowska-Langier**, K. Zdunek, S. Okrasa
Nukleonika Vol. 61 No 2 (2016) 191-194

269. Formal synthesis of (−)-podophyllotoxin through the photocyclization of an axial chiral 3,4-bisbenzylidene succinate amide ester – a flow photochemistry approach
K. Lisiecki, K.K. Krawczyk, P. Roszkowski, **J.K. Maurin**, Z. Czarnocki
Org. Biomol. Chem. Vol. 14 (2016) 460

270. Exactly soluble model of the time-resolved fluorescence return to thermal equilibrium in many-particle systems after excitation
A. Czachor
Phys. B Vol. B 483 (2016) 54

271. A comparison of the cosmic-ray energy scales of Tunka-133 and KASCADE-Grande via their radio extensions Tunka-Rex and LOPES
W.D. Apel, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
Phys. Lett. B Vol. 763 (2016) 179-185

272. A search for pair production of new light bosons decaying into muons
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. 752 (2016) 146

273. Angular analysis of the decay $B^0 \rightarrow K^{*0}\mu^+\mu^-$ from 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. 753 (2016) 424

274. Azimuthal anisotropy of charged jet production in $\sqrt{s_{NN}}$=2.76 TeV Pb–Pb collisions
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 753 (2016) 511-525

275. Centrality evolution of the charged–particle pseudorapidity density over a broad pseudorapidity range in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 754 (2016) 373–385

276. Combined search for anomalous pseudoscalar HVV couplings in VH(H →bbbar) production and H → VV decay
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. 759 (2016) 672

277. Direct photon production in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 754 (2016) 235-248

278. Elastic scattering in geometrical model
Z. Plebaniak, T. Wibig
Phys. Lett. B Vol. 761 (2016) 469

279. Elliptic flow of muons from heavy-flavour hadron decays at forward rapidity in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 753 (2016) 41-56

280. First direct mass measurements of stored neutron-rich $^{129, 130, 131}$Cd isotopes with FRS-ESR
R. Knoebel, ... , **Z. Patyk**, ... et al.
Phys. Lett. B Vol. 754 (2016) 288

281. First observation of the decay $D0 \rightarrow K^{-}\pi^{+}\mu^{+}\mu^{-}$ in the ρ0-ω region of the dimuon mass spectrum
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 757 (2016) 558

282. Forward-central two-particle correlations in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 753 (2016) 126-139

283. Hypertriton and anti-hypertriton production in Pb–Pb collision at sqrt(sNN) = 2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 754 (2016) 360–372

284. Inclusive and differential measurements of the ttbar charge asymmetry 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. 757 (2016) 154

285. Interplay among transversity induced asymmetries in hadron leptoproduction
C. Adolph, ... , **W. Augustyniak**, **K. Klimaszewski**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Phys. Lett. B Vol. 753 (2016) 406

286. Jet-like correlations with neutral pion triggers in pp and central Pb-Pb collisions at 2.76 TeV
J. Adam, ... , **A. Deloff**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 763 (2016) 238-250

287. K^{-} absorption on two nucleons and ppK^{-} bound state
O. VazquezDoce, ... , **S. Wycech**, ... et al.
Phys. Lett. B Vol. 758 (2016) 134

288. Limits on the effective quark radius from inclusive ep scattering at HERA
H. Abramowicz, ... , **M. Adamus**, **T. Tymieniecka**, ... et al.
Phys. Lett. B No 757 (2016) 468

289. Longitudinal double spin asymmetries in single hadron quasi-real photoproduction at high p_T
C. Adolph, ... , **W. Augustyniak**, **K. Klimaszewski**, **K. Kurek**, **B. Mariański**, **A. Sandacz**, **A. Szabelski**, **P. Sznajder**, ... et al.
Phys. Lett. B Vol. 753 (2016) 573

290. Measurement of CP observables in $B^{\pm} \rightarrow DK^{\pm}$ and $B^{\pm} \rightarrow D\pi^{\pm}$ with two- and four-body D 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. 760 (2016) 117

291. Measurement of electrons from heavy-flavour hadron decays in p–Pb collisions at $\sqrt{s_{NN}}$=5.02TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 754 (2016) 81-93

292. Measurement of spin correlations in ttbar production using the matrix element method in the muon+jets final state 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.
Phys. Lett. B Vol. 758 (2016) 321

293. Measurement of the $B^0_s \to J/\psi\eta$ lifetime
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 762 (2016) 484

294. Measurement of the CP-violating phase and decay-width difference in $B^0_s \to \psi(2S)\phi$ 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. 762 (2016) 253

295. Measurement of the CP-violating weak phase ϕ_s and the decay width difference $\Delta\Gamma_s$ using the $B^0_s \to J/\psi\phi(1020)$ decay channel 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.
Phys. Lett. B Vol. 757 (2016) 97

296. Measurement of the Inelastic Cross Section in Proton-Lead 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.
Phys. Lett. B Vol. 759 (2016) 641

297. Measurement of the ratio $B(B^0_s \to J/psi\ f_0(980))$ / $B(B^0_s \to J/psi\ phi(1020))$ in pp collisions at √s= 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.
Phys. Lett. B Vol. 756 (2016) 84

298. Measurement of the W boson helicity fractions in the decays of top quark pairs to lepton+jets final states produced in pp collisions at √s= 8TeV
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. 762 (2016) 512

299. Measurement of the ZZ production cross section and $Z \to l^+l^-l'^+l'^-$ branching fraction 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. 763 (2016) 280

300. Measurement of the $Z\gamma \to \nu\nu(bar)\gamma$ production cross section in pp collisions at √s= 8 TeV and limits on anomalous $ZZ\gamma$ and $Z\gamma\gamma$ trilinear gauge boson 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.
Phys. Lett. B Vol. 760 (2016) 448

301. Measurement of the $\phi \to \pi 0e+e-$ transition form factor with the KLOE detector
A. Anastasi, ... , **M. Berłowski**, **W. Krzemień**, **A. Kupść**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 757 (2016) 362-367

302. Measurements of long-range near-side angular correlations in $\sqrt{s_{NN}}$=5TeV proton-lead collisions in the forward region
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 762 (2016) 473

303. Measurements of ttbar charge asymmetry using dilepton final states 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. Traczyk**, **P. Zalewski**, ... et al.
Phys. Lett. B Vol. 760 (2016) 365

304. Multi-strange baryon production in p–Pb collisions at $\sqrt{s_{NN}}$=5.02TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 758 (2016) 389-401

305. Multiplicity dependence of charged pion, kaon, and (anti)protonproduction at large transverse momentumin p–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. 760 (2016) 720-735

306. Observation of the $\Lambda^0_b \to \Lambda\phi$ 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. 759 (2016) 282

307. Pseudorapidity and transverse-momentum distributions of charged particles in proton–proton collisions at $\sqrt{s}$ = 13 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 753 (2016) 319-329

308. Pseudorapidity dependence of the anisotropic flow of charged particles in Pb–Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 762 (2016) 376-388

309. Search for a Higgs boson decaying into $\gamma^*\gamma \to ll\gamma$ with low dilepton mass 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. 753 (2016) 341

310. Search for a low-mass pseudoscalar Higgs boson produced in association with a bbbar pair 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. 758 (2016) 296

311. Search for a narrow baryonic state decaying to pKS0 and pbar KS0 in deep inelastic scattering at HERA
H. Abramowicz, ... , **M. Adamus**, **T. Tymieniecka**, ... et al.
Phys. Lett. B Vol. 759 (2016) 446

312. Search for an Isospin I = 3 Dibaryon
P. Adlarson, ... , **W. Augustyniak**, **M. Berłowski**, **A. Kupść**, **B. Mariański**, **H.P. Morsch**, **D. Pszczel**, **J. Stepaniak**, **A. Trzciński**, **J. Zabierowski**, **P. Żupráński**, ... et al.
Phys. Lett. B Vol. 762 (2016) 455-461

313. Search for B^+_c decays to the $pp\pi^+$ final state
R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 759 (2016) 313

314. Search for exotic decays of a Higgs boson into undetectable particles and one or more photons
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. 753 (2016) 363

315. Search for lepton flavour violating decays of the Higgs boson to eτ and eμ 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. 763 (2016) 472

316. Search for neutral MSSM Higgs bosons decaying to $\mu^+\mu^-$ 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.
Phys. Lett. B Vol. 752 (2016) 221

317. Search for Neutral Resonances Decaying into a Z Boson and a Pair of b Jets or Tau Leptons
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. 759 (2016) 369

318. Search for new phenomena in monophoton 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. 755 (2016) 102

319. Search for R-parity violating decays of a top squark 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. 760 (2016) 178

320. Search for supersymmetry in electroweak production with photons and large missing transverse energy 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.
Phys. Lett. B Vol. 759 (2016) 479

321. Search for supersymmetry in events with a photon, a lepton, and missing transverse momentum 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.
Phys. Lett. B Vol. 757 (2016) 6

322. Search for supersymmetry in events with soft leptons, low jet multiplicity, and missing transverse energy 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. 759 (2016) 9

323. Search for supersymmetry in the multijet and missing transverse momentum final state in pp collisions at 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. 758 (2016) 152

324. Search for the lepton-flavour violating decay $D^0 \to e^\pm \mu^\mp$
V. Batozskaya, ... , **K. Klimaszewski**, **W. Krzemień**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
Phys. Lett. B Vol. 754 (2016) 167

325. Search for W′ decaying to tau lepton and neutrino 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. 755 (2016) 196

326. Search for weakly decaying \\\\bar{Λn} and ΛΛ exotic bound states in central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV
J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **P. Kurashvili**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Lett. B Vol. 752 (2016) 267-277

327. Searches for a heavy scalar boson H decaying to a pair of 125 GeV Higgs bosons hh or for a heavy pseudoscalar boson A decaying to Zh, in the final states with $h\rightarrow\tau\tau$
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. 755 (2016) 217

328. Study of Z boson production in pPb collisions at $\sqrt{s_{NN}}$=5.02TeV
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. 759 (2016) 36

329. The spin dependent odderon in the diquark model
L. Szymanowski, J. Zhou
Phys. Lett. B Vol. 760 (2016) 249

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Phys. Lett. B Vol. 753 (2016) 18

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Phys. Lett. B Vol. 754 (2016) 59

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P. Kubes, ... , **D. Załoga**, ... et al.
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E. Nácher, ... , **M. Gierlik**, ... et al.
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G. Marquínez-Durán, ... , **N. Keeley**, **Ł. Standyło**, **I. Strojek**, ... et al.
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S.K. Pandit, ... , **N. Keeley**, ... et al.
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T. Anticic, ... , **H. Białkowska**, **B. Boimska**, ... et al.
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D.V. Gorpinchenko, A.G. Magner, J. Bartel, **J. Błocki**
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A. Sobiczewski
Phys. Rev. C Vol. 94 (2016) 051302(R)

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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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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
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J. Aasi, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
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Y. Zhang, ... , **P. Mijakowski**, **K. Frankiewicz**, ... et al.
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I. Aniceto, **M. Spaliński**
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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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M. Spaliński
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K. Abe, ... , **P. Mijakowski**, **K. Frankiewicz**, ... et al.
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R. Aaij, ... , **V. Batozskaya**, **K. Klimaszewski**, **K. Kurek**, **D. Melnychuk**, **M. Szczekowski**, **A. Ukleja**, **W. Wiślicki**, ... et al.
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K. Abe, ... , **M. Kabirnezhad**, **J. Łagoda**, **P. Mijakowski**, **P. Przewłocki**, **E. Rondio**, **J. Zalipska**, ... et al.
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H. Bergeron, **E. Czuchry**, J.P. Gazeau, **P. Małkiewicz**
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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
Phys. Rev. Lett. Vol. 116 (2016) 241103

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J. Adam, ... , **A. Deloff**, **I. Ilkiv**, **O. Kovalenko**, **P. Kurashvili**, **R. Nair**, **T. Siemiarczuk**, **G. Wilk**, ... et al.
Phys. Rev. Lett. Vol. 116 (2016) 222301

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K. Abe, ... , **P. Mijakowski**, **P. Przewłocki**, **J. Zalipska**, **E. Rondio**, **J. Łagoda**, **M. Kabirnezhad**, ... 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.
Phys. Rev. Lett. Vol. 117 (2016) 261801

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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. 116 (2016) 172302

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K. Abe, ... , **M. Kabirnezhad**, **J. Łagoda**, **P. Przewłocki**, **P. Mijakowski**, **E. Rondio**, **J. Zalipska**, ... et al.
Phys. Rev. Lett. Vol. 116 (2016) 181801

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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. 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.
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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. 117 No 8 (2016) 082002

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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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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... 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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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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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. 117 (2016) 051802

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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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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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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
Phys. Rev. Lett. Vol. 116 (2016) 221101

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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
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B.P. Abbott, ... , **A. Królak**, **A. Kutynia**, **A. Zadrożny**, ... et al.
Phys. Rev. X Vol. 6 (2016) 041014

433. High performance detectors for upgraded gamma ray diagnostics for JET DT campaigns
I. Zychor, ... , **G. Bołtruczyk**, **A. Burakowska**, **M. Gierlik**, **M. Gosk**, **M. Grodzicka**, **J. Iwanowska-Hanke**, **S. Korolczuk**, **R. Kwiatkowski**, **S. Mianowski**, **M. Moszyński**, **J. Rzadkiewicz**, **P. Sibczyński**, **A. Syntfeld-Każuch**, **Ł. Świderski**, **M. Szawłowski**, **T. Szczęśniak**, **J. Szewiński**, **A. Szydłowski**, **A. Urban**, ... et al.
Phys. Scr. Vol. 91 (2016) 064003

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I.E. Garkusha, ... , **M.J. Sadowski**, **E. Składnik-Sadowska**, ... et al.
Phys. Scr. Vol. 91 (2016) 904001

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P. Sobkowicz
Physica A Vol. 458 (2016) 17-36

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I. Jozwik, **J. Jagielski**, G. Gawlik, **R. Ratajczak**, G. Panczer, N. Moncoffre, A. Wajler
Physics and Chemistry of Minerals Vol. 43 (2016) 439

437. Research on soft X-rays in high-current plasma-focus discharges and estimation of plasma electron temperature
E. Składnik-Sadowska, ... , **D. Załoga**, **M.J. Sadowski**, **R. Kwiatkowski**, **K. Malinowski**, **W. Surała**, ... et al.
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A. Sowa-Staszczak, ... , **R. Mikołajczak**, **B. Janota**, ... et al.
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P. Sobkowicz
PLOS One Vol. 11 (2016) e0155098

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S. Domański, **M.A. Gryziński**, **M. Maciak**, **Ł. Murawski**, **P. Tulik**, **K. Tymińska**
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441. Neutrina - cząstki duchy, czy na pewno aż tak nieuchwytne?
J. Zalipska
Postępy Fizyki Vol. 67 No 4 (2016) 173

442. Comments on recent studies of high-temperature plasma at the NCBJ in Poland
M.J. Sadowski, **J. Żebrowski**
Probl. Atom. Sci. Technol., Series Plasma Phys. Vol. 106 No 6 (2016) 291-296

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E. Składnik-Sadowska, ... , **M.J. Sadowski**, **K. Malinowski**, **W. Surała**, **D. Załoga**, ... et al.
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A. Wojciechowski
Prog. Nucl. Energy Vol. 92 No 92 (2016) 81-90

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M. Borysiewicz, W. Kacprzyk, **S. Potempski**
Przemysł Chem. Vol. 3 (2016) 604-609

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L. Dobrzyński, K.W. Fornalski, Y. Socol, **J. Reszczyńska**
Radiat Res Vol. 186 (2016) 396

447. Change in the sensitivity of PM-355 track detectors for protons after long – term storage
A. Malinowska, **M. Jaskóła**, **A. Korman**, **A. Szydłowski**, K. Malinowski, B. Sartowska, **M. Kuk**
Radiat. Meas. Vol. 93 (2016) 55-59

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J. Farah, ... , **M.A. Gryziński**, ... et al.
Radiat. Meas. Vol. 96 (2016) 42

449. Scintillation timing characteristics of (La,Gd)2Si2O7:Ce and Gd2SiO5:Ce single crystal scintillators: A comparative study
W. Chewpraditkul, ... , **T. Szczęśniak**, **Ł. Świderski**, **M. Moszyński**, ... et al.
Radiat. Meas. Vol. 92 (2016) 49

450. Timing characteristics of the scintillation response of $Gd_3Al_2Ga_3O_{12}$:Ce and $Gd_3Al_{2.6}Ga_{2.4}O_{12}$:Ce single crystal scintillators
O. Sakthong, ... , **T. Szczęśniak**, **M. Grodzicka**, **P. Sibczyński**, **M. Moszyński**, ... et al.
Radiat. Meas. Vol. 87 (2016) 24-28

451. A new large-volume metal reference standard for radioactive waste management
F. Tzika, ... , **A. Listkowska**, **Z. Tymiński**, ... et al.
Radiat. Prot. Dosim. Vol. 168 (2016) 293

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W. Krzemień
Radiother. Oncol. Vol. 118 (2016) 117

453. Gamma-ray spectroscopy at MHz counting rates with a compact LaBr3 detector and silicon photomultipliers for fusion plasma applications
M. Nocente, ... , **G. Bołtruczyk**, **A. Brosławski**, **M. Gosk**, **S. Korolczuk**, **I. Zychor**, ... et al.
Rev. Sci. Instrum. Vol. 87 (2016) 11E714

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D. Rigamonti, ... , **G. Bołtruczyk**, **M. Gosk**, **S. Korolczuk**, **S. Mianowski**, **I. Zychor**, ... et al.
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R. Korab, **W. Jaworski**, **K. Wawrzyniak**, **M. Jakubek**, **K. Królikowski**
Rynek Energii Vol. 123 No 2 (2016) 9-16

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R. Sitek, **T. Bolek**, R. Dobosz, T. Plocinski, J. Mizera
Surf. Coat. Technol. Vol. 304 (2016) 584-591

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J. Jagielski, ... , **Ł. Kurpaska**, **A. Kosińska**, ... et al.
Surf. Coat. Technol. Vol. 306 (2016) 176-180

458. Badania gleby ze stanowiska Begastri (prow. Murcja, Południowo-wschodnia Hiszpania)
A. Chołuj, P. Kalbarczyk, **E. Miśta**
Syndesmoi Vol. 5 (2016) 339-342

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J. Szawkalo, D. Blachut, P. Roszkowski, P. Pomaranski, **J.K. Maurin**, **A. Budzianowski**, Z. Czarnocki
Tetrahedron Vol. 72 No 43 (2016) 6779

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P. Pomarański, S. Samanta, P. Roszkowski, **J.K. Maurin**, Z. Czarnocki
Tetrahedron Lett Vol. 57 (2016) 4713–4717

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K. Nowakowska-Langier, ... , **R. Kwiatkowski**, **K. Malinowski**, **E. Składnik-Sadowska**, **M.J. Sadowski**, ... et al.
Vacuum Vol. 128 (2016) 259-264

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A. Zwolińska, **D. Rybka**, **J. Szabelski**
Academia (2016)

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P. Zalewski
Delta Vol. 510 No 11 (2016) 21

3. Fotoprodukcja nadtlenku wodoru z wody morskiej
P. Zalewski
Delta Vol. 506 No 7 (2016) 21

4. Idus Martiae Anno Domini 2016
P. Zalewski
Delta Vol. 504 No 5 (2016) 21

5. Kwantowa nieodwracalność
P. Zalewski
Delta Vol. 501 No 2 (2016) 23

6. Lokalny realizm po kompresji
P. Zalewski
Delta Vol. 505 No 6 (2016) 21

7. Neutrina na biegunie
P. Przewłocki
Delta Vol. 0 No 3 (2016) 4

8. Pierwsza bezpośrednia detekcja fal grawitacyjnych
P. Zalewski
Delta Vol. 503 No 4 (2016) 21

9. Piśmienne gołębie
P. Zalewski
Delta Vol. 510 No 11 (2016) 21

10. Przesłanki
P. Zalewski
Delta Vol. 502 No 3 (2016) 21

11. Wielka struktura w wielkich przeglądach
A. Pollo
Delta Vol. 3 (2016)

12. Z wyczuciem, czyli po ludzku?
P. Zalewski
Delta Vol. 505 No 6 (2016) 21

13. Zaskakujący metan
P. Zalewski
Delta Vol. 506 No 7 (2016) 21

14. Małe mobilne laboratorium a duża inwestycja środowiskowa (The small mobile laboratory as a large environmental investment)
J. Sernicki
Rynek Inwestycji No 9-10 (2016) 220

15. Kosmos, łączność radiowa i szkolne lekcje
A. Budzianowski, T. Ciepielowski
Urania - Postępy Astronomii Vol. LXXXVII No 1 (2016) 16

16. Pluton : zagrożenia i wykorzystanie Znaczenie plutonu dla energetyki
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Wiedza i Życie (2016)

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R. Acciarri, ... , **D. Stefan**, **R. Sulej**, ... et al.
ArXiv Vol. 1 No 1601.02984 (2016) 1

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M. Kabirnezhad, ... , **K. Kowalik**, **J. Łagoda**, **P. Mijakowski**, **P. Przewłocki**, **E. Rondio**, **J. Zalipska**, ... et al.
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H. Abramowicz, ... , **M. Adamus**, ... et al.
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M. Kabirnezhad, ... , **J. Łagoda**, **P. Mijakowski**, **P. Przewłocki**, **E. Rondio**, **J. Zalipska**, ... et al.
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11. TITUS: the Tokai Intermediate Tank for the Unoscillated Spectrum
J. Łagoda, ... et al.
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B. Słowiński
Book of abstracts. ION Implantation and other applications of ions and electrons. ION 2016. Kazimierz Dolny, Poland. June 13-16, 2016 (2016) 33

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A. Strupczewski
Energetyka Cieplna i Zawodowa No 6 (2016) 46-51

14. Gotowi na OZE?
A. Strupczewski
Energetyka Cieplna i Zawodowa No 5 (2016) 46-52

15. Kłopoty z OZE
A. Strupczewski
Energetyka Cieplna i Zawodowa No 4 (2016) 22-26

16. Fusion-fission probabilities, cross sections, and structure notes of superheavy nuclei
M. Kowal, **T. Cap**, P. Jachimowicz, **J. Skalski**, K.S. -Wilczyńska, **J. Wilczyński**
EPJ Web Conf. Vol. 131 (2016) 04005

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W. Krzemień, ... et al.
EPJ Web Conf. Vol. 130 (2016) 1

18. Probing the transversity spin structure of a nucleon in neutrino- production of a charmed meson
B. Pire, **L. Szymanowski**, **J. Wagner**
EPJ Web of Conference Vol. 112 (2016) 01018

19. GPDs in heavy meson production and Compton scattering
D.Yu. Ivanov, B. Pire, **L. Szymanowski**, **J. Wagner**
EPJ Web of Conferences Vol. 112 (2016) 01020

20. High-energy resummation effects in the production of Mueller- Navelet dijets at the LHC
B. Ducloué, **L. Szymanowski**, S. Wallon
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R. Boussarie, B. Pire, **L. Szymanowski**, S. Wallon
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A. Boettcher, **Z. Marcinkowska**
European Nuclear Society Conference Vol. ENC2016 (2016) 19-24

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T. Batsch, ... , **A. Ćwiek**, **A. Majcher**, **K. Małek**, **K. Nawrocki**, **M. Sokołowski**, **G. Wrochna**, **A. Zadrożny**, ... et al.
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A. Sandacz
J of Phys: Conf Series Vol. 678 (2016) 012045

25. KASCADE-Grande: Review, recent Results, Future Endavors
S. Schoo, ... , **P. Łuczak**, **J. Zabierowski**, ... et al.
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K. Andrzejewski, **A. Strupczewski**
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D. Włodarczyk, **E. Miśta**, I. Żmuda-Trzebiatowska, P. Kalbarczyk, M. Kolbadinejad, A. Lashkari
Nauki Ścisłe i zabytki, materiały z konferencji Kraków, 25.09.2015 (2016) 101

28. Badania proweniencyjne i technologiczne obiektów archeologicznych wykonanych ze stopów srebra i miedzi
E. Miśta, **A. Gójska**, P. Kalbarczyk
Nauki Ścisłe i zabytki, materiały z konferencji Kraków, 25.09.2015 (2016) 91

29. Możliwości wykorzystania reaktora jądrowego MARIA w nauce o konserwacji
M. Dorosz, **E. Miśta**, **J.J. Milczarek**
Nauki Ścisłe i zabytki, materiały z konferencji Kraków, 25.09.2015 (2016) 7

30. In memoriam: Janusz Wilczyński (1938-2015) (popular article)
A. Sobiczewski
Nucl. Phys. News Vol. 26 No 1 (2016) 38

31. Experimental Study of the Physical Properties of ADS Systems - Measurement of High Energy Neutron Flux Density by Using the Y89 Threshold Detectors
M. Bielewicz, **E. Strugalska-Gola**, **S. Kilim**, **M. Szuta**
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32. Atom to najlepszy wybór dla Polski – potwierdzają to analizy i praktyka
A. Strupczewski
Postępy Techniki Jądrowej Vol. 59 No 1 (2016) 17-27

33. Pi of the Sky involvement in LSC-Virgo electromagnetic follow-up project
A. Zadrożny, M. Sokolowski, L. Mankiewicz, A. Zarnecki
Proc. SPIE Int. Soc. Opt. Eng. Vol. 10031 (2016) 1003141

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S. Bacholle, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
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T. Paul, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 578

36. Absolute calibration of the Photo-Detector Module of the EUSO-Balloon experiment and improvements for future missions
C. Moretto, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 655

37. Analysis of EUSO-Balloon data with Offline
B. Panico, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 667

38. Atmospheric Effects for the Ground-Based Calibration of Orbital UV Telescopes
G. Chiritoi, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 586

39. Calibration of the EUSO-TA Prototype Instrument
J. Adams, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 582

40. Cloud Optical Depth obtained from the Infrared Camera data and the UV Flashers mounted on a helicopter flying under the EUSO-Balloon during its flight
G. SaezCano, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 658

41. Cloud Top Height Estimation from WRF Model: Application to the Infrared Camera onboard EUSO-balloon
A. Merino, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 377

42. Determination of the detection performances of the Euso-Balloon UV camera
S. Dagoret-Campagne, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 607

43. Development of optical systems for the KLYPVE experiment
P. Klimov, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 671

44. EUSO-Balloon mission to record extensive air showers from near space
L. Wiencke, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 631

45. EUSO-Balloon trigger efficiency in preparation of a long duration flight
S. Bacholle, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 608

46. EUSO-Balloon: Observation and Measurement of Tracks from a laser in a Helicopter
J. Eser, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 638

47. EUSO-TA, a ground telescope at the Telescope Array to test JEM-EUSO detector performance
M. Casolino, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 636

48. Evaluation of scientific performance of JEM-EUSO mission with Space-X Dragon option
K. Shinozaki, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 617

49. Expected acceptance of the KLYPVE/K-EUSO space-based mission for the observation of ultra-high energy cosmic rays
N. Sakaki, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 647

50. Ground calibration of MAPMT and SiPM for JEM-EUSO
M. Karus, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 612

51. Implementation of the JEM-EUSO Space Mission Infrared Camera Simulation and Reconstruction Code in the Offline Framework
L. DelPeral, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 683

52. JEM-EUSO observational capabilities for different UHE primaries
A. Guzman, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 600

53. JEM-EUSO Science
A. Olinto, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 632

54. K-EUSO: An improved optical system for KLYPVE ultra-high energy cosmic ray space telescope
F. Kajino, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 634

55. Measurement of the cross-section ratio $\sigma_{\psi(2S)}/\sigma_{J/\psi(1S)}$ in deep inelastic exclusive ep scattering at HERA
H. Abramowicz, ... , **M. Adamus**, ... et al.
Proceedings of Science (PoS) Vol. DIS2015 (2016) 78

56. Mini-EUSO: a pathfinder for JEM-EUSO to measure Earth's UV background from the ISS
M. Ricci, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 599

57. Night Time Measurement of the UV Background by EUSO-Balloon
S. Mackovjak, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 685

58. Observation of neutrinos with JEM-EUSO: an updated view
E. Iwotschkin, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 1142

59. Pattern recognition study for different levels of UV background in JEM-EUSO experiment
B. Pastircak, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 661

60. Performance of the EUSO-Balloon optics
C. Catalano, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 622

61. Performance of the Spanish Infrared Camera onboard the EUSO-Balloon (CNES) flight on August 25, 2014.
J.F. Soriano, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 653

62. Possibilities of selected space weather and atmospheric studies in JEM-EUSO project?
K. Kudela, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 113

63. Preliminary results from the EUSO-Balloon flight
M. Bertaina, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 358

64. Search for significant background variations in the EUSO-Balloon data
A. Jung, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 373

65. Sensitivity of the JEM-EUSO detector to UHE tau neutrino
G. Vankova, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 1153

66. Tests of JEM-EUSO First Level Trigger using EUSO-Balloon data
G. Suino, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 645

67. The Angular Resolution of the JEM-EUSO Mission: an Updated View
T. Mernik, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 601

68. The atmospheric science of JEM-EUSO
M. RodriguezFrias, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 680

69. The Calibration of EUSO Balloon using airborne light sources mounted to a Helicopter
J. Adams, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 580

70. The Data Processor System of EUSO-Balloon: In Flight Performance
G. Osteria, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 659

71. The EUSO at TurLab project
R. Caruso, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 674

72. The EUSO-Balloon mission
P. VonBallmoos, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 322

73. The Expected Angular Resolution Performance of the Tilted JEM-EUSO Instrument
T. Mernik, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 602

74. The JEM-EUSO Global Light System Laser Station Prototype
P. Hunt, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 626

75. The JEM–EUSO energy and Xmax reconstruction performances
F. Fenu, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 604

76. The simulation of cosmic rays in EUSO–Balloon: performances of the direction and energy reconstruction
F. Fenu, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 609

77. The Spanish Infrared Camera onboard the EUSO-BALLOON (CNES) flight on August 24, 2014 M.D. Rodríiguez Frias
M.D. RodríiguezFrias, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 687

78. The WRF model contribution to the Cloud Top Height retrieval in EUSO-Balloon experiment
I. Tabone, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 642

79. Towards a SiPM based fluorescence camera for JEM-EUSO
A. Haungs, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 643

80. Ultra high energy cosmic ray detector KLYPVE on board the Russian Segment of the ISS
P. Klimov, ... , **T. Batsch**, **J. Karczmarczyk**, **B. Szabelska**, **J. Szabelski**, **T. Tymieniecka**, **T. Wibig**, ... et al.
Proceedings of Science (PoS) Vol. ICRC2015 (2016) 669

81. Optical properties of symbiotic X-ray binary V2116 Oph
A. Majczyna, J. Madej, M. Należyty, A. Różańska, A. Udalski
Proceedings of the Polish Astronomical Society Vol. 3 (2016) 133

82. Bayesian-Based Approach to Application of the Genetic Algorithm to Localize the Abrupt Atmospheric Contamination Source
A. Wawrzyńczak-Szaban, M. Jaroszyński, **M. Borysiewicz**
Recent Advances in Computational Optimization Vol. 1 (2016) 225

83. Performance study of the gamma-ray bursts polarimeter POLAR
J.C. Sun, ... , **T. Batsch**, **D. Rybka**, **J. Szabelski**, **A. Zwolińska**, ... et al.
SPIE (2016)

84. Analiza i ocena kosztów energii elektrycznej z różnych źródeł energii w Polsce
A. Strupczewski
Wewnętrzny raport B NCBJ Vol. SJ Nr: B No 27 (2016)

OTHERS

1. ABC kwantowej teorii pola
St. Mrówczyński
Publishing house of Jan Kochanowski University

2. Aneks 2016/1 do Eksploatacyjnego Raportu Bezpieczeństwa Reaktora MARIA. Analizy bezpieczeństwa testowego napromieniania tarcz NWMI do produkcji Mo-99
K. Pytel, E. Borek-Kruszewska, M. Dorosz, J. Jaroszewicz, M. Lipka, M. Migdal. Z. Marcinkowska, Z. Przybysz, R. Prokopowicz, M. Wierzchnicka, ... et al.

3. Aneks 2016/2 do Eksploatacyjnego Raportu Bezpieczeństwa Reaktora MARIA. Analizy bezpieczeństwa testowego napromieniania nisko wzbogaconych tarcz uranowych do produkcji Mo-99
K. Pytel, **E. Borek-Kruszewska**, **J. Jaroszewicz**, **J. Lechniak**, **Z. Marcinkowska**, **Z. Przybysz**, **M. Wierzchnicka**
NCBJ

4. Applying IRIDM to the nuclear safety authority activities
M. Borysiewicz, **K. Kowal**, **S. Potempski**, **P. Prusiński**
Politechnika Lubelska, Lublin

5. Computational Studies of the Impulse Plasma Deposition Method
M. Rabiński, K. Zdunek
InTech

6. Improving neutrino oscillation analysis with near detector measurements in T2K experiment
J. Łagoda
NCBJ

7. Interlaced Energy Linac with Smooth Energy Regulation
S. Wronka
Institute of Electronics Systems Warsaw University of Technology

Nauki ścisłe i zabytki
E. Miśta, **A. Gójska**, P. Kalbarczyk
Wydział Chemii UJ (Kraków)

8. Oddziaływania nadsubtelne i właściwości magnetoelektryczne $(BiFeO_3)_x$-$(BaTiO_3)_{1-x}$
K. Kowal
Lublin University of technology, Lublin

9. Overview of modern approaches to multiphysics, multiscale problems in nuclear technology
T. Kwiatkowski, **S. Potempski**, **P. Prusiński**, **M. Spirzewski**
Politechnika Lubelska, Lublin

10. Paving the way to Gen IV Nuclear Reactors
L. Dobrzyński, **M. Kirejczyk**
NCBJ

11. Podstawy fizyczne energetyki jądrowej
B. Słowiński
Printing House of Warsaw University of Technology, Warsaw, Poland

12. RAPORT Energia Elektryczna Dla Pokoleń, Monografia II Kongresu Elektryki Polskiej, Warszawa 11 kwietnia 2016
M. Bartosik**A. Strupczewski**, ... et al.
Association of Polish Electrical Engineers, Warszawa

13. Real-time on-line decision support systems for nuclear emergencies
M. Borysiewicz, **S. Potempski**, **H. Wojciechowicz**, **A. Wawrzyńczak-Szaban**, **P. Kopka**,
Politechnika Lubelska, Lublin

14. Report of PQR for ^{99}Mo/^{99m}Tc Radionuclide Generator (Report No. 12/16)
Z. Szopa
OR POLATOM

15. Report of PQR for PoltechMDP (Report No.5/16)
Z. Szopa
OR POLATOM

16. Report of PQR for PoltechMIBI (Report No. 6/16)
Z. Szopa
OR POLATOM

17. Report of PQR for Tektrotyd (Report No.7/16)
Z. Szopa
OR POLATOM

18. Rozwój polskiego akceleratora do radioterapii śródoperacyjnej (rozdział książki pt. Radioterapia śródoperacyjna, pod redakcją D. Murawa i W. P. Polkowski)
A. Wysocka-Rabin, **P. Adrich**, **E. Pławski**
Via Medica, Gdansk

19. Safety Aspects of Modern Nuclear Power
M. Borysiewicz, **R. Możdżonek**, **A. Wasiuk**
Politechnika Lubelska, ul. Nadbystrzycka 38D, 20-618 Lublin

20. Safety Aspects of Modern Nuclear Power,
M. Skrzypek, **E. Skrzypek**

Politechnika Lubelska, Wydział Elektrotechniki i Informatyki, ul. Nadbystrzycka 38A 20-618 Lublin

21. Zaufajmy energetyce jądrowej
A. Strupczewski
*PGE (Warsaw)_*

22. Zaufajmy Energetyce Jądrowej
A. Strupczewski
Polish Power Group and National Centre for Nuclear Research

AUTHOR INDEX