NARODOWE CENTRUM BADAŃ JĄDROWYCH

NATIONAL CENTRE FOR NUCLEAR RESEARCH

ANNUAL REPORT
2015

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FOREWORD

During 2015 NCBJ operated under quite stable conditions. Three important projects were completed. These were: Accelerators and Detectors, Computing Centre Swierk (Polish acronym: CIS) and 4 Labs. Innovative technologies for medical accelerators were proposed under the first project and the construction of a new plasma chamber was completed under the third. The number of papers published in refereed journals increased to nearly 600 and the number of citations reached more than 8000 this year. The corresponding Hirsch index increased to 125 giving NCBJ the 5th position in Poland among all institutes and universities.

A new Department named Complex Systems (Polish acronym DUZ) was formed. It comprises two Laboratories: the Laboratory of Information Technologies and the Division of Nuclear Energy and Environmental Studies. Both make extensive use of the computer resources of CIS. The supercomputer in CIS (155th on the TOP500 list of the world's supercomputers) is currently used mainly for basic research in particle physics, analysing petabytes of data from the Large Hadron Collider at CERN, and for time consuming molecular calculations for projected new radiopharmaceutical products in close cooperation with the POLATOM Radioisotope Centre and the Institute of Nuclear Chemistry and Technology (IChTJ). Although we still expect that NCBJ will play a key role in the Technical Support Organisation for the nuclear power plant to be built in Poland, there has been little progress in this field due to the rather slow development of the Polish nuclear programme. In spite of this, the International School on Nuclear Power was very successfully organised for the 8th time and gathered about 180 participants from many countries. The School attracted as many as 26 lecturers from 9 countries, and was supplemented by 3 workshops (on-site at Swierk and at the National Repository in Różan, about 140 km from Warsaw).

In 2015 NCBJ was for the first time co-organiser (together with CERN) of the CERN Accelerator School, highly evaluated by the CERN authorities. Another important event, organised together with the Faculty of Physics of the University of Warsaw, was 19th annual International Conference on Particle Physics and Cosmology (COSMO-15).

The NCBJ Research Council awarded 3 habilitations and 9 PhDs in 2015. In June Lech Szymanowski was awarded the full professor title by the President of Poland, Bronisław Komorowski, while in September the newly elected President of Poland, Andrzej Duda , awarded Michał Spaliński the full professor title.

From year-to-year an increase in the number of younger generation employees is observed. Throughout this year university graduates could compete in the Graduate of the Year contest. Monika Szołucha, who performed neutron calculations at the MARIA reactor, won the national phase of the contest. She competed in the international finals, with 5 other participants from Brazil, France, The Netherlands, Russia, and Great Britain.

Radioisotope production at NCBJ is possible thanks to the MARIA nuclear reactor. It is the 4th most powerful research reactor in Europe and it produces radioisotopes, Mo-99 and Tc-99m in particular, for two million patients a year. The reactor staff, in collaboration with the POLATOM Radioisotope Centre, are preparing themselves for full production line synthesis of the Tc-99m isotope, indispensable in most hospitals with nuclear medicine wards. POLATOM prepared a new project called CERAD (Centre for the Design and Synthesis of Radiopharmaceuticals for Molecular Targeting) which will allow the development of a large range of new radioisotopes produced using a 30 MeV Cyclotron – the heart of the project. The project was approved and will be launched soon.

2015 was announced by UNESCO as the “International Year of Light” and was a highly dynamic year for DESY Lab., home of the largest free-electron laser in Europe. NCBJ continued its contribution to the 3.5 km long XFEL in Hamburg, and is also involved in the preparation of instruments for the ESS - the European Neutron Spallation Source - which will serve the community of neutronographers. Much work has also gone into updating the neutron instruments installed on the horizontal channels of the MARIA reactor. In 2014 the MARIA reactor celebrated its 40th anniversary of successful work.

In 2015 we also celebrated the 60th anniversary of the founding of our Institute. Bronisław Komorowski, President of Poland, awarded some outstanding Polish nuclear physicists/chemists, some employees of the former Institute of Nuclear Research who actively supported the democratic movement in Poland during the 1980s, as well as some of the most deserving NCBJ/ IChTJ employees, Officers' and Knights' Crosses of the Polonia Restituta Order and Crosses of Merit.

Krzysztof Kurek
Director
National Centre for Nuclear Research

GENERAL INFORMATION

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30 km SE from Warsaw	(divisions BP1, BP2, BP3)	(division BP4)
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SCIENTIFIC COUNCIL (2011-2015)

The Scientific Council was elected on 1 July 2011 by the scientific, technical and administrative staff of the Institute. As a result of merging The Andrzej Sołtan Institute for Nuclear Studies and The Institute of Atomic Energy a supplementary election was conducted on 23 September 2011. The Council has the right to confer PhD and *habilitation* degrees in physics (DSc).

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Janusz Mika, Professor, Professor		former Institute of Atomic Energy
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Janusz Ziółkowski, Professor	-	The N. Copernicus Astronomical Centre, Warsaw

SCIENTIFIC COUNCIL (2015-2019)

The new Scientific Council was elected on 1.07.2015 by the scientific, technical and administrative staff of the Institute. The one elected for the term 2011-2015 concluded its work accordingly. The Council has the right to confer PhD and habilitation DSc degrees in physics.

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- MARIA REACTOR OPERATIONS DIVISION (EJ2)
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- REACTOR RESEARCH AND TECHNOLOGY DIVISION (EJ3)
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- RADIATION PROTECTION MEASUREMENT LABORATORY (LPD)
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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. High-energy atomic physics.
7. Exotic atoms.

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. Detectors, accelerators, physics of materials & applications

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

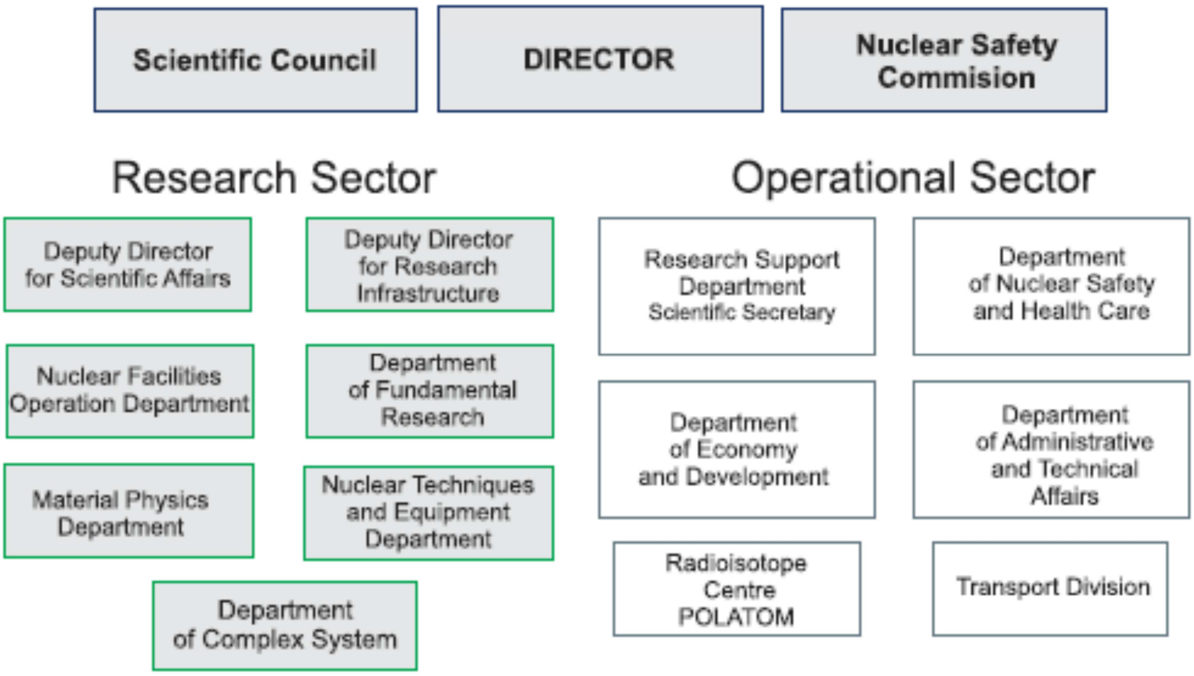
1. Materials structure studies by nuclear methods.
2. Technology of modifying surfaces of industrially used materials.

VI. Nuclear technology in energy generation

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.



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54. PIJAROWSKA-KRUSZYNA Justyna
55. PŁAWSKI Eugeniusz
56. PLEWA Grzegorz
57. PLUCIŃSKI Paweł (*)
58. RAJEWSKA Aldona (*)
59. ROMAŃCZUK Małgorzata
60. RZEMEK Katarzyna
61. SASINOWSKA Iwona
62. SAWICKA Agnieszka
63. SENDAL Jagoda
64. SŁAPA Mieczysław (**)
65. SOBKOWICZ Paweł
66. SOCHA Dariusz
67. SOWIŃSKI Mieczysław (**)
68. STANISZEWSKA Joanna
69. STEFAN Dorota
70. STRUPCZEWSKI Andrzej
71. ŚWIDERSKA Karolina
72. SZABELSKA Barbara
73. SZYMCZYK Władysław(**)
74. SZYSZKO vel Chorąży Tomasz
75. TARCHALSKI Mikołaj
76. TRACZYK Piotr (*)
77. TYMIŃSKI Zbigniew
78. WASILEWSKI Adam
79. WOJDOWSKA Wioletta
80. ZADROŻNY Adam
81. ZARĘBA Barbara
82. ŻOŁĄDEK-NOWAK Joanna
83. ŻÓŁTOWSKA Małgorzata

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

VISITING SCIENTISTS

1	Aprile E.	Columbia University, New York, USA	16-17.11	BP2
2	Ackerman C.M.	NRG, Petten	08.06.	EJ1/UZ3
3	Adamczyk M.	IAEA, Austria	31.08.	EJ1/UZ3
4	Balaji R.	INSA Renne, France	24-25.11	LBM
5	Balashevskyi O.	Energoatom", UKR	02–06.11	EJ1/UZ3
6	Baron-Wiechec A.	Culham Centre for Fusion Energy	23.06	TJ4
7	Belovsky L.	Nuclear Power Plant Research Institute (VUJE), Slovenia	02–06.11	EJ1/UZ3
8	Bilicki M.	University of Cape Town, Republic *of* South Africa	19.01-23.01.	BP4
9	Bilicki M.	Leiden University, Nederlands	20.11.2015	BP4
10	Bomark N.	University of Agder,Norwegian	05-08.12	BP2
11	Boussarie J.P.	Institute of Nuclear Physics,Orscy,France	18-24.03	BP2
12	Capdevielle J.-Noël	Laboratoire AstroParticule et Cosmologie - APC, Université Paris Diderot, France	7.10-22.10	BP4
13	Capdevielle N.P.	University of Paris,France	12.04-01.05	BP4
14	Carrington M.	Brandon University, Canada	14.04-12.06	BP3
15	Chewpraditkul W.	KMUTT, King Mongkut’s University of Technology Thonburi, Bangkok, Tailand	27.09-24.10	TJ3
16	Chewpraditkul Weerapong	KMUTT, King Mongkut's University of Technology Thonburi, Bangkok, Thajland	27.09.-24.10.	TJ3
17	Choi K.Y.	Tajwan	30.05-02.06	BP2
18	Choudhury A.	Harish-Chandra Research Institute,Indie	27.04-09.05	BP2

			15-21.11	
19	Darányi A.	MTA EK, Hungarian Academy of Sciences Centre for Energy Research, Hungary	21-22.10	EJ1/UZ3
20	Dařílek P.	Nuclear Power Plant Research Institute (VUJE), Slovenia	21-22.10	EJ1/UZ3
21	Durkalec A.	Laboratoire d'Astrophysique de Marseille, France	16.12.14 – 5.01.15	BP4
22	Duspiva J.	Nuclear Power Plant Research Institute (VUJE), Slovenia	02–06.11	EJ1/UZ3
23	Fedorko L.	Mochovce NPP	02 06.11	EJ1/UZ3
24	Gadó J.	MTA EK, Hungarian Academy of Sciences Centre for Energy Research, Hungary	21-22.10	EJ1/UZ3
25	Garosi P.	CAEN, Viareggio, Italy	08-10.06	TJ3
26	Garrido	CSNSM, Orsay, France	26-31.10	BP1
27	Geissel H	GSI-Darmstadt, Germany	24.09 - 2.10	BP1
28	Główka M.	Warsaw University of Technology	06.07-31.07	Polatom
29	Gorodetzky P.	APC, Universite Paris_7, France	14-17.12	BP4
30	Grabowski A.	CEA,Saclay, France	11-16.10	TJ3
31	Grosseau Poussard J.L.	Universite La Rochelle, France	21.09	LBM
32	Gusztav M.	MTA EK, Hungarian Academy of Sciences Centre for Energy Research, Hungary	21-22.10	EJ1/UZ3
33	Hamel M.	CEA LIST,, Saclay, France	12-16.10	TJ3
34	Hatala B.	Nuclear Power Plant Research Institute (VUJE), Slovenia	21-22.10	EJ1/UZ3
35	Horváthm Á.|	MTA EK, Hungarian Academy of Sciences Centre for Energy Research, Hungary	21-22.10	EJ1/UZ3
36	Hózer Z.	MTA EK, Hungarian Academy of Sciences Centre for Energy Research, Hungary	21-22.10	EJ1/UZ3
37	Hryhorenko O.	Institut for Nuclear Research,Kiev,Ukraine	19-23.09	BP1
38	Iovene A.	CAEN, Viareggio, Italy	08-10.06	TJ3
39	Kereszturi A.	MTA EK, Hungarian Academy of Sciences Centre for Energy Research, Hungary	21-22.10	EJ1/UZ3
40	Klamra W.	Departament of Physics Royal Institute of technology, Stockholm, Sweden	07-17.12	TJ3
41	Klocok J	Nuclear Power Plant Research Institute (VUJE), Slovenia	21-22.10	EJ1/UZ3
42	Kool P.B.	Radworks, Holand	18-20.03	TJ1
43	Kvizda B.	Nuclear Power Plant Research Institute (VUJE), Slovenia	21-22.10	EJ1/UZ3
44	Ladygina M.	Institute of Plasma Physics, Kharkov, Ukraine	21.09.–03.10.	TJ3
45	Lansberg J.P.	Institute of Nuclear Physics,Orsay,France	14-20.06	BP2
46	Leclercq R.	ADIT, USA	20-21.05	TJ3
47	Łodygina M.	Institute of Plasma Physics,Kharkov,Ukraine	21.09-03.10	TJ5
48	Lotrus P.	Saclay, France	18.02	TJ1
49	Loiseau B.	Universite Paris VI, France	16-26.11	BP2
50	Lukashevich A.	Virginijus VILEINISKIS LEI	02– 06.11	EJ1/UZ3
51	Magner A.	Institute for Nuclear Research,Kiev,Ukraine	15-31.05	BP2
52	Magner A.	Institut for Nuclear Research,Kiev,Ukraine	21.09-04.10	BP2
53	Malini V.	Commercial service provided to TWI Ltd.	14-18.12	TJ4
54	Massacrier L	Institute of Nuclear Physics,Orsay,France	14-20.06	BP2

55	Mazurek T.	Warsaw University of Technology	01.08-31.08	Polatom
56	Mielczarek J.	Universite de Grenoble, on leave from NCBJ	27.07.-2.08.	BP4
57	Moretti S.	University of Southampton,UK	16-17.11. 5-8.12	BP2
58	Neuer M.	Division of Measurement and Automation, INNORIID, Germany	23.04.-24.04.	TJ3
59	Neuer M.	Division of Measurement and Automation, INNORIID, Germany	07-13.04	TJ3
60	Nocente M.	Instituto di Fisica del Plasma, Milano, Italy	23-27.02	TJ4
61	Parnovskyi S.	University of Kiev, Ukraine	21-27.09	BP2
62	Perevoznikov O.	Energoatom", UKR	02–06.11	EJ1/UZ3
63	Perseo V.	University of Milano Bicocca, Italy	30.04-31.07	TJ4
64	Pin-Wei Wang	Laboratoire d'Astrophysique de Marseille, France	2.06-8.06.	BP4
65	Prat P.	Laboratoire AstroParticule et Cosmologie - APC, Université Paris Diderot, France	14-17.12	BP4
66	Reymond J.-M.	Saclay, France	18.02	TJ1
67	Rigamonti D.	University of Milano Bicocca, Italy	22.02-18.03; 28.09-02.10	TJ4
68	Rousse J.-Y.	Saclay, France	18.02	TJ1
69	Sakthong O.	KMUTT, King Mongkut's University of Technology Thonburi, Bangkok, Thajland	27.09.-24.10.	TJ3
70	Semina V	Joint Institute for Nuclear Researche Dubna, Russia	06-13.12	LBM
71	Shams A.	NRG, Petten	25.05-29.05.	EJ1/UZ3
72	Sheubani A.	Nuclear Science and Technology Research Institute (INSTRI).Atomic Energy Organization of Iran	24-25.11	Polatom
73	Skarpa F.	Institute of Nuclear Physics,Orsay, France	12-24.10	BP2
74	Sreebunpeng K.	KMUTT, King Mongkut’s University of Technology Thonburi, Bangkok, Tailand	07-13.04	TJ3
75	Stempniewicz M. M.	NRG, Petten	08.06.	EJ1/UZ3
76	Takeuchi Tsutomu T.	Nagoya University, Japan	27-31.07. 12-17.10. 28-31.12.	BP4
77	Tardocchi M.	Instituto di Fisica del Plasma „Piero CValdirola”, Milano, Italy	02.10	TJ4
78	Tkaczyk A.	University of Tartu, Estonia	02.10.	EJ1/UZ3
79	Trifonov A.r	Joint Institute of Power and Nuclear Research "Sosny	02–06.11	EJ1/UZ3
80	Vasile A.	CEA, France	21-22.10	EJ1/UZ3
81	Walicka I.	Warsaw University of Technology	06.07-31.07	Polatom
82	West A.	ADIT, USA	20-21.05	TJ3
83	Witzanyová N.	Nuclear Power Plant Research Institute (VUJE), Slovenia	02–06.11	EJ1/UZ3
84	Wróblewska Z.	Warsaw University of Technology	06.07-20.07	Polatom
85	Yann L.	Saint-Gobain Crystals	27.05.	TJ3
86	Young Rang Uhm	Korea Atomic Energy Research Institute, Republic of Korea	14-18.09	Polatom
87	Zaitsev D.	International Humanitarian University, Odessa, Ukraine	24.11.	BP4
88	Żuk I.W.	SOSNY,Minsk, Belarus	10-13.06 13-16.10	EJ1
89	Zybin P.	Zaporizhzhya NPP, UKR	02–06.11	EJ1/UZ3

PROJECTS

RESEARCH PROJECTS IMPLEMENTED WITH THE FUNDS FOR SCIENCE

National Science Centre

1. Recombination dose meter of new generation for exposure assessment on workplaces in radiation fields of reactors and accelerators
   Principal Investigator: M. Gryziński, PhD
   No. N N404 1350 39
2. Analytic structure of the scattering amplitudes of hard exclusive processes in QCD
   Principal Investigator: J. Wagner, PhD
   No. 2011/01/D/ST2/02069
3. Nuclear states of antiprotons and strange mesons
   Principal Investigator: Prof. S. Wycech
   No. 2011/03/B/ST2/00270
4. Non-equilibrium quark-gluon plasma
   Principal Investigator: Prof. St. Mrówczyński
   No. 2011/03/B/ST2/00110
5. In vitro and in vivo investigations of the radiometals influence on the ability of CCK2R receptors imaging by the radiolabelled gastrin analogs
   Principal Investigator: Assoc. Prof. R. Mikołajczak
   No. 2011/03/B/ST5/02734
6. Isotropization of cosmological models
   Principal Investigator: O. Hrycyna, PhD
   No. 2012/04/S/ST9/00020
7. Cosmological models testing with deep galaxy surveys
   Principal Investigator: Assoc Prof. A. Pollo
   No. 2012/07/B/ST9/04425
8. Application of holographic methods to the study of stronly coupled Yang-Mills plasma
   Principal Investigator: Assoc Prof. M. Spaliński
   No. 2012/07/B/ST2/03794
9. 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
10. Critical phenomena in the nuclear nonextensive systems
    Principal Investigator: J. Rożynek, PhD
    No. 2013/09/B/ST2/029897
11. Participation of the POLGRAW group in VIRGO gravitational wave observatory
    Principal Investigator: Prof. A. Królak
    No. DPN/N176.VIRGO/2009
12. COMPASS experiment- study of the structure of the nucleon
    Principal Investigator: Prof. A. Sandacz
    No. 2011/01/M/ST2/02350
13. T2K – the second generation neutrino experiment
    Principal Investigator: Prof. E. Rondio
    No. 2011/01/M/ST/02578
14. 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

15. 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
16. 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
17. Study of CP symmetry breaking and search for New Physics in LHCb experiment
    Principal Investigator: Prof W. Wiślicki
    No. 2013/10/M/ST2/00629
18. Multiple choice problem in quantum cosmology
    Principal Investigator: P. Małkiewicz, PhD
    No. 2013/09/D/ST2/03714
19. Classification if z~1
    Principal Investigator: K. Małek, PhD
    No. 2013/09/D/ST9/04030
20. Studies of CPT symmetry violation
    Principal Investigator: W. Krzemień, PhD
    No. 2014/12/S/ST2/00459
21. Axino dark matter in scenarios with low reheating temperature of the Universe after
    Principal Investigation: S. Trojanowski, PhD
    No. 2014/13/N/ST2/02555
22. 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
23. 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
24. Search for a new exotic boson in light meson decays
    Principal Investigator: D. Pszczel
    No. 2014/15/N/ST2/03179
25. 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
26. 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
27. 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
28. T2K - the second generation neutrino experiment
    Principal Investigator: Prof. E. Rondio
    No. 2014/14/M/ST2/00850
29. Classification and clustering analysis of infrared-selected galaxies
    Principal Investigator: A. Solarz, PhD
    No. 2015/16/S/ST9/00438

Ministry of Science and Higher Education

1. Observation of astrophysical processes in strong gravitional fields wiith high time resolution in different ranges of spectrum and polarization
   Principal Investigator: Assoc. Prof. L. Mankiewicz
   No. ID2010000160
2. Study of Mueller-Navelet jets in the CMS
   Principal Investigator; T. Fruboes, PhD
   DPN/MOB131/III/2013
3. 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
4. Location of manganese atoms in semiconductor lattice after ion implantation and pulse plasma treatment
   Principal Investigator: Assoc. Prof. Z. Werner
   No. W7/ELETTRA/2014
5. Participation in calculations and design of the proton linac in ESS project
   Principal Investigator: S. Wronka, PhD
   No. W174/ESS/2014
6. Assesment of Regional Capabilities for new reactors Development through an Integrated Approach
   Principal Investigator: B. Mysłek-Laurikainen, PhD
   No. W41/7.PR-EURATOM/2015
7. Preparing ESNII for HORIZON 2020
   Principal Investigator: A. Przybyszewska, MSc.
   No. W13/7.PR-EURATOM/2015
8. The development and construction of an Electron Linear Accelerator for the GBAR Experiment
   Principal Investigator: S. Wronka, PhD
   No. W17/GBAR/2015
9. Intermediate bands produced by pulsed electron melting of Ti implanted GaAs and GaP
   Principal Investigator: Z. Werner, PhD
   No. W27/SPIRIT/2015
10. Mobilnośc Plus – IV edycja programu
    Principal Investigator: S. Trojanowski, PhD
    No. DN/MOB/029/IV/2015
11. Structural transformations in RE-ion bombarded ZnO epitaxial layers
    Principal Investigator: R. Ratajczak, PhD
    No. W28/SPIRIT/2015
12. Development and qualification of a deterministic scheme for the evaluation of gamma heating in experimental reactors with expoitation as example MARIA reactor and Jules Horowitz Reactor
    Principal Investigator: M. Tarchalski, PhD
    No. W226/JHR CEA/2012
13. Nuclear Reactor Safety Simulation Platform
    Principal Investigator: M. Spirzewski, MSc.
    No. W121/7.PR EURATOM/2013
14. Advanced Safety Assessment: Extended PSA
    Principal Investigator: M. Borysiewicz, PhD
    No. W36/7.PR EURATOM/2014

15. Preparation of ALLegro – Implementing Advanced Nuclear fuel cycle in Central Europe
    Principal Investigator: A. Przybyszewska, MSc.
    No. W57/7.PR EURATOM/2013

National Centre for Research and Development

1. Device for fast localization of the radioactive isotopes, dedicated for border guard
   Principal Investigator: S. Wronka, PhD
   No. PMPP/W/01-09.11
2. **HTRPL (SPREJ1)** - The development of high- temperature reactors for industrial applications (research network leader – AGH Univeristy of Science and Technology Cracow)
   Strategic Program "Technologies Supporting Development of Safe Nuclear Power Engineering"
   No. SP/J/1/166183/12
3. **ALTECH -** Alternative methods of technetium-99m production
   Applied Research Programme – programme path A
   No PBS1/A9/2/2012
4. **DOSIMEMS -** Passive, wireless MEMS dosimeter for the high radiation dose monitoring
   MNT ERA-NET
   No MNT/DOSIMEMS/2012
5. **ISOTTA -** ISOTope Trace Analysis (network leader - University of Silesia in Katowice)
   ERA-NET ASPERA-2
   No ERA-NET-ASPERA/03/11
6. **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
7. **GRAN-T-MTC -** Phase I clinical trial using a novel CCK-2/gastrin receptor-localizing radiolabelled peptide probe for personalized diagnosis and therapy of patiens with prograssive or metastatic medullary thyroid carcinoma
   ERA NET TRANSCAN
   No ERA-NET-TRANSCAN/01/2013
8. **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
9. **INTRA-DOSE -** Kompleksowy System do Radioterapii Śródoperacyjnej (leader – National Centre for Nuclear Research)
   Applied Research Programme – programme path B
   No PBS2/B9/26/2014
10. **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
11. **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
12. **MCAS -** Universal, multichannel control and data acquisition system (leader – National Centre for Nuclear Research)
    TANGO
    No TANGO1/267932/NCBR/2015

13. **GRAFEL -** Zaawansowane uszczelnienia połączeń ruchomych na bazie kompozytów elastromerowo-grafenowych (leader – National Centre for Nuclear Research)
    Applied Research Programme – programme path B
    No PBS3/B6/24/2015

RESEARCH PROJECTS GRANTED BY FOREIGN INSTITUTIONS

1. ESS - The European Spallation Source and the Superconducting Proton Linac
   Agreement No. 01/IPJ/2009
2. CERN – Design and construction of the Linac4 accelerator
   No. K1562/LINAC4
3. IAEA - Accelerator-based alternatives to non-HEU production of Mo-99/Tc-99m
   No. 17419
4. EURAMET - Ionizing radiation metrology for the metallurgical industry
   Principal Investigator : Z. Tymiński, MSc
   MetroMetal JRP IND04
5. EURAMET - Metrology for radioactive waste management
   Principal Investigator: Z. Tymiński, MSc
   MetroRWM JRP ENV09
6. CEA – Development and qualification of a deterministic scheme for the evaluation of gamma heating in experimental reactors with exploitation as example MARIA reactor and Jules Horowitz Reactor
   Principal Investigator : M. Tarchalski, MSc
   Commisariat a l'energie Atomique et aux Energie Alternatives No 13PPLA000012
7. EURAMET – Biologically Weighted Quantities in Radiotherapy
   Principal Investigator: S. Pszona, PhD
   BioQuaRT JRP No SIB06

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

1. **NURESAFE -** Nuclear Reactor Safety Simulation Platform
   Contract No. 323263 (2013-2015)
2. **ALLIANCE -** Preparation of ALLegro – Implementing Advanced Nuclear Fuel Cycle in Central Europe
   Contract No. 323295 (2013-2015)
3. **NC2I-R -** Nuclear Cogeneration Industrial Initiative - Research and Development Coordination
   Contract No. 605167 (2013-2015)
4. **ASAMPSA_E** - Advanced Safety Assessment: Extended PSA
   Contract No. 605001 (2013-2016)
5. **ARCADIA -** Assessment of Regional CApabilities for new Reactors Development through an Integrated Approach
   Contract No. 605116 (2013-2016)
6. **EuCARD-2 -** Enhanced European Coordination for Accelerator Research & Development
   Contract No. 312453 (2013-2017)
7. **TAWARA_RTM** - TAP WATER RADIOACTIVITY REAL TIME MONITOR
   Contract No. 312713 (2013-2016)
8. **ESNII plus -** Preparing ESNII for HORIZON 2020
   Contract No. 605172 (2013-2017)

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

10. **SKPLUS –** Super-Kamiokande plus
    Contract No. 641540 (2015-2019)

11. **C-BORD –** Effective Container inspection at BORDer control points
    Contract No. 653323 (2015-2018)

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

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

14. **EUROfusion** – Implementation of activities described in the Roadmap to Fusion during Horizon 2020 through a Joint programme of the members of the EUROfusion consortium
    Contract No. 633053 (2014-2018)

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

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

PROJECTS CO-FINANCED BY THE EUROPEAN UNION UNDER THE EUROPEAN REGIONAL DEVELOPMENT FUND (ERDF), SWISS CONTRIBUTION

1. **CIS -** Computing Centre in Świerk: infrastructure and services for power industry
   Implementation period: 05.01.2009–31.12.2015
   Project value: 124 390 408,74 PLN
   ERDF: 98 996 681,68 PLN
   Designated subsidy**:** 17 470 002,65 PLN
   Agreement No.: POIG.02.03.00-00-013/09

2. **4LAB -** Strenghtening of the innovation potential of the institute in Świerk for development of technologies based on ionising radiation
   Implementation period: 01.01.2010-30.06.2015
   Project value: 39 675 524,67 PLN
   ERDF: 33 675 466,00 PLN
   Agreement No.: RPMA.01.01.00-14-030/10-00

3. **PNT -** Construction of the Science and Technology Park along with the modernization of accompanying infrastructure of the Centre in Świerk
   Implementation period: 01.01.2010-30.11.2015
   Project value: 49 997 138,58 PLN
   ERDF: 42 289 853,64 PLN
   Agreement No.: RPMA.01.04.00-14-008/10-00

4. **BayesFITS -** Bayesian approach to multi-parameter problems in physics and beyond involving parallel computing and large data-sets
   Implementation period: 01.01.2011-31.12.2015
   Project value: 5 360 480,00 PLN
   ERDF: 4 556 408,00 PLN
   Agreement No.: WELCOME/2010-3/1

5. **PSAP -** Information Technologies for Astrophysical Observations in wide range of energy (leader – National Centre for Nuclear Research)
   Implementation period: 01.10.2011–30.06.2016
   Project values: 4 396 116,61 PLN
   SWISS Contribution: 86,82%
   Agreement No: 3/2011

6. **HOMING PLUS -** Mechanical properties of zirconium/zirconia system at high temperatures - the role of internal and interfacial stresses
   Implementation period: 01.02.2014—31.12.2015
   Project values: 287 000,00 PLN
   ERDF: 243 950,00 PLN
   Agrement No.: HOMING PLUS/2013-8/7

7. PWP. Utworzenie i realizacja interdyscyplinarnych, anglojęzycznych, międzynarodowych, stacjonarnych studiów doktoranckich Innovative Nuclear and Sustainable Power Engineering (leader –Warsaw University of Technology)
   Implementation period: 01.01.2014 – 30.06.2015
   Project value: 3 134 342,00 PLN
   ESF: 2 664 190,70 PLN
   Agreement No.: UDA-POKL.04.01.01-00-038/13-00

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

	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

Professor title

1. *Michał Spaliński* (National Centre for Nuclear Research)

2. *Lech Szymanowski* (National Centre for Nuclear Research)

Habilitation

1. *Ryszard Broda* (National Centre for Nuclear Research)
   "Wydajność detekcji liczników z ciekłym scyntylatorem w pomiarach aktywności radionuklidów"

2. *Michał Szleper* (National Centre for Nuclear Research)
   „The Higgs boson and the physics of WW scattering before and after Higgs discovery"
3. *Sławomir Wronka* (National Centre for Nuclear Research)
   „Interlaced Energy LINAC"

PhD theses

1. *Arkadiusz Łuczyk* (National Centre for Nuclear Research)
   "Power Dissipation Reduction in SMOVE Superscalar Processor Architecture"

2. *Artur Wodyński* (National Centre for Nuclear Research)
   "The influence of relativistic effects on the nuclear magnetic resonance spectra"

3. *Zofia Kalinowska* (Institute of Plasma Physics and Laser Microfusion)
   Badanie transformacji energii promieniowania laserowego do fali uderzeniowej w procesie oddziaływania tego promieniowania z płaskimi tarczami masywnymi z różnych materiałów w odniesieniu do koncepcji udarowego zapłonu termojądrowego"

4. *Roch Kwiatkowski* (National Centre for Nuclear Research)
   „Analiza wyników najnowszych pomiarów jonów, elektronów i promieniowania widzialnego plazmy w układach PF-360 i PF-1000"

5. *Sebastian Trojanowski* (National Centre for Nuclear Research)
   "Supersymmetric dark matter in light of recent searches for nem physics"

6. *Kamil Szewczak* (Central Laboratory for Radiological Protection)
   „Ocena narażenia radiologicznego podczas badań fuzyjnych na układzie PF-1000"

7. *Adam Zadrożny* (National Centre for Nuclear Research)
   "Search for gravitational waves in coincidence with optical observations"

8. *Paweł Sznajder* (National Centre for Nuclear Research)
   "Study of azimuthal asymmetries in exclusive leptoproduction of vector mesons on transversely polarized protons and deuterons"

9. *Marcin Michał Bielewicz* (National Centre for Nuclear Research)
   "Spektrometria neutronów o energiach powyżej 10MeV w ołowiowo-uranowym zastawie eksperymentalnym"

DEPARTMENTS AND DIVISIONS OF THE INSTITUTE

NUCLEAR FACILITIES OPERATION DEPARTMENT

Director of Department: Grzegorz Krzysztoszek, MSc Eng
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e-mail: Grzegorz.Krzysztoszek@ncbj.gov.pl

Overview

The MARIA research reactor operated for 4806 hours in 2015 at power ranging from 18 to 25 MW. The reactor was mainly used for irradiation of materials used in radioisotope production for the RC (Radioisotopes Centre) “Polatom” and the Mallinckrodt Pharmaceuticals company and for performing physical research at the outlet of the reactor horizontal beam ports. Especially intensive work took place between mid-October till early December, when 168 pieces of irradiated uranium targets for production of Mo-99 were dispatched from the reactor for processing in the Netherlands.

On the basis of prepared nuclear safety and radiological protection documents, the MARIA reactor has been authorized by the President of the National Atomic Energy Agency for operation up to March 31st 2025.

In collaboration between NCBJ, CEA-JHR and Aix-Marseille University measurements were made in the reactor using the KAROLINA calorimeter, an ionization chamber and two SPNDs (self-powered neutron detectors). These experiments allowed a comparison of the results of measurements with calculations.

In preparation for the export of the last batch of spent nuclear fuel to the Russian Federation, technology allowing the protection of MR type fuel elements during air transport was developed.

At the end of the year an agreement for the supply of nuclear fuel was signed. This will ensure the reactor operation for the next three years.

Grzegorz Krzysztoszek

MARIA REACTOR OPERATIONS DIVISION

Head of Division: Andrzej Gołąb, MSc Eng
phone: +48 22 2731088
e-mail: a.golab@ncbj.gov.pl

Overview

There are 50 employees (engineers and technicians) working in the Maria Reactor Operation Unit.

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

In 2015 the reactor operated 4300 hours at power levels from 18 MW to 25 MW.

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

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

Irradiation of target materials such as: TeO_2, KCl, Lu_2O_3, $SmCl_2$, S, Co etc. was performed for the Radioisotope Centre Polatom and irradiation of uranium targets was performed for Covidien. In addition production of ^{192}Ir seeds used for Intravascular Radiation Therapy and low activity ^{192}Ir source ribbon for oncology applications were carried out.

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

The commercial irradiation of uranium plates for ^{99}Mo production was carried out at the MARIA reactor in 2015 within 17 reactor operation cycles. Since July 2015 uranium plates have been irradiated at three positions inside the irradiation rig. This means that one irradiation cycle performs the irradiation of 24 uranium targets. Average activity of ^{99}Mo at the end of irradiation (EOI) obtained from one irradiation channel was 260 TBq for 8 targets loaded inside the irradiation channel and 360 TBq for channels with 12 uranium targets. Production of the radioisotope ^{99}Mo by irradiation of highly-enriched uranium (HEU) targets reached the level 10^4 TBq in 2015.

An important activity performed in 2015 was focused on preparation of the technology for irradiation oflow enriched uranium plates for ^{99}Mo production, related to the Global Threat Reduction Initiative.

Andrzej Gołąb

PERSONNEL

Technical staff

Marian Bąk
Sylwester Bąk
Wiesława Bąk
Zdzisław Bąk
Bolesław Broda
Michał Czarnecki, MSc Eng
Wiesław Ćwiek
Andrzej Frydrysiak, MSc Eng
Marcin Gadoś
Andrzej Gołąb, MSc Eng
Ryszard Góralski
Kazimierz Grzenda
Ireneusz Hora
Jacek Idzikowski, MSc Eng
Ireneusz Iwański, Eng
Janusz Jaroszewicz, MSc Eng
Krzysztof Jezierski, MSc Eng
Rober Keler
Dariusz Krawczyński
Waldemar Kultys
Edward Kurdej
Dariusz Kwiatkowski
Rober Laskus
Franciszek Lech
Jan Lechniak, MSc Eng
Krzysztof Lechnik
Jan Macios
Mateusz Łysiak

Research and technical staff

Janusz Jaroszewocz, MSc Eng
Krzysztof Majchrowski
Rober Marczak
Adrian Michalski
Dariusz Mucha
Paweł Nowakowski, MSc Eng
Hanna Odziemczyk
Ireneusz Owsianko, MSc Eng
Mariusz Ostanek
Krzysztof Sierańsk*
Wiesław Sikorski
Stefan Skorupa
Mieczysław Skwarczyński
Ryszard Stanaszek, MSc Eng
Janusz Suchocki
Piotr Szaforz, MSc Eng
Paweł Święch
Emil Wilczek, MSc Eng
Piotr Witkowski, Eng
Tomasz Witkowski
Paweł Wojtczuk
Marcin Wójcik
Jarosław Zienkiewicz, M Sc Eng
Krzysztof Żołądek

*part time employed

REPORTS

Estimation of radiological protection on the territory of Nuclear Centre Świerk and its vicinity (2014)
B. Filipiak, ... , **Z. Haratym**, **J. Ośko**, **T. Pliszczyński**, **B. Snopek**, **B. Boimski**, **S. Domański**, **M. Dymecka**, **R. Ejsmont**, **M. Feczko**, **A. Garboliński**, **B. Karpińska**, **J. Lechniak**, **A. Pawełczuk**, **B. Piotrkowicz**, **K. Rzemek**, **R. Sosnowiec**, **M. Szostak**, **W. Śniegoń**, **M. Tulik**, **M. Umaniec**, **K. Wiśniewska**, **K. Wojdowska**, **J. Wojnarowicz**, **Z. Worch**, **D. Zielińska**, ... et al.

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Application of the Code of Conduct in Polish research reactor Maria
A. Gołąb
Regional Meeting on Applications of the Code of Conduct on Safety of Research Reactors (Portugal, Lisbona, 2015-11-02 - 2015-11-06)

Full core conversion from HEU to LEU fuel in MARIA reactor
G. Krzysztoszek
The 9-th Technical Meeting on Lessons Learned from the RRRFR Programme (Uzbekistan, Samarkand, 2015-06-03 - 2015-06-05)

MARIA research reactor in supply chain of Mo-99
G. Krzysztoszek
Mo-99 2015 Topical Meeting on Molybdenum-99 Technological Development (USA, Boston, 2015-08-31 - 2015-09-03)

Oral Presentation

Recent upgrades and new scientific infrastructure of research MARIA research reactor, Otwock-Świerk, Poland
M.A. Gryziński, **J. Jaroszewicz**, **J. Milczarek**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

The 14 MeV Neutron Irradiation Facility in MARIA 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**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

Poster

Recent upgrades and new scientific infrastructure of research MARIA research reactor, Otwock-Świerk, Poland
M.A. Gryziński, **J. Jaroszewicz**, **J. Milczarek**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

The 14 MeV neutron irradiation facility in MARIA 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**
RRFM European Research Reactor Conference 2015 (Romania, Bucharest, 2015-04-19 - 2015-04-23)
European Nuclear Society, Brussels, Belgium No. (2015)
First Results of MC type LTA and Fuel Elements Sipping Tests After Conversion in MARIA Reactor

M. Migdał, **J. Lechniak**, **E. Borek-Kruszewska**
RERTR-2015 - 36th International Meeting on Reduced Enrichment for Research and Test Reactors (Korea, Seoul, 2015-10-11 - 2015-10-14)

LECTURES, COURSES AND EXTERNAL SEMINARS

MARIA reserach reactor operation in 2014[b]
G. Krzysztoszek
Athens, IPTA, 2015-05-22

The Characteristics and Irradiation Capabilities of MARIA research reactor in NCBJ Świerk[b]
G. Krzysztoszek
Cadarache, CEA-INSTN, 2015-11-04

[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

RESEARCH REACTOR TECHNOLOGY DIVISION

Head of Division: Janusz Piąstka, MSc Eng
phone: +48 22 2731091
e-mail: j.piastka@ncbj.gov.pl

Overview

The main tasks of the Division are to support the operation of the MARIA research reactor in:

- neutronics, thermal-hydraulic calculations and safety analysis,
- design of new equipment and technological systems for production and experiments,
- preparation of project documentation, construction, technical equipment and technological reactor systems in the framework of modernization or renovation,
- measurement technology, including in-core measurements,
- new nuclear detectors, their calibration and manufacture,
- repair of equipment and technological systems of the reactor,
- reactor spent fuel management,
- production of equipment or technological systems based on our own documentation or other authorized design units in the mechanical workshop,
- conducting the warehouse and archives of the department.

The Division operates under the new Quality Assurance Programme for the MARIA Reactor Facility called PZJ-MARIA-15.

The Division consists of five groups:

- Reactor Measurement and Analysis Group,
- Reactor Technology Group,
- Design and Technology Group,
- Technical Group,
- Mechanical Workshop.

There are 26 employees including 4 researchers with PhD degrees.

The main work carried out in 2015 dealt with:

MARIA Reactor Safety Report -2015, Safety Classification of Structures, Systems and

Components in the MARIA Research Reactor and the Quality Assurance Programme for the MARIA Reactor Facility, PZJ-MARIA-15, were prepared and approved by the Nuclear Safety Department of the National Atomic Energy Agency.

Preparation of technical documentation associated with encapsulation of spent fuel for Spent Fuel Shipment from the MARIA reactor to the Russian Federation in 2016 under the project on removal of the Russian-origin SFAs due to the Global Treat Reduction Initiative. ***The work was performed*** under the Blanket Master Contract No 00108513.

Technology of irradiation of annular uranium targets for molybdenum production was prepared.

Neutronic, thermo-hydraulic and safety calculations and analyses for experimental irradiations in the MARIA reactor. Neutronic calculations for MARIA reactor operation. Irradiation of target materials in thermal, fast and 14 MeV neutron field in the MARIA reactor for scientific and research purposes. Irradiationby high-dose gamma rays adjacent to spent nuclear fuel. Analysis of the isotopic composition of irradiated materials by gamma spectrometry, measurements of minerals.

Experiments in the MARIA reactor in cooperation with CEA and Aix-Marsille University – a set of in-core instrumentation, including new-design nuclear heating calorimeters, used to characterize the radiation field in the MARIA reactor. The measurements are used to verify the numerical codes for nuclear reactors.

Janusz Piąstka

REPORTS

Quality Assurance Program for MR Type Spent Fuel Encapsulation for Shipment in 2016 in brief
PZJ KAPS_MR_2016
E. Borek-Kruszewska, **J. Piąstka**
NCBJ, Raport Nr B-34/2015

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Postępowanie z wypalonym paliwem z reaktora badawczego MARIA
E. Borek-Kruszewska, **J. Piąstka**
Badania materiałowe na potrzeby elektrowni konwencjonalnych i jądrowych oraz przemysłu energetycznego (poland, zakopane, 2015-06-17 - 2015-06-19)
NCBJ No. (2015)

Możliwości wykorzystania reaktora jądrowego w nauce o konserwacji
M. Dorosz, **E. Miśta**, **J.J. Milczarek**
Naki ścisłe i zabytki (Poland, Kraków, 2015-09-25 - 2015-09-25)

Comparison of calibration of sensors used for the quantification of nuclear energy rate deposition, the 4th advancements in nuclear instrumentation measurement methods and their application (animma), 20-24 april 2015, lisbon congress center.
J. Brun, **M. Tarchalski**, C. REynard-Carette, **K. Pytel**, A. Lyoussi, **J. Jagielski**, D. Fourmentel, J-F. Villard
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)

Oral Presentation

MARIA - kolejne 10 lat. Wybrane analizy bezpieczeństwa.
M. Lipka
Jubileuszowe sympozjum Narodowego Centrum Badań Jądrowych (Poland, Otwock, 2015-06-15 - 2015-06-15)

Safety Analysis in the MARIA reactor
M. Lipka
IAEA Training Workshop on Research Reactor Related Modelling: from Core Optimization to Safety Analysis and Various Applications (Austria, Wiedeń, 2015-10-12 - 2015-10-16)

The 14 MeV Neutron Irradiation Facility in MARIA 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**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

Development and experimental qualification of a calculation scheme for the evaluation of gamma heating in experimental reactors. Application to MARIA and Jules Horowitz (JHR) MTR Reactors
M. Tarchalski, **K. Pytel**, P. Siréta, A. Lyoussi, C. Reynard-Carette, **J. Jagielski**, **M. Wróblewska**, D. Fourmentel, L. Barbot, J. Brun, **Z. Marcinkowska**, C. Gonnier, G. Bignan, J.F. Villard, C. Destouches, **A. Boettcher**, **R. Prokopowicz**, A. Luks
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)

Recent upgrades and new scientific infrastructure of research MARIA research reactor, Otwock-Świerk, Poland
M.A. Gryziński, **J. Jaroszewicz**, **J. Milczarek**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

Delayed Gamma Measurements in Different Nuclear Research Reactors Bringing Out the Delayed Contribution with the Gamma Spectra Calculations
D. Fourmentel, V. Radulovic, L. Barbot, J-F. Villard, G. Zerovnik, L. Snoj, **M. Tarchalski**, **K. Pytel**
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)

Numerical and Experimental Thermal Responses of Single cell and Differential Calorimeters: from Out-of-Pile Calibration to Irradiation Campaigns
J. Brun, **M. Tarchalski**, C. Reynard-Carette, **K. Pytel**, A. Lyoussi, **J. Jagielski**, D. Fourmentel, J.F. Villard, M. Carette
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)

Calculation to Experiment Comparison of SPND Signals in Various Nuclear Reactor Environments
L. Barbot, V. Radulović, D. Fourmentel, L. Snoj, **M. Tarchalski**, V. Dewynter-Marty, F.Malouch.
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)

Seismic Impact on MARIA reactor reactivity and power changes
M. Lipka
RRFM European Research Reactor Conference 2015 (Romania, Bucharest, 2015-04-19 - 2015-04-23) European Nuclear Society, Brussels, Belgium No. (2015)

Poster

First Results of MC type LTA and Fuel Elements Sipping Tests After Conversion in MARIA Reactor
M. Migdal, **J. Lechniak**, **E. Borek-Kruszewska**
RERTR-2015 - 36th International Meeting on Reduced Enrichment for Research and Test Reactors (Korea, Seoul, 2015-10-11 - 2015-10-14)

The 14 MeV neutron irradiation facility in MARIA 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**
RRFM European Research Reactor Conference 2015 (Romania, Bucharest, 2015-04-19 - 2015-04-23) European Nuclear Society, Brussels, Belgium No. (2015)

Recent upgrades and new scientific infrastructure of research MARIA research reactor, Otwock-Świerk, Poland
M.A. Gryziński, **J. Jaroszewicz**, **J. Milczarek**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

LECTURES, COURSES AND EXTERNAL SEMINARS

Thermal to 14 MeV neutron converter in MARIA reactor for fusion applications[a]
R. Prokopowicz
Warsaw, Polish Physical Society, Plasma Physics Section, 2015-03-17

[a)] in Polish

DIDACTIC ACTIVITY

E. Borek-Kruszewska - Keeping practices students of Warsaw University of Technology Faculty of Power and Aeronautical Engineering (3 persons)

M. Dorosz - Neutron flux measurements for ITC PW students 24 IV 2015

M. Dorosz - Neutron flux measurements for WAT students 1-2 VI 2015

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 "Analysis of the fuel element cooling in the nominal conditions" in the Faculty of Power and Aeronatical Engineering, Warsaw University of Technology

Z. Marcinkowska - Introduction to Nuclear Power, Warsaw University lecture.

Z. Marcinkowska - Neutron characteristic of MARIA reactor core. Diffusion model.

R. Prokopowicz - Neutron measurements in MARIA reactor - laboratory classes in reactor physics for Warsaw University of Technology

R. Prokopowicz - Validation of the MARIA reactor MCNP numerical model by means of neutron activation measurements, University of Warsaw

K. Pytel - Reactor physics exercises for students of Warsaw Technical University

K. Pytel - Supervision of intership of student from Aix Marseille University

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

Z. Marcinkowska
NCBJ Scientific Council

PERSONNEL

Research scientists

Marcinkowska Zuzanna, PhD
Pytel Krzysztof, PhD
Prokopowicz Rafał, PhD Eng
Dorosz Michał, MSc
Tarchalski Mikołaj, MSc Eng

Rersearch-technical staff

Borek-Kruszewska Elżbieta, PhD Eng
Wierzchnicka Małgorzata, MSc Eng

Technical and administrative staff

Czajka Wacław
Kaczyńska Danuta
Kurdej Jadwiga
Kozieł Alina, MSc
Lipka Maciej, MSc Eng
Migdal Marek
Piąstka Janusz, MSc Eng
Polak Jerzy, MSc Eng
Przybysz Zbigniew
Pytel Beatrycze, MSc
Sobiech Elżbieta
Święch Bogdan
Wróbel Wiesław
Wilczek Ireneusz
Wilczek Janusz
Wójcik Mieczysław
Zawadka Antoni
Zduńczyk Zbigniew
Żurawski Adam

RADIATION PROTECTION MEASUREMENTS LABORATORY

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Overview

The activities of the Radiation Protection Measurements Laboratory are focused on environmental monitoring and the 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,
- **Research in dosimetry (described below 1°)**
- **Setting up neutron station at the MARIA reactor (described below 2°) – internal project "Neutrony H2".**

In 2015 the Radiation Protection Measurement 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 dr. eng. Michał A. Gryziński – contact by e-mail m.gryzinski@ncbj.gov.pl or by phone: +48 22 2731157). The research group consists of six PhD's, 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 ionization chambers;
- Design and construction of recombination ionization chambers and dosimeters;
- Investigation of processes of ionization and recombination of ions in gases under pressure up to 5 MPa;
- Metrology of mixed radiation fields (including pulsed and high energy fields);
- Neutron dosimetry in a wide energy spectrum (neutron spectrometry – passive and active)
- Verification of installed dosimetry systems (medical applications);
- Polish Society of Medical Physics – reactivation of the Radiation Protection section. The main goal of the section is maintaining the membership of Poland in the IRPA (International Radiation Protection Association);
- Coordination of the preparation of an Integrated Management System for NCBJ;
- Developing the concept of absorbed dose distribution assessment based on PET and SPECT imaging, computer simulations and Monte Carlo calculations for SIRT therapy;
- Shields testing: stands for isotope sources and reactor fields (testing concrete samples for 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 (10^9 n cm^{-2}s^{-1});
- Thermo-hydraulic analyses (CFD) of the neutron converter, aimed to optimize 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

Introductory measurements of particulate matter concentration in ambient air in the vicinity of a potential location of a nuclear power plant (Krokowa commune)
M. Bogusz, **J. Bzdak**, **M. Lasiewicz**, **B. Mysłek-Laurikainen**, **M. Sowiński**, **H. Trzaskowska**
Narodowe Centrum Badań Jądrowych

Assesment of the conditio of radiological protection in the territory and in the vicinity of the National Radioactive Waste Repository inRóżan (2014)
M. Dymecka, **A. Garboliński**, **Z. Haratym**, **T. Pliszczyński**, **B. Snopek**, **W. Śniegoń**, **D. Zielińska**

Estimation of radiological protection on the territory of Nuclear Centre Świerk and its vicinity (2014)
B. Filipiak, ... , **Z. Haratym**, **J. Ośko**, **T. Pliszczyński**, **B. Snopek**, **B. Boimski**, **S. Domański**, **M. Dymecka**, **R. Ejsmont**, **M. Feczko**, **A. Garboliński**, **B. Karpińska**, **J. Lechniak**, **A. Pawełczuk**, **B. Piotrkowicz**, **K. Rzemek**, **R. Sosnowiec**, **M. Szostak**, **W. Śniegoń**, **M. Tulik**, **M. Umaniec**, **K. Wiśniewska**, **K. Wojdowska**, **J. Wojnarowicz**, **Z. Worch**, **D. Zielińska**, ... et al.

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

EURADOS survey on in-vivo monitoring data of exposed foreigners in Japan due to Fukushima Daiichi NPP accident
M.A. Lopez, P. Fojtik, D. Franck, **J. Ośko**
EURADOS Annual Meeting 2015 (Croatia, Dubrovnik, 2015-02-09 - 2015-02-12)

Kontrola narażenia wewnętrznego na promieniowanie jonizujące - zasady monitoringu i szacowania dawki
J. Ośko
II Konferencja z zakresu detekcji promieniowania jonizującego oraz kontroli jakości w rentgenodiagnostyce, radioterapii i medycynie nuklearnej (Poland, Klimkówka, 2015-05-11 - 2015-05-15)

Emisje substancji szkodliwych z elektrowni jądrowych w czasie eksploatacji
M. Wielgosz, **A. Strupczewski**
Międzynarodowe Targi Energetyczne (Poland, Kielce, 2015-03-05 - 2015-03-05)
Eko-atom (in press)

Current status of Boron Neutron Capture Therapy Today
E.A. Jakubowska
The Application of Nuclear Technology to Support National Sustainable Development: Health, Agriculture, Energy, Industry and Environment - International Symposium (Indonesia, Salatiga, 2015-10-26 - 2015-10-28)

Current Status of Boron Neutron Capture Cancer Therapy in Europe
M. Wielgosz, **M.A. Gryziński**, **E.A. Jakubowska**, **M. Maciak**, **K. Tymińska**
The Application of Nuclear Technology to Support National Sustainable Development: Health, Agriculture, Energy, Industry and Environment - International Symposium (Indonesia, Salatiga, 2015-10-26 - 2015-10-28)

Oral Presentation

Passive multi-layer neutron spectrometer for neutron radiation dosimetry
M. Maciak, N. Golnik, K. Dworecki, **S. Domański**, P. Tulik, **A. Araszkiewicz**
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)
SPIE Proceeding No.9662 (2015) p. 96622E

The research and training station based on intelligent fission converter at the Maria reactor.
M.A. Gryziński, **M. Wielgosz**, **M. Maciak**
VIII Young Researchers BNCT Meeting (Italy, Pavia, 2015-09-13 - 2015-09-17)

Filter/moderator system for a BNCT beam of epithermal neutrons at nuclear reactor MARIA.
K. Tymińska
VIII Young Researchers BNCT Meeting (Italy, Pavia, 2015-09-13 - 2015-09-17)

Filter/Moderator system for epithermal neutron beam at H-2 canal of MARIA reactor – numerical **model.**
K. Tymińska
Kongres z okazji 50-lecia Polskiego Towarzystwa Fizyki Medycznej (Poland, Warszawa, 2015-09-03 - 2015-09-05)

Determination of absorbed dose and radiation quality near eye phantom irradiated with therapeutic proton beam using a ring shaped recombination chamber
E.A. Jakubowska, **N. Golnik**, **M.A. Gryziński**
RAD 2015 Conference (Serbia and Montenegro, Budva, 2015-06-07 - 2015-06-11)

Lessons learned from the EURADOS Survey on in-vivo monitoring data and internaldose assessments of foreigners exposed in Japan at the time of Fukushima DaiichiNPP accident
M.A. Lopez, P. Fojtik, D. Franck, **J. Ośko**, U.C. Gerstmann, C. Scholl, A.L. Lebacq
International Conference on Individual Monitoring of ionising Radiation (Belgium, Bruges, 2015-04-20 - 2015-04-24)

BNCT research-educational station at MARIA reactor.
M. Wielgosz, **M. Maciak**
Congress of Polish Society of Medical Physics 50th anniversary of PSMP (Poland, Warszawa, 2015-09-03 - 2015-09-05)

Heat exchange modelling in uranium fuel assembly.
D. Zgorzelski, **M. Wielgosz**
XI Międzynarodowa Konferencja Elektroniki i Telekomunikacji Studentów i Młodych Pracowników Nauki (Poland, Warszawa, 2015-04-23 - 2015-04-24)

Intelligent uranium fission converter for neutrons production on the periphery of the nuclear reactor core (MARIA reactor in Świerk - Poland)
M. Maciak, **M.A. Gryziński**, **M. Wielgosz**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

Multipurpose epithermal neutron beam on new research station at MARIA research reactor in Świerk-Poland
M. Maciak, **M.A. Gryziński**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

Dosimetry for Radiation Protection with Recombination Chambers
E.A. Jakubowska, P. Tulik, **M. Maciak**
Kongres z okazji 50-lecia Polskiego Towarzystwa Fizyki Medycznej (Poland, Warszawa, 2015-09-03 - 2015-09-05)

Recent upgrades and new scientific infrastructure of research MARIA research reactor, Otwock-Świerk, Poland
M.A. Gryziński, **J. Jaroszewicz**, **J. Milczarek**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

Dosimtery for BNCT
E.A. Jakubowska, P. Tulik
Kongres z okazji 50-lecia Polskiego Towarzystwa Fizyki Medycznej (Poland, Warszawa, 2015-09-03 - 2015-09-05)
PTFM No. (2015) p. 26

Przeciwnowotworowa terapia borowo-neutronowa. Stanowisko szkoleniowe.
M.A. Gryziński, **M. Wielgosz**, **M. Maciak**
III Międzynarodowa Konferencja Radiofarmaceutyczna (Poland, Łódż, 2015-05-28 - 2015-05-29)

Characterization of low-LET radiation fields for irradiation of biological samples using recombination chambers
P. Tulik, S. Lepak, K. Domańska, **E.A. Jakubowska**
11th International Conference Mechatronic 2015 (Poland, Warszawa, 2015-09-21 - 2015-09-23)

Poster

Reneissance of the Boron Neutron Capture Therapy, BNCT
M.A. Gryziński, **M. Maciak**, **M. Wielgosz**
RAD 2015 Conference (Serbia and Montenegro, Budva, 2015-06-07 - 2015-06-11)
RAD Association, Niš, Serbia ISBN: 978-86-80300-01-6 No.3 (2015) p. 79 - 81

What we know about Oslo meteorite from cosmogenic isotope analysis
Z. Tymiński, M. Stolarz, T. Kubalczak, **K. Tymińska**, **E. Kołakowska**, **T. Dziel**, **A. Burakowska**, **E. Miśta**, **P. Saganowski**
European Planetary Science Congress (France, Nantes, 2015-09-27 - 2015-10-02)

Long time observations of the emission change of an old californium source
S. Domański, **B. Boimski**, **P. Tulik**
RAD 2015 Conference (Serbia and Montenegro, Budva, 2015-06-07 - 2015-06-11)

How to calibrate neutron dose ratemeters.
S. Domański, **B. Boimski**, **K. Wiśniewska**
Kongres z okazji 50-lecia Polskiego Towarzystwa Fizyki Medycznej (Poland, Warszawa, 2015-09-03 - 2015-09-05)

Research stand for concrete shielding tests
Ł. Murawski, **M.A. Gryziński**, **K. Tymińska**
RAD 2015 Conference (Serbia and Montenegro, Budva, 2015-06-07 - 2015-06-11)
RAD Association, Nis, Serbia No.3 (2015) p. 199-201

Characterization of reference neutron fields at polish secondary standard Dosimetry Laboratory
P. Tulik, **S. Domański**
RAD 2015 Conference (Serbia and Montenegro, Budva, 2015-06-07 - 2015-06-11)

Mobile device for automatic measurements of exposure to ionizing radiation.
Ł. Murawski
Congress of Polish Society of Medical Physics 50th anniversary of PSMP (Poland, Warszawa, 2015-09-03 - 2015-09-05)

Intelligent uranium fission converter for neutrons production on the periphery of the nuclear reactor core (MARIA reactor in Świerk - Poland)
M. Maciak, **M.A. Gryziński**, **M. Wielgosz**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

Multipurpose epithermal neutron beam on new research station at MARIA research reactor in Świerk-Poland
M.A. Gryziński, **M. Maciak**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

Measurements of iodine activity in thyroid after radioiodine therapy
J. Ośko, **T. Pliszczyński**, **R. Sosnowiec**, A. Gendek, **A. Dudziński**
Kongres z okazji 50-lecia Polskiego Towarzystwa Fizyki Medycznej (Poland, Warszawa, 2015-09-03 - 2015-09-05)

Recent upgrades and new scientific infrastructure of research MARIA research reactor, Otwock-Świerk, Poland
M.A. Gryziński, **J. Jaroszewicz**, **J. Milczarek**, **R. Prokopowicz**, **K. Pytel**, **M. Tarchalski**
Advancements in Nuclear Instrumentation Measurement Methods and their Applications - ANIMMA 2015 (Portugal, Lisboa, 2015-04-20 - 2015-04-24)

The pilot study on internal exposure monitoring of nuclear medicine personel
P. Tulik, K. Malec, **J. Ośko**, A. Budzyńska
Kongres z okazji 50-lecia Polskiego Towarzystwa Fizyki Medycznej (Poland, Warszawa, 2015-09-03 - 2015-09-05)

X-ray and neutron radiography studies of archaeological objects
E. Miśta, **J.J. Milczarek**, P. Tulik, **I. Fijał-Kirejczyk**
11th International Conference Mechatronics 2015 (Poland, Warsaw, 2015-09-21 - 2015-09-23)

Wykorzystanie obrazowania radiograficznego w badaniach archeometrycznych i konserwatorskich
E. Miśta, **J.J. Milczarek**, **I. Fijał-Kirejczyk**, P. Tulik, **T. Kosiński**, **W. Dziewiecki**
Chemia analityczna w ochronie zabytków XV edycja (Poland, Warsaw, 2015-12-04 - 2015-12-05)

LECTURES, COURSES AND EXTERNAL SEMINARS

Radiochemical methods for determination alpha and beta emitting isotopes in biological and environmental samples[a]
K. Rzemek
Klimkówka, II Konferencja z zakresu detekcji promieniowania jonizującego oraz kontroli jakości w rentgenodiagnostyce, radioterapii i medycynie nuklearnej , 2015-05-12

Stand for testing the effectiveness of shielding against ionizing radiation in nuclear power stations[a]
Ł. Murawski
Zakopane, National Centre for Nuclear Research, Materials Research Laboratory, 2015-06-18

BNCT Workshop [b]
E.A. Jakubowska
Cracow, National Center for Nuclear Research, Polish Society for Medical Physics, 2015-09-07

a) in Polish
b) in English

INTERNAL SEMINARS

Competences of Environmental Analysis Laboratory[b]
A. Burakowska, J. Bzdak, M. Bogusz
Otwock-Świerk, National Centre for Nuclear Research, 2015-02-24

b) in English

DIDACTIC ACTIVITY

S. Domański - NCBJ employee training. Combined courses A, B, A-A.

M. Dymecka - Radiation Protection Training, 8th International School on Nuclear Power, 27-30.10.2015

J. Ośko - External supervisor of Damian Renik's master thesis "Preparation and calibration of the portable device for thyroid contamination measurements", Warsaw University, Faculty of Physics

J. Ośko - Master thesis conultant. Katarzyna Malec, "The assesment of medical staff internal exposure", Warsaw University of Technology,
Faculty of Electronics and Information Technology

J. Ośko - Radiation protection training course for NCBJ staff, 22-25 June 2015

J. Ośko - Radiation Protection Training, 8th International School on Nuclear Power, 27-30.10.2015

A. Pawełczuk - Prowadzenie szkoleń z zakresu ochrony radiologicznej w ramach instruktażu wstępnego dla nowoprzyjmowanych pracowników oraz praktykantów i doktorantów (przeszkolono 85 osób).

T. Pliszczyński - Radiation Protection Training, 8th International School on Nuclear Power, 27-30.10.2015

K. Rzemek - Radiation Protection Training, 8th International School on Nuclear Power, 27-30.10.2015

R. Sosnowiec - Radiation Protection Training, 8th International School on Nuclear Power, 27-30.10.2015.

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

S. Domański
Polish Society of Medical Physics

N. Golnik
The Committee on Medical Physics, Radiobiology and Diagnostic Imaging of the Polish Academy of Sciences , member
Polish Society of Medical Physics, Vice President
European Radiation Dosimetry Group, EURADOS, representative of the voting member, member of the WG11 working group
Member, Polish Radiation Research Society
Polish Journal of Medical Physics and Engineering, Polish Journal of Medical Physics and Engineering, Polish Society of Medical Physics

M.A. Gryziński
Session chairman on Kongres z okazji 50-lecia Polskiego Towarzystwa Fizyki Medycznej in Warszawa, Poland
Member of Organizing Committee on Kongres z okazji 50-lecia Polskiego Towarzystwa Fizyki Medycznej in Warszawa, Poland
Member of Advisory Board on Kongres z okazji 50-lecia Polskiego Towarzystwa Fizyki Medycznej in Warszawa, Poland
President of the Mazovia branch
członek grupy roboczej WG3 "Dosimetry and treatment planning"
Corresponding member EURADOS WG9 - Radiation protection dosimetry in medicine
Corresponding member EURADOS WG11 - High energy radiation fields
voiting member
voiting member
National Centre for Nuclear Research

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

Ł. Murawski
Member of Organizing Committee on Congress of Polish Society of Medical Physics 50th anniversary of PSMP in Warszawa, Poland
Polish Society of Medical Physics

J. Ośko
Session chairman on II Konferencja z zakresu detekcji promieniowania jonizującego oraz kontroli jakości w rentgenodiagnostyce, radioterapii i medycynie nuklearnej in Klimkówka, Poland
Session chairman on Warsaw Medical Physics Meeting in Warszawa, Poland
Member of Advisory Board on Warsaw Medical Physics Meeting in Warszawa, Poland
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
Polish Journal of Medical Physics and Engineering, Editorial Advisory Board Polish Society of Medical Physics

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

M. Wielgosz
Member of Organizing Committee on Congress of Polish Society of Medical Physics 50th anniversary of PSMP in Warszawa, Poland
Polish Society of Medical Physics

M. Zielczyński
Member, Polish Society of Medical Physics
Member, Polish Radiation Research Society

PERSONNEL

Research scientist

Bartosik Łukasz, PhD Eng (since 1.09.2015)
Domański Szymon, MSc
Gryziński Michał A., PhD Eng
Haratym Zbigniew, PhD
Jakubowska Edyta, MSc Eng
Maciak Maciej, MSc Eng
Murawski Łukasz, Eng
Ośko Jakub, PhD Eng
Pliszczyński Tomasz, MSc Eng
Rzemek Katarzyna, MSc Eng
Tulik Piotr, PhD Eng
Tymińska Katarzyna, PhD
Wielgosz Monika, PhD Eng

Technical and administrative staff

Araszkiewicz Agnieszka, MSc
Boimski Błażej, Eng
Bogusz Małgorzata, MSc Eng (since 16.10.2015)
Dymecka Małgorzata, MSc Eng
Ejsmont Ryszard, Tech.
Feczko Maciej
Garboliński Andrzej, Tech.
Karpińska Barbara
Korab Marzena, MSc.
Kurdej Alicja, Tech.
Leszko Aneta (since 1.09.2015)
Mądry Magdalena, MSc (since 21.11.2015)
Pawełczuk Andrzej, Eng
Piotrkowicz Barbara
Prusińska Maria, MSc Eng
Snopek Bożydar, Eng
Sosnowiec Renata, Tech
Szostak Magdalena, MSc (until 31.08.2015)
Śniegoń Wiesława, MSc Eng
Umaniec Marianna, Tech
Wiśniewska Kazimiera
Wojdowska Katarzyna, MSc
Worch Zofia
Zielińska Danuta

MATERIAL PHYSICS DEPARTMENT

Director of Department: Professor Jacek Jagielski
phone: +48 22 2731443
e-mail: Jacek.Jagielski@ncbj.gov.pl

Overview

In 2015 research activities in MPD were concentrated on the continuation of our previous work on studies of materials expected to be used in a nuclear environment and the use of nuclear techniques for modification and analysis of solids. Main achievements in 2015 were: (i) obtaining two European grants (in common with other NCBJ Departments) VINCO and BRILLIANT, (ii) agreement with the HelmholtzZentrum Berlin on the acquisition of experimental devices from HZB and (iii) successful completion of the 4Lab Project sponsored by EU structural funds. It is worth pointing out that the VINCO project is coordinated by DFM NCBJ. Two smaller grants for projects on copper nitride and graphene-reinforced elastomers were obtained from NCN and NCBiR. DFM is involved in NCBJ is preparations to play the role of TSO in the Polish Nuclear Power Plant Plan. The key component is the Materials Research Laboratory (MRL) which is the unique facility in Poland disposing of the equipment needed to perform analyses of radioactive structural materials. The Laboratory was designed for testing surveillance specimens from a planned nuclear power plant. MRL has the Certificate of Testing Laboratory Accreditation No. AB 025. The Laboratory has also been granted 2nd Degree Approval No LB-038/27 by the Office of Technical Inspection. It also has the License of the National Radiological Protection and Nuclear Safety Department Nr. 1/93/"MET" for investigation of irradiated materials up to 100Ci. The hot laboratory consists of an assembly of 12 lead hot cells arranged in a single line. All cells are designed to handle 3700 GBq (100Ci) of 1 MeV gamma emitter. Each of the cells is equipped with a viewing window and with master-slave or tongs manipulators. The hot cells are connected by a special inert transport system. The assembly of hot cells is equipped with ventilating and active waste systems.

Among the main research topics in the MPD are:

- X-ray diffraction: structure of safe antidepresive alkaloid aptazepine obtained in first enantioselective synthesis and topography investigations of crystal lattice defects in ferroelectric niobates with tungsten bronze structure.
- Neutron scattering: magnetic and atomic short range order in $Mn_{0.3}Ni_{0.3}Cu_{0.4}$ pseudo-binary alloy studied with neutron elastic scattering, studies of the drying process.
- Mechanical properties: studies of strength and hardness of materials used in nuclear engineering, analysis of the role of irradiation on functional properties of elastomers.
- Corrosion properties: studies of zirconium corrosion in nuclear reactors, modification of oxidation resistance using plasma or ion-beam doping of steels.
- Studies of the synthesis and mechanical properties of Oxide-Dispersed Strenghtened (ODS) steels.
- Development of new ferromagnetic semiconductors for spintronics.
- Studies of the dependence of specific features of plasma surface engineering methods on the structure of the deposited layers.
- Optimisation of thin film Pb photocathodes

The researchers of the MPD published 73 scientific publications and made 69 presentations at conferences in 2015.

Jacek Jagielski

NUCLEAR METHODS IN SOLID STATE PHYSICS DIVISION

Head of Division: Jacek J. Milczarek, PhD
phone: +48 22 2731233
e-mail: Jacek.Milczarek@ncbj.gov.pl

Overview

The Department is involved in research on 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-ray (XRD and synchrotron radiation) and thermal neutron (neutron scattering and neutron radiography) techniques. Some specialized techniques such as high pressure systems, rapid quenching and sol-gel method have also been applied. A few theoretical and computational studies on properties of uranium oxide have also been carried out.

The Department consists of three labs:

Regional Laboratory of Neutronography,
X-ray Diffraction Laboratory,
Technology of nano-systems

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

The main work completed in 2015 dealt with:

- X-ray diffraction studies of active pharmaceutical compounds.
- Enantioselective synthesis of (*S*)-(+)-mianserin and (*S*)-(+)-epinastine
- Synthesis and structure of new chiral (+)-3-carene-based monotosylated diamines.
- Complex crystalline phases in the MSO_3F-$Ag(SO_3F)(2)$ phase diagram (M = Na, K, Rb, Cs).
- Electron and Scanning Microscopy characterization of nanostructured coatings.
- Micro- and nano-scale structure of Al_2O_3-TiO_2 composite coatings.
- Nanoscale matrices of phosphors for biomedical applications.
- Toxicity of active optical nanoparticles in $YAl_3(BO_3)_4$:Cr^{+3}.
- The effect of phase decomposition on phonon spectra in $Mn_{0.3}Ni_{0.3}Cu_{0.4}$ pseudo-binary alloy.
- Effect of hydrostatic extrusion on the crystalline structure of copper single crystals.
- Small angle neutron scattering studies on Cr doped ODS steels.
- Spontaneous migration of water in quasi-2-dimensional systems with strong evaporation.
- Application of neutron imaging in cultural heritage and paleontological research.
- The neutron imaging investigation of metallic finds of the Late Roman and Early Migration periods from the Łężany archaeological site.

Jacek J. Milczarek

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Możliwości wykorzystania reaktora jądrowego w nauce o konserwacji
M. Dorosz, **E. Miśta**, **J.J. Milczarek**
Naki ścisłe i zabytki (Poland, Kraków, 2015-09-25 - 2015-09-25)

Thermal neutron imaging of archaeological artefacts and bio-archaeological remains from Poland
J.J. Milczarek
Application of 3d Neutron Imaging and Tomography in Cultural Heritage Research, Final Research Coordination Meeting of the Coordinated Research Project, Iaea (Italy, Firenze, 2015-04-20 - 2015-04-24) IAEA No. (2015)

Oral Presentation

Badania obiektów archeologicznych kultury przeworskiej przy użyciu radiografii i tomografii neutronowej
I. Fijał-Kirejczyk, **J.J. Milczarek**, **E. Miśta**, **J. Żołądek-Nowak**, **J. Żołądek**, **Z. Jurkowski**
IX Ogólnopolska Konferencja Rozpraszanie Neutronów i Metody Komplementarne w Badaniach Fazy Skondensowanej (Poland, Chlewiska koło Siedlec, 2015-06-07 - 2015-06-11)

Water migration in composite systems with synthetic zeolites
I. Fijał-Kirejczyk, **J.J. Milczarek**, **J. Żołądek-Nowak**, M. Majdan, **Z. Jurkowski**, **J. Żołądek**
XX ZEOLITE FORUM Scientific Meeting of The Polish Zeolite Association (Poland, Stryszawa, 2015-09-22 - 2015-09-26)

Poster

X-ray and neutron radiography studies of archaeological objects
E. Miśta, **J.J. Milczarek**, P. Tulik, **I. Fijał-Kirejczyk**
11th International Conference Mechatronics 2015 (Poland, Warsaw, 2015-09-21 - 2015-09-23)

Wykorzystanie obrazowania radiograficznego w badaniach archeometrycznych i konserwatorskich
E. Miśta, **J.J. Milczarek**, **I. Fijał-Kirejczyk**, P. Tulik, **T. Kosiński**, **W. Dziewiecki**
Chemia analityczna w ochronie zabytków XV edycja (Poland, Warsaw, 2015-12-04 - 2015-12-05)

Studies on the Structure of Composites Based on Oxide Systems
L. Górski
Konwersatorium Krystalograficzne (Poland, Wrocław, 2015-06-25 - 2015-06-27)

DIDACTIC ACTIVITY

J.J. Milczarek - Lectures on "Application of Neutrons in Research and Technology of Materials"
Faculty of Materials Science and Engineering, Warsaw University of Technology

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

K. Cmiel
Association of Engineers and Technicians of Chemical Industry
J. Jankowska-Kisielińska
member Polish Society of Neutron Scattering

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

K. Wieteska
Session chairman on Badania Materiałowe na Potrzeby Elektrowni Konwencjonalnychi Jądrowych oraz Przemysłu Energetycznego in Zakopane, Poland
Member of Advisory Board on Badania Materiałowe na Potrzeby Elektrowni Konwencjonalnych i Jądrowych oraz Przemysłu Energetycznego in Zakopane, Poland
member, Polish Synchrotron Radiation Society

PERSONNEL

Research scientists

Budzianowski Armand, PhD
Cieślik Iwona, PhD
Czachor Andrzej,Professor
Dąbrowski Ludwik, Professor
Fijał-Kirejczyk Izabela, PhD
Górski Ludwik, PhD
Jankowska-Kisielińska Joanna, PhD
Maurin Jan, PhD Sc
Milczarek Jacek J., PhD
Świderska Karolina, MSc
Żołądek-Nowak Joanna, MSc

Technical staff
Jurkowski Zdzisław
Wójcik Tadeusz
Żołądek Jan

PLASMA/ION BEAM TECHNOLOGY DIVISION

Head of Division: Cezary Pochrybniak, PhD
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Overview

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

- Development of new ferromagnetic semiconductors for spintronics – ZnO single crystals Co ion implanted: investigation of structural and magnetic features,
- Study of IPD plasma pulse features under gas injection conditions,
- High Intensity Plasma Ion Beams in technological applications,
- Superconductive cathodes for efficient electron gun - optimisation of thin Pb films on Nb photocathodes,
- Molecular dynamics simulations of defect transformation at various stress level,
- ZNOLUM project –detailed investigation of light emitting photonics structures,
- Archerometry – materials study of archaerological objects using non- and microinvasive methods,
- Strengthening of the innovation potential of the Institute in Świerk for the development of technologies based on ionizing radiation – 4Labs Project (definitely finished on 30 VI 2015).

A ferromagnetic semiconductor operating at room temperature with ferromagnetism (FM) controlled by an electronic system (charge carriers) is the dream of researchers interested in the development of spintronics. We focused on ZnO doped with cobalt which is believed to be a prospective material in which high temperature FM is predicted theoretically. Admittedly FM was detected in ZnO but its interpretation is far from complete – the results of various groups are inconsistent with one another and depend to a great extent on the preparation technology. We also began new investigations on multi band gap semiconductors. Our first results – highly doped GaP by titanium ions looks very interesting. We rebuilt the crystalline structure ofa semiconductor doped with high a dose of titanium.

We have also focused on IPD technology for synthesis of metastable alloy layers. The Impulse Plasma Deposition (IPD) technique is the only method of plasma surface engineering (among plasma based technologies) which allows the synthesis of layers on a cold unheated substrate and ensures good adhesion. This year we studied in detail Fe-Cu alloy layers.

A thin Pb film photocathode is a promising material, planned to be used in a superconducting electron linac. One way in which we tried to prepare this was by high vacuum arc deposition using the compact deposition system constructed in late 2011. The second way we tried to prepare such layers was using the hot plasma method, HIPIB. Pulsed plasma treatment has been recognized as a promising method for the preparation of thin film superconducting photocathodes and will be developed in further activities. A thick film of Pb must be deposited on the back wall of a modified electron gun resonator.

We focused on the development of efficient tools for the simulation of defects in single crystals – the McChassy code. This is a very useful tool for our research in solid state crystalline structures in NRA and RBS, investigations. RBS, especially in 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.

The archaeometry studies on ancient objects tried to answer/reconstruct e.g. the circulation of silver in Early Medieval Poland and others. This kind of precious object needs special treatment by non- and microinvasive methods, such as SEM, EDS, EDX, XRD, Raman Spectroscopy and neutronography. These methods allow a wide-ranging study of archaeological relics. Archaeometry is the subject of a PhD thesis.

In 2015 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

Study on pigments used in ancient tiles originate from archaelogical site in Aveh, Iran
E. Miśta
Iran (in press)

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Thin layer Pb photocathode deposition for improved performance of SRF guns (status in May 2015)
R. Nietubyć, **J. Lorkiewicz**, J. Sekutowicz, **M. Barlak**, D. Kostin, **A. Kosińska**, R. Barday, R. Xiang, **R. Mirowski**, **M. Frelek**, **W. Pawlak**, **T. Sworobowicz**, **J. Witkowski**, **W. Grabowski**
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)

OES studies of plasmoids distribution during the coating deposition with the use of the IPD method controlled by the gas injection
K. Nowakowska-Langier, R. Chodun, K. Zdunek, S. Okrasa, **R. Kwiatkowski**, **K. Malinowski**, **E. Składnik-Sadowska**, **M.J. Sadowski**
9-th Symposium on Vacuum based Science and Technology in conjunction with the 14-th Annual Meeting of the German Vacuum Society (DVG) (Poland, Kolobrzeg, 2015-11-17 - 2015-11-19)

Skarby Pojezierza Mazurskiego w świetle badań starozytnych aliaży
E. Miśta, **A. Gójska**
Odkryte na nowo – archeolodzy i historycy na tropach tajemnic Warmii i Mazur (Poland, Mrągowo, 2015-12-09 - 2015-12-10)

Air prospection of the Baltic Sea
E. Miśta, K. Trela
2-nd National PhD and Student Science Conference: Interregional contacts in the Baltic Sea. Trade, conflicts, migrations, dispersion of ideas (Poland, Gdańsk, 2015-05-14 - 2015-05-15)

Mechanism of damage buildup in ion bombarded compound single crystals
A. Turos, **J. Jagielski**, L. Thome
The 19th International Conference on Surface Modification of Materials by Ion Beams (SMMIB-19) (Thailand, Chiang Mai, 2015-11-22 - 2015-12-27)
Surf. Coat. Technol. (2015)

Comparison of calibration of sensors used for the quantification of nuclear energy rate deposition, the 4th advancements in nuclear instrumentation measurement methods and their application (animma), 20-24 April 2015, Lisbon Congress Center.
J. Brun, **M. Tarchalski**, C. Reynard-Carette, **K. Pytel**, A. LyoussI, **J. Jagielski**, D. Fourmentel, J-F. Villard
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)

Badania proweniencyjne oraz technologiczne artefaktów archeologicznych wykonanych ze stopów srebra i miedzi
E. Miśta, W. Duczko, **A. Turos**, P. Kalbarczyk, J. Dudek, A. Kędzierski, D. Wyczółkowski, M. Widawski, J. Gaca
Nauki ścisłe i zabytki (Poland, Kraków, 2015-09-25 - 2015-09-25)
Kraków No. (2015)

Możliwości wykorzystania reaktora jądrowego w nauce o konserwacji
M. Dorosz, **E. Miśta**, **J.J. Milczarek**
Naki ścisłe i zabytki (Poland, Kraków, 2015-09-25 - 2015-09-25)

Analiza chemiczna dekoracyjnych kafelków nasciennych z Iranu
D. Włodarczyk, **E. Miśta**, I. Żmuda-Trzebiatowska, P. Kalbarczyk, M. Kolbadinejad, A. Lashkari
Naki ścisłe i zabytki (Poland, Kraków, 2015-09-25 - 2015-09-25)
Kraków No. (2015)

Recent high-temperature plasma studies by the NCBJ team, Poland
M.J. Sadowski, **E. Składnik-Sadowska**, **R. Kwiatkowski**, **K. Malinowski**, **K. Nowakowska-Langier**, **J. Żebrowski**, **K. Czaus**, **W. Surała**, **D. Załoga**, M. Kubkowska, M. Paduch, E. Zielinska, P. Kubes, I. Garkusha, V. Makhlay, M. Ladygina
ICDMP Annual Meeting and Workshop (Poland, Warsaw, 2015-09-11 - 2015-09-13)

Oral Presentation

Signal acquisition in Cherenkov-type diagnostics of electron beams within tokamak facilities
M. Rabiński, **L. Jakubowski**, **M.J. Sadowski**, **J. Żebrowski**, **M.J. Jakubowski**, **K. Malinowski**, **R. Mirowski**
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)

Improvement of Pb-based thin layers deposited on Nb substrate
A. Kosińska, **M. Barlak**, **J. Lorkiewicz**, J. Sekutowicz, **R. Nietubyć**, **Ł. Kurpaska**, **K. Nowakowska-Langier**
YUCOMAT 2015 (Serbia and Montenegro, Herceg Novi, 2015-08-31 - 2015-09-04)

Elektrodynamiczne przyspieszanie obiektów
A. Horodeński, **C. Pochrybniak**, A. Sitnik
XX Międzynarodowa Konferencja Naukowo–Techniczna Uzbrojenie' 2015 (Poland, Jachranka, 2015-06-08 - 2015-06-11)

Polsko-francuska współpraca naukowa dla wsparcia rozwoju energetyki jądrowej. French – Polish Collaboration on nuclear materials: NCBJ story and my personal experience
C. Mieszczyński
MADRALIN- 2015 Wybrane aspekty bezpieczeństwa jądrowego w Polsce (Poland, Warszawa, 2015-11-24 - 2015-11-25)

Modification of the surface layer of zirconium alloys using high intense pulsed plasma beams (HIPPB)
B. Sartowska, W. Starosta, L. Waliś, **M. Barlak**
21st International QUENCH Workshop (Germany, Karslruhe, 2015-10-27 - 2015-10-29)
Karslruhe Institute of Technology Editor: Martin Steinbruck No. (2015)

Badania obiektów archeologicznych kultury przeworskiej przy użyciu radiografii i tomografii neutronowej
I. Fijał-Kirejczyk, **J.J. Milczarek**, **E. Miśta**, **J. Żołądek-Nowak**, **J. Żołądek**, **Z. Jurkowski**
IX Ogólnopolska Konferencja Rozpraszanie Neutronów i Metody Komplementarne w Badaniach Fazy Skondensowanej (Poland, Chlewiska koło Siedlec, 2015-06-07 - 2015-06-11)

Development and experimental qualification of a calculation scheme for the evaluation of gamma heating in experimental reactors. Application to MARIA and Jules Horowitz (JHR) MTR Reactors
M. Tarchalski, **K. Pytel**, P. Siréta, A. Lyoussi, C. Reynard-Carette, **J. Jagielski**, **M. Wróblewska**, D. Fourmentel, L. Barbot, J. Brun, **Z. Marcinkowska**, C. Gonnier, G. Bignan, J.F. Villard, C. Destouches, **A. Boettcher**, **R. Prokopowicz**, A. Luks
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)

Numerical and Experimental Thermal Responses of Single cell and Differential Calorimeters: from out-of-Pile Calibration to Irradiation Campaigns
J. Brun, **M. Tarchalski**, C. Reynard-Carette, **K. Pytel**, A. Lyoussi, **J. Jagielski**, D. Fourmentel, J.F. Villard,

M. Carette
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)

Development of the Cherenkov-type diagnostic system to study runaway electrons in tokamaks
L. Jakubowski, **K. Malinowski**, **R. Mirowski**, **M. Rabiński**, **M.J. Sadowski**, **J. Żebrowski**, **M.J. Jakubowski**
1st EPS Conference on Plasma Diagnostics (Italy, Frascati, 2015-04-14 - 2015-04-17)

Poster

X-ray and neutron radiography studies of archaeological objects
E. Miśta, **J.J. Milczarek**, P. Tulik, **I. Fijał-Kirejczyk**
11th International Conference Mechatronics 2015 (Poland, Warsaw, 2015-09-21 - 2015-09-23)

The role of magnetic energy on glow discharge localization under reduced pressure
K. Nowakowska-Langier, RafalChodun, KrzysztofZdunek, SebastianOkrasa
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Analiza składu chemicznego ceramiki naściennej (XIII_XV w.) z Qom, Aveh i Mashhad w Iranie
M. Rudnicka, **E. Miśta**, I. Żmuda-Trzebiatowska, P. Kalbarczyk, M. Kolbadinejad, A. Lashkari, G. Śliwiński
Chemia analityczna w ochronie zabytków XV edycja (Poland, Warsaw, 2015-12-04 - 2015-12-05)

Advanced characterization of the crystal evolution via channeling and MC simulations - Application to nuclear oxides bombarded with low-energy ions
F. Garrido, T.H. Nguyen, **L. Nowicki**, C. Bachelet, J. Bourcois, A. Debelle, A. Gentils, Y. Haddad, S. Mylonas, L. Thome
IBA 2015- 22nd International Conference on Ion Beam Analysis (Croatia, Opatija, 2015-06-14 - 2015-06-19)
Nucl. Instr. and Meth. B (2015)

Wykorzystanie obrazowania radiograficznego w badaniach archeometrycznych i konserwatorskich
E. Miśta, **J.J. Milczarek**, **I. Fijał-Kirejczyk**, P. Tulik, **T. Kosiński**, **W. Dziewiecki**
Chemia analityczna w ochronie zabytków XV edycja (Poland, Warsaw, 2015-12-04 - 2015-12-05)

Coating and processing of thin lead layers on niobium for photocathodes in superconducting RF electron injectors
R. Nietubyć, **J. Lorkiewicz**, **A. Kosińska**, **M. Barlak**, J. Sekutowicz, D. Kostin, R. Barday, R. Xiang, **R. Mirowski**, **J. Witkowski**, **W. Grabowski**
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)
Phys. Scr. (2015)

Damage buildup and structure recovery in RE-ion implanted ZnO
R. Ratajczak, E. Guziewicz, **A. Turos**, **A. Stonert**, D. Snigurenko, K. Kopalko
IBA 2015- 22nd International Conference on Ion Beam Analysis (Croatia, Opatija, 2015-06-14 - 2015-06-19)

Durability changes of cobalt-tungsten carbide tools after ion implantation
J. Narojczyk, D. Morozov, **Z. Werner**, **M. Barlak**, M. Łagodziński
9-th Symposium on Vacuum based Science and Technology in conjunction with the 14-th Annual Meeting of the German Vacuum Society (DVG) (Poland, Kolobrzeg, 2015-11-17 - 2015-11-19)

Zinc oxide films grown at low temperature– electrical properties and hydrogen contamination
E. Guziewicz, T.A. Krajewski, D. Snigurenko, D. Jarosz, E. Przezdziecka, G. Luka, R. Jakiela, K. Kopalko, **A. Stonert**, **R. Ratajczak**

Jaszowiec2015- 44th International School and Conference on the Physics of Semiconductors (Poland, Wisła, 2015-06-20 - 2015-06-25)

Pokrycia ochronne koszulek cyrkonowych dla zwiększenia ich odporności na utlenianie w warunkach awarii typu LOCA
W. Starosta, **M. Barlak**, P. Tomassi, B. Sartowska, L. Waliś, M. Miłkowska
MADRALIN- 2015 Wybrane aspekty bezpieczeństwa jądrowego w Polsce (Poland, Warszawa, 2015-11-24 - 2015-11-25)

Structural, optical and electrical properties of ZnO single crystals andepitaxial films implanted with Er and Yb
E. Guziewicz, **R. Ratajczak**, D. Snigurenko, M. Stachowicz, T.A. Krajewski, **A. Stonert**, **A. Turos**
Jaszowiec2015- 44th International School and Conference on the Physics of Semiconductors (Poland, Wisła, 2015-06-20 - 2015-06-25)

Physico-chemical study on iron ores, materials and furnace residue originate from International Iron Smelting Days Workshop in Poland
E. Miśta, P. Linke, W. Weker, P. Kalbarczyk, K. Trela, I. Żmuda-Trzebiatowska
Archaeometallurgy in Europe 2015 (Spain, Madrid, 2015-06-01 - 2015-06-03)

Epitaxial ZnO films implanted with Er and Yb
A. Guziewicz, **R. Ratajczak**, D. Snigurenko, M. Stachowicz, T.A. Krajewski, **A. Stonert**
XVII International Conference on II-VI Compounds and Related Materials (II-VI 2015) (France, Paris, 2015-09-13 - 2015-09-18)

Badania właściwości mechanicznych i strukturalnych stali typu ODS przeznaczonych dla energetyki termojądrowej.
W. Pawlak, **J. Jagielski**, **Ł. Kurpaska**, M. Lewandowska, M. Chmielewski, I. Jóźwik, K. Perkowski
Jubileuszowe Sympozjum Narodowego Centrum Badań Jądrowych (Poland, Otwock, 2015-06-15 - 2015-06-15)

Hydrogen contamination in ZnO films grown at low temperature
E. Guziewicz, T.A. Krajewski, D. Jarosz, E. Przeździecka, G. Luka, D. Snigurenko, R. Jakiela, K. Kopalko, **A. Stonert**, **R. Ratajczak**, J.W. Sobczak
XVII International Conference on II-VI Compounds and Related Materials (II-VI 2015) (France, Paris, 2015-09-13 - 2015-09-18)

Air prospection of the Baltic Sea region
E. Miśta, K. Trela
The first international conference on Truso, (Poland, Elbląg, 2015-05-17 - 2015-05-18)

Comparative study of radiation-induced damage in magnesium aluminate spinel by means of IL, CL and RBS/c techniques
I. Jozwik, **J. Jagielski**, G. Gawlik, **P. Jóźwik**, **R. Ratajczak**, G. Panczer, N. Moncoffre, A. Wajler, A. Sidorowicz, L. Thome
IBA 2015- 22nd International Conference on Ion Beam Analysis (Croatia, Opatija, 2015-06-14 - 2015-06-19)

Structural, optical and electrical properties of ZnO single crystals and epitaxial films implanted with Er and Yb
E. Guziewicz, **R. Ratajczak**, D. Snigurenko, M. Stachowicz, T.A. Krajewski, **A. Stonert**, **A. Turos**
XVII International Conference on II-VI Compounds and Related Materials (II-VI 2015) (France, Paris, 2015-09-13 - 2015-09-18)

Quasiamorphous ZnO layers produced by the ALD technique
A. Turos, E. Guziewicz, **A. Stonert**, D. Snigurenko, B.S. Witkowski, R. Diduszko, M. Behar
XVII International Conference on II-VI Compounds and Related Materials (II-VI 2015) (France, Paris, 2015-09-13 - 2015-09-18)

Research on the corrosion and ornamentation of the metal artifacts from archaeological site Czaszkowo,

Poland.
P. Kalbarczyk, **E. Miśta**, A. Rzeszotarska-Nowakiewicz, T. Nowakiewicz
XXV Analytical Seminar in Poznan: Modern methods of sample preparation and determination of trace quantities of elements (Poland, Poznań, 2015-04-09 - 2015-04-10)

Studies of pulsed plasma-ion streams during their free propagation and interaction with SiC-targets
E. Składnik-Sadowska, **R. Kwiatkowski**, **K. Malinowski**, **M.J. Sadowski**, **K. Czaus**, **D. Załoga**, **J. Żebrowski**, **K. Nowakowska-Langier**
International Conference on Plasma Science ICOPS-2015 (Turkey, Antalya, 2015-05-24 - 2015-05-28)

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**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

What we know about Oslo meteorite from cosmogenic isotope analysis
Z. Tymiński, M. Stolarz, T. Kubalczak, **K. Tymińska**, **E. Kołakowska**, **T. Dziel**, **A. Burakowska**, **E. Miśta**, **P. Saganowski**
European Planetary Science Congress (France, Nantes, 2015-09-27 - 2015-10-02)

LECTURES, COURSES AND EXTERNAL SEMINARS

Synthesis of copper nitride layers by pulsed magnetron sputtering method[a]
K. Nowakowska-Langier
Warsaw, Institute of Fundamental Technological Research Polish Academy of Sciences , 2015-11-18

Progress in deposition and smoothing of thin-layer lead photocathodes on niobium; test results and future prospects[b]
J. Lorkiewicz
Berlin, Helmholtz Centre Berlin (HZB), 2015-02-13

Recent achievements in cathodic arc deposited thin film Pb photocathodes flattening[b]
J. Lorkiewicz
Hamburg, Deutsches Elektronen Synchrotron (DESY), 2015-04-08

Plasma pulsed irradiation preparation of lead coated photo-cathodes[b]
R. Nietubyć
Barcelona, ., 2015-04-21

Status of preparation at NCBJ Swierk of thin-layer lead photocathodes for SRF injectors[b]
J. Lorkiewicz
Rossendorf, Helmholtz Zentrum Dresden Rossendorf, 2015-12-04

a) in Polish
b) in English

INTERNAL SEMINARS

Science popularization on the changing-educational-landscape of Poland [a]
L. Nowicki
Otwock-Swierk, NCBJ, 2015-01-15
Archaeometry in NCNR[a]
E. Miśta
Otwock, National Centre for Nuclear Research, 2015-05-13

Material microanalysis in archaeometallurgical research[a]
E. Miśta
Otwock-Swierk, National Centre for Nuclear Research, FM2 Division, 2015-10-14

Project IBIS II - history, and plans for future[a]
A. Horodeński
Świerk, National Center for Nuclear Research, 2015-11-12

Rentgenowskie badania strukturalne wzrostu cienkich warstw Nb na szafirze (001).[a]
R. Nietubyć
Otwock-Świerk, NCBJ, 2015-11-25

a) in Polish

DIDACTIC ACTIVITY

E. Miśta -
The course conducted in the framework of the Vistula Children University "What archaeologist doing with the atom?", April 2015

K. Nowakowska-Langier - "Preliminary studies of synthesis and characterisations of copper nitride layers"

A. Turos - scientific advisor of PhD thesis of Przemyslaw Jozwik

A. Turos - Thesis advisor of Ewelina Miśta

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

J. Jagielski
Boehmische Physical Society
Nuclear Physics Committee Polish Physical Society
Member and President of the Scientific Council of the 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

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

PERSONNEL

Scientific staff

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

Research – technical staff

Horodeński Andrzej, MSc Eng

Kosińska Anna, MSc Eng
Kowalska Ewa, MSc Eng
Mirowski Robert, MSc Eng
Miśta Ewelina, MSc
Namyślak Kamil MSc Eng
Strzelecki Grzegorz, MSc.

Technical Staff

Bojarczuk Janusz
Gniadek Krzysztof
Karpisz Stanisław
Kuk Mirosław
Staszkiewicz Bogdan
Trembicki Andrzej
Wiraszka Andrzej
Zagórski Jerzy

Administrative staff

Woźnica Magdalena, MSc

MATERIAL RESEARCH LABORATORY

Head of Division: Ewa Hajewska, PhD
phone: +48 22 231061
e-mail: Ewa.Hajewska@ncbj.gov.pl

Overview

The Material 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 of materials irradiated in nuclear reactors. All studies performed in MRL are conducted according to a Quality Assurance Program.

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

- Instron 8500 Dynamic Testing System with two 100 kN frames for testing tensile and compressive strength, low cycle fatigue resistance, fracture toughness, bend characteristics and crack growth resistance at -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 at -150 °C to 800 °C temperature range, for determination of significant force and deflection values, partial energy values and characteristical 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 the 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 samples from irradiated reactor components
- Sample preparation for metallographic examination
- Optical microscopy
- Thermal treatment and annealing
- Chemical analysis

At the end of 1998, the laboratory for non-destructive testing of materials was put into operation in the MRL. The non-destructive laboratory is equipped with new equipment and uses different methods of investigation, such as: visual inspection, liquid penetration inspection, ultrasonic examination, radiographic inspection and structure investigation.

MRL holds the Accreditation Certificate of Testing Laboratory No AB 025 which confirms fulfillment of the ISO/IEC 17025:2001 criteria and since 1995 holds the Certificate of Testing Laboratory 2nd Degree Approval No LB-038/27 granted to the MRL by the Office of Technical Inspection. This indicates that MRL fulfils the criteria of the standard PN-EN IOS/IEC 17025:2005.

In 2015 several research projects funded by MNiSW, IAEA, FNP (Foundation for Polish Science) and NCBJ were carried out MRL. Currently, two new projects funded by the European Commission: VINCO and BRILLIANT are in operation. In 2015 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 an investigation of the mechanical properties of irradiated layers. In 2015 MRL researchers published 3 high impact journal papers and participated in 5 international conferences.

Ewa Hajewska

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Przykłady zastosowania metod NDT do badania wybranych elementów konstrukcji elektrowni jądrowych
B. Zając
Nieniszczące Badania Materiałów (Poland, Zakopane, 2015-03-18 - 2015-03-20)

In-situ phase and stress analysis of high temperature zirconia scale developed on pure zirconium and Zr-Nb1% alloy as studied by Raman spectroscopy.
Ł. Kurpaska
XIIIth International Conference on Molecular Spectroscopy (Poland, Wrocław, 2015-09-09 - 2015-12-13)
J. Mol. Struct. (2015)

Mechanical properties of irradiated Gd-based pyrochlores as studied by nanoindentation technique – effect of grains and grain boundaries
Ł. Kurpaska
18th International Conference on Radiation Effects in Insulators (REI-18) (India, Jaipur, 2015-10-26 - 2015-10-31)
Nucl. Instr. and Meth. B (2015)

Thin layer Pb photocathode deposition for improved performance of SRF guns (status in May 2015)
R. Nietubyć, **J. Lorkiewicz**, J. Sekutowicz, **M. Barlak**, D. Kostin, **A. Kosińska**, R. Barday, R. Xiang, **R. Mirowski**, **M. Frelek**, **W. Pawlak**, **T. Sworobowicz**, **J. Witkowski**, **W. Grabowski**
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)

Oral Presentation

Improvement of Pb-based thin layers deposited on Nb substrate
A. Kosińska, **M. Barlak**, **J. Lorkiewicz**, J. Sekutowicz, **R. Nietubyć**, **Ł. Kurpaska**, **K. Nowakowska-Langier**
YUCOMAT 2015 (Serbia and Montenegro, Herceg Novi, 2015-08-31 - 2015-09-04)

Poster

Badania właściwości mechanicznych i strukturalnych stali typu ODS przeznaczonych dla energetyki termojądrowej.
W. Pawlak, **J. Jagielski**, **Ł. Kurpaska**, M. Lewandowska, M. Chmielewski, I. Jóźwik, K. Perkowski
Jubileuszowe Sympozjum Narodowego Centrum Badań Jądrowych (Poland, Otwock, 2015-06-15 - 2015-06-15)

Identifying sub-oxide phases at the metal-oxide interphase developed on pure zirconium using Raman spectroscopy technique
Ł. Kurpaska
European Congress and Exhibition on Advanced Materials and Processes - EUROMAT 2015 (Poland, Warszawa, 2015-09-20 - 2015-09-24)

Microstructural and mechanical evaluation of the zirconium // zirconia interphase.
Ł. Kurpaska
2015 MRS Fall Meeting & Exhibit (USA, Boston, 2015-11-29 - 2015-12-04)

LECTURES, COURSES AND EXTERNAL SEMINARS

Ultrasonic Phased Array and TOFD. Application examples of OmniScan[a]
B. Zając, G.Olszewski
Warsaw, Olympus Polska, 2015-02-26

Badania materiałowe na potrzeby elektrowni konwencjonalnych i jądrowych oraz przemysłu energetycznego National Centre for Nuclear Research, Jubilee Symposium[a]
B. Zając, G. Olszewski, Z. Rozemblicki
Otwock-Swierk, National Centre for Nuclear Research, 2015-06-15

Badania materiałowe na potrzeby elektrowni konwencjonalnych i jądrowych oraz przemysłu energetycznego; XXII Seminarium naukowo-techniczne
G. Olszewski, B. Zając, Z. Rozemblicki
Zakopane, LBM, NCBJ, 2015-06-17

The modern equipment for the structural materials study in dynamic load condition[a]
J. Wasiak
Zakopane, National Centre for Nuclear Research, Material Research Laboratory, 2015-06-19

Work safety of high-pressure steam pipelines of power units under modernization[a]
J. Wasiak
Zakopane, National Centre for Nuclear Research, Material Research Laboratory, 2015-06-19

The estimation of measurement uncertainty - workshop[a]
M. Frelek
Warsaw, POLLAB - Polish Research Laboratories Club, 2015-06-29

Materialgraphy - workshop[a]
M. Frelek
Warsaw, Struers Sp. z o.o, 2015-10-08

European XFEL Users Meeting 2015[b]
W. Pawlak
Hamburg, European XFEL, DESY, 2015-01-28

Elements of the back - end of the nuclear fuel cycle: geological storage of nuclear spent fuel[b]
M. Frelek
Oskarshamn, Royal Institute of Technology (KTH), Linnaues University in Sweden, Swedish Nuclear Fuel and Waste Menagement Company (SKB), NOVA Center, 2015-06-08

8. International School of Nuclear Power[b]
M. Frelek
Warsaw, National Centre for Nuclear Research, 2015-10-26

Modern laboratory - DNA 4Y series. Weight measurements in the light of the requirements of accreditation and certification procedure.[a]
M. Frelek
Warsaw, Radwag - Electronical Scales, 2015-03-18

Accreditation in regulated territory. The rules, conditions and current status.[a]
M. Frelek
Warsaw, Polish Centre for Accreditation, 2015-03-18

Lab problems - the series of lectures [a]
M. Frelek
Warsaw, Polish Research Laboratories Club POLLAB and Polish Committee for Standardization, 2015-03-19

Quality assurance for ISO/IEC 17025 accredited laboratories with CRMs and PT Schemes[b]
M. Frelek
Warsaw, Tusnovics Instruments Sp. z o.o and ERA A Waters Company, 2015-03-19

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

DIDACTIC ACTIVITY

Ł. Kurpaska - Promoter of the engineering work. M. Gapińska University of Warsaw. Title of work "Physical, chemical, mechanical properties and crystallographic structure of polymorphic variants of zirconia implanted ions Ar2 +"

B. Zając - Eddy Current testing course level 2 according to PN-EN 4179 for Staff Training Center "INTERPROFESJA"18-22.052015, Warszawa

B. Zając - Ultrasonic testing course level 2 according to PN-EN ISO 9712 for Staff Training Center "INTERPROFESJA", 24-29.09.15; 16-25.11.15, Warszawa

PERSONNEL

Research scientists
Waldemar Bilous, PhD
Małgorzata Frelek, MSc Eng
Ewa Hajewska, PhD
Łukasz Kurpaska, PhD
Wioleta Pawlak, MSc Eng
Martyna Przyborska, MSc Eng
Tadeusz Wagner, MSc Eng
Jan Wasiak, PhD
Mariusz Wieczorkowski, MSc Eng
Bogdan Zając, MSc Eng.

Technical and administrative staff
Konrad Ćwiek
Mirosław Jagodziński
Jagoda Zdzisław, Eng
Stanisław Mucha
Grzegorz Olszewski, Eng
Alicja Ostrowska
Zbigniew Rozenblicki
Jadwiga Wojciechowska-Kwaśniewska
Tadeusz Zych

DEPARTMENT OF FUNDAMENTAL RESEARCH

Director of Department: Professor Grzegorz Wilk
Phone: +48 22 5532226
e-mail: wilk@fuw.edu.pl

Overview

The scientific activity of DBP in 2015 is presented in 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), to which I refer for details and further references. Here I present a short overview. The main achievements selected for achievements of the whole Institute to be presented to the general public are:

(*) Publication by M.P.Hellera and M.Spalińskiego (from BP2) on *Hydrodynamics Beyond the Gradient Expansion: Resurgence and Resummation*; Phys. Rev. Lett. 115, 072501 (2015).

(*) The pivotal role of Prof. **L. Roszkowski** (from BP2) in the organization in Warsaw of the famous international conference *COSMO-15* must be specially acknowledged.

The Nuclear Physics Division (BP1) concentrated on low energy nuclear physics (mostly in collaboration with the Heavy Ion Laboratory, University of Warsaw; plans to collaborate with ISOLDE at CERN are in progress). Its activity in high energy nuclear physics connected with the Hermes collaboration at the Deutsches Elektronen Synchrotron (DESY) in Hamburg was finally closed. Also activity connected with the large-scale international collaboration PANDA in the FAIR project was practically frozen because of very serious problems and delays in work on this project experienced at the GSI laboratory. Attempts to renew the activity of the BP1 division towards true nuclear physics have been undertaken and are now supervised by the new head of BP1, Prof. Z.Patyk (moved to BP1 from BP2).

The Theoretical Physics Division (BP2) works in close collaboration with experimental groups at CERN, GSI, Kamiokande and Frascatti and in collaboration with the Universities of Warsaw, Kielce, Paris, Liege, London and such institutes as PAN, CERN, GSI, JINR, RIKEN. It concentrates on the properties of heavy and superheavy nuclei; properties of nuclear matter and nuclear collisions; exotic atoms; phenomenology of collisions of hadrons and leptons; supersymmetry and cosmology, nonlinear effects in extended media and the Bayesian approach to multi-parameter problems in physics and beyond. In all of them many new interesting results were found (cf. http://www.ncbj.gov.pl/en/theoretical-physics-division-bp2 for detailed information). Its main achievements have already been mentioned above. The others are mentioned in the report by the division leader.

The activities of the High Energy Physics Division (BP3) concentrated mostly on the LHC experiments ALICE, CMS, and LHCb and on neutrino physics. At the end of 2015 LHC re-started after the shutdown and new data are constantly being collected. This year special emphasis should be put on the work on prompt photon production done in great part by the Warsaw group of the PHOS detector at the ALICE experiment. Our Neutrino Physics group, as part of the K2K collaboration, shaes a part of the glory caused by the 2015 Nobel prize in neutrino physics. This group alsoadded to its previous achievements new, very valuable results in 2015.

Among the achievements of the Division of Astrophysics, (BP4), are the first successful test of the EUSO-Ballon experiment, new results in investigations of the large scale of the Universe and, still unofficially, participation in the possible discovery of gravitational waves (most probably this will be the main subject of scientific interest in 2016, see links to the recent materials posted on the NCBJ web page:

http://www.ncbj.gov.pl/en/aktualnosci/gravitational-waves-discovered-100-years-after-einstein-had-predicted-them

http://www.ncbj.gov.pl/en/aktualnosci/what-known-gravitational-waves

http://www.ncbj.gov.pl/en/aktualnosci/looking-optical-transitions-possibly-related-candidates-gravitational-waves

Grzegorz Wilk

NUCLEAR PHYSICS DIVISION

Head of Division: Professor Zygmunt Patyk
phone: +48 22 55 32 229
e-mail: zygmunt.patyk@ncbj.gov.pl

Overview

Our scientific activities in 2015 concentrated mainly on two subjects: low energy nuclear physics and medium energy physics.

- Activities of the low-energy direct reactions group in 2015 resulted in ten publications in refereed journals and an invited talk at the XXXIV Mazurian Lakes Conference on Physics. A new collaboration with our colleagues from Padua under the aegis of the POLITA agreement has already produced results with a publication in Phys. Rev. C 92, 024615 (2015) on the reactions induced by ^{7}Be incident on a ^{58}Ni target. Mr. Oleksandr Hryhorenko successfully passed the entrance examination for admittance as a PhD student and should join the group in that capacity in September/October 2016.

- In a collaboration with GSI-Darmstadt the masses of 25 exotic nuclei were determined for the first time. Nuclei were extracted from the reaction of ^{238}U on a beryllium target. Masses were determined in an isochronous mass spectrometer under two different conditions with an uncertainty of a few keV. The results were partly published in Physics Letters B.

- The group is involved in the Hermes collaboration at the Deutsches Elektronen Synchrotron (DESY) in Hamburg. The group has finished the analysis of transverse target-spin asymmetry in exclusive ω–meson electro-production. The results were published in Eur. Phys. J. C35 600 (2015). The Hermes collaboration ceased basic activity (at the end of 2014). However, the group will work at least through the current year to finish an analysis and prepare publications. The group is continuing an analysis of the decay of the Δ resonance into the lepton pair $^{+}$e $^{-}$e at the WASA experiment. The angular distribution of decay products of the virtual photon is studied in order to establish the polarization states of the photon. The WASA experiment has also ceased taking data and part of the group is involved in analyses of the COMPASS experiment.

- Prof. B. Zwięglinski, dr A. Trzcinski, and eng. G. Kęsik are engaged in a large-scale international collaboration PANDA (antiProton ANnihilations at DArmstadt) in the FAIR project. In 2015 their activities were focused on preparation of tripartite (FAIR_Gmbh-JU-NCBJ) and bipartite (JU-NCBJ) contracts permitting the opening of the funding stream. Among the annexes of the contracts is a technical report containing a detailed description of the slow-control system for the cluster-jet target of the PANDA detector. This is one of the two contributions planned by NCBJ to PANDA. The participation of eng. A. Chłopik [NCBJ Dept. TJ-4] in the project is acknowledged.

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Zygmunt Patyk

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Strong Coupling Effects in Near-barrier Heavy-ion Elastic Scattering
N. Keeley, K.W. Kemper, **K. Rusek**
XXXIV Mazurian Lakes Conference on Physics (Poland, Piaski, 2015-09-06 - 2015-09-12)

Oral Presentation

Wzrost zainteresowania reakcją syntezy $^{11}B(p, \alpha)2\alpha$, czy uda się powrócić do koncepcji zbudowania ultra czystego reaktora jądrowego? Polski wkład w badania.
A. Malinowska, **A. Szydłowski**, **M. Jaskóła**
XLIII Zjazd Fizyków Polskich (Poland, Kielce, 2015-09-06 - 2015-09-11)

Two identical pions correlations at small relative momenta in collisions of Al+Al and Ni+Ni at 1.9A GeV
V. Charviakova, R. Kotte, K. Piasecki, T. Matulewicz
XI Workshop on Particle Correlations and Femtoscopy (Poland, Warsaw, 2015-11-03 - 2015-11-07)

Poster

Determination of impact parameters in aligned breakup of projectile-like fragments in $^{197}Au + {}^{197}Au$ collisions at 23A MeV
T. Cap, K. Siwek-Wilczyńska, **J. Wilczyński**, F. Amorini, L. Auditore, G. Cardella, E. DeFilippo, E. Geraci, L. Grassi, A. Grzeszczuk, E. LaGuidara, J. Han, T. Kozik, G. Lanzalone, I. Lombardo, R. Najman, N.G. Nicolis, A. Pagano, M. Papa, **E. Piasecki**, S. Pirrone, R. Płaneta, G. Politi, F. Rizzo, P. Russotto, I. Skwira-Chalot, A. Trifiró, M. Trimarchi, G. Verde, W. Zipper
XXXIV Mazurian Lakes Conference on Physics (Poland, Piaski, 2015-09-06 - 2015-09-12)
Acta Phys. Pol. B (2016)

Two identical particle correlations at small relative momenta in collisions of Al+Al and Ni+Ni at 1.9A GeV
V. Charviakova, R. Kotte, K. Piasecki, T. Matulewicz
XXXIV Mazurian Lakes Conference on Physics (Poland, Piaski, 2015-09-06 - 2015-09-12)

LECTURES, COURSES AND EXTERNAL SEMINARS

Dynamical Non-locality in Nuclear Potentials; Demonstration of a Practical Method[b]
N. Keeley
Warsaw, University of Warsaw, 2015-04-16

Transverse-target-spin asymmetry in exclusive ω electroproduction[b]
B. Mariański
Hamburg, DESY Hamburg, 2015-07-30

DC87 status Transverse-target-spin asymmetry in exclusive ω electroproduction[b]
B. Mariański
Hamburg, DESY Hamburg, 2015-11-17

Exclusive ω meson production in Compas from 2012 data[b]
B. Mariański
Geneva, CERN, 2015-11-30

Exclusive ω meson production in Compas.[b]
B. Mariański
Genewa, CERN, 2015-12-09

[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.

V. Charviakova - Physics Workshop for schoolkids, Faculty of Physics, University of Warsaw

V. Charviakova - Summer School of Physics, Department of Physics, University of Warsaw. Lectures in the physics workshop.

A. Korman - Protection of the diploma dissertation of the PW student Łukasz Fura

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

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

N. Keeley
Fellow of the Institute of Physics

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

PERSONNEL

Research scientists

Witold Augustyniak, PhD*
Marian Jaskóła, Professor*
Nicholas Keeley, Assoc. Prof.
Andrzej Korman, PhD
Bohdan Mariański, PhD
Dmytro Melnychuk, PhD to September 30
Zygmunt Patyk, Professor from July 1
Ernest Piasecki, Professor.* to November 30
Ewa Ruchowska, PhD to October 31
Andrzej Trzciński, PhD
Paweł Żuprański, Assoc. Prof.*
Bogusław Zwięgliński, Professor*
Janusz Wilczyński, Professor to October 22

Technical and administrative staff

Dorota Dobrowolska
Ryszard Kacprzak* to October 31
Grażyna Kęsik, Eng.
Wiesław Pietrzak* to December 11
Zbigniew Szczepaniak to August 31

*part-time employee

THEORETICAL PHYSICS DIVISION

Head of Division: Michał Kowal, Professor NCBJ
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Overview

The Theoretical Physics Department consists of 30 physicists and 4 PhD students working on different aspects of low and high energy physics, plasma and nonlinear phenomena as well as on general problems of quantization of particle dynamics, astrophysics, string theory and cosmology. The “BayesFITS” project devoted to the Bayesian approach to multi-parameter problems in physics and beyond involving parallel computing and large data-sets was also carried out within our department.

Close collaboration with experimental groups at CERN (COMPASS, CMS and ALICE) and other laboratories (like; GSI, Kamiokande or Frascatti) should be mentioned. Results of our scientific activity in 2014 were presented in 170 publications in total, 25 with less than 5 co-authors. Our results were presented at more than 60 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;
- theoretical cosmology;
- string theory;
- nonlinear effects in extended media.

In all of them very inereting results were achived. Of special relevance and interest in 2015 are the following work:

1. **Michal P. Heller** and **Michał Spaliński**
   Hydrodynamics Beyond the Gradient Expansion: Resurgence and Resummation
   Phys. Rev. Lett. 115, 072501

2. B. Pire and **L. Szymanowski**
   Neutrino Production of a Charmed Meson and the Transverse Spin Structure of the Nucleon
   Phys. Rev. Lett. 115, 092001

3. P. Jachimowicz, **M. Kowal**, and **J. Skalski**
   Candidates for long-lived high-K ground states in superheavy nuclei
   Phys. Rev. C 92, 044306

4. Hervé Bergeron, **Ewa Czuchry**, Jean-Pierre Gazeau, **Przemysław Małkiewicz**, and **Włodzimierz Piechocki**
   Smooth quantum dynamics of the mixmaster universe
   Phys. Rev. D 92, 061302(R)
5. **Jacek Rożynek**
   Nuclear equation of state and finite nucleon volumes
   Journal of Physics G: Nuclear and Particle Physics, Volume 42, Number 4, 045109

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

Michał Kowal

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

SUSY dark matter: lessons from and for the early Universe, and related issues
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, K. Turzynski, **A. Williams**
PLANCK 2015 (Greece, Ioannina, 2015-05-25 - 2015-05-29)

Diffractive production of jets at high-energy in the QCD shock-wave approach
R. Boussarie, A.V. Grabovsky, **L. Szymanowski**, S. Wallon
Photon 2015: International Conference on the Structure and Interactions of the Photon and the 21th International Workshop on Photon-Photon Collisions and International Workshop on High Energy Photon Linear Colliders (Russia, Novosibirsk, 2015-01-15 - 2015-01-19)
No. (2015)

Smoking guns of supersymmetric dark matter
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, K. Turzynski, **A. Williams**
The Spacetime Odyssey Continues (Sweden, Stockholm, 2015-06-02 - 2015-06-05)

Production of a forward Jpsi and a backward jet at the LHC
R. Boussarie, B. Ducloué, **L. Szymanowski**, S. Wallon
Photon 2015: International Conference on the Structure and Interactions of the Photon and the 21th International Workshop on Photon-Photon Collisions and International Workshop on High Energy Photon Linear Colliders (Russia, Novosibirsk, 2015-01-15 - 2015-01-19)
No. (2015)

SUSY dark matter: lessons from and for the early Universe
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, K. Turzynski, **A. Williams**
DSU-15, Dark Side of the Universe (Japan, Kyoto, 2015-12-14 - 2015-12-18)

Candidates for Long Lived High-K Ground States in Super Heavy Nuclei
P. Jachimowicz, **M. Kowal**, **J. Skalski**
Super Heavy Nuclei International Symposium (USA, College Station, 2015-03-31 - 2015-04-02)

Probing GPDs in photoproduction processes at hadron colliders
D.Y. Ivanov, B. Pire, **L. Szymanowski**, **J. Wagner**
Photon 2015: International Conference on the Structure and Interactions of the Photon and the 21th International Workshop on Photon-Photon Collisions and International Workshop on High Energy Photon Linear Colliders (Russia, Novosibirsk, 2015-01-15 - 2015-01-19)
No. (2015)

Accessing transversity GPDs in neutrino-production of a charmed meson
B. Pire, **L. Szymanowski**
16th conference on Elastic and Diffractive Scattering (EDS 15) (France, Borgo, Corse, 2015-06-29 - 2015-07-04)
No. (2015)

Adiabatic Fission Barriers
P. Jachimowicz, **M. Kowal**, **J. Skalski**
XXII Nuclear Physics Workshop "Marie & Pierre Curie" Kazimierz Dolny, Poland 2015 (Poland, Kazimierz Dolny, 2015-09-22 - 2015-09-27)

Towards resolving generic singularity problem of general relativity
W. Piechocki
Quantum Gravity in Cracow (Poland, Cracow, 2015-05-08 - 2015-05-10)

Photon dissociation into two and three jets: initial and final state corrections
R. Boussarie, A. Grabovsky, **L. Szymanowski**, S. Wallon,
16th conference on Elastic and Diffractive Scattering (EDS 15) (France, Borgo, Corse, 2015-06-29 - 2015-07-04)

Neutralino dark matter: interplay of direct, indirect, and LHC searches
E. Sessolo
IBS-MultiDark Workshop (Spain, Madrid, 2015-11-23 - 2015-11-28)

Level spacing distribution of the Bianchi IX model
W. Piechocki
7th Workshop on Quantum Chaos and Localisation Phenomena (Poland, Warsaw, 2015-05-29 - 2015-05-31)

Mueller-Navelet jets at the LHC
B. Ducloué, **L. Szymanowski**, S. Wallon
16th conference on Elastic and Diffractive Scattering (EDS 15) (France, Borgo, Corse, 2015-06-29 - 2015-07-04)

Possible Implication of a Single Nonextensive p_T Distribution for Hadron Production in High-Energy pp Collisions
G. Wilk
11-th Polish Workshop on Relativistic Heavy-Ion Collisions (Poland, Warszawa, 2015-01-17 - 2015-01-18)

Reconstructing CMSSM parameters at the LHC with $\sqrt{s}$=14 TeV via the golden decay channel
A. Fowlie, **L. Roszkowski**, **M. Kazana**
SUSY 2015 - the 23rd International Conference on Supersymmetry and Unification of Fundamental Interactions (USA, Lake Tahoe, 2015-08-23 - 2015-08-29)

Nuclear Equation of State and with finite nucleon volumes.
J. Rożynek
Quarks and Nuclear Physics (Chile, Valparaiso, 2015-03-02 - 2015-03-06)

On quasi-power law ensembles
G. Wilk
International School on Complexity; 15th Course: New trends in statistical mechanical foundations of complexity - applications in high energy physics, plasma physics, long-range interactions, edge of chaos, and elsewhere. Directors: G. BENEDEK – R. GALVAO – A. RAPISARDA – C. TSALLIS (Italy, Erice; Ettore Majorana Foundation and Centre for Scientific Culture, 2015-07-27 - 2015-08-03)

On ubiquity of quasi-power law distributions
G. Wilk
Foundations of Complex Systems Science - CS-DC 15 World e-conference (USA, Tempe, 2015-09-30 - 2015-10-01)

Theoretical description of decay properties of superheavy nuclei
A. Sobiczewski
Super Heavy Nuclei International Symposium (USA, College Station, 2015-03-31 - 2015-04-02)

Dark matter: How to kill a candidate and how to keep it alive
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, K. Turzynski, **A. Williams**
Understanding the early Universe (Switzerland, Geneva, 2015-01-06 - 2015-01-16)

Decay chains of superheavy nucleus 293-117
A. Sobiczewski
XXXIV Mazurian Lakes Conference on Physics (Poland, Piaski, 2015-09-06 - 2015-09-12)

Affine Coherent States in Quantum Cosmology
P. Małkiewicz
14th Marcel Grossmann Meeting (Italy, Rome, 2015-07-13 - 2015-07-18)

Looking for supersymmetry: the power of complementarity in LHC and dark matter searches
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, **A. Williams**
Rencontres de Moriond: QCD and High Energy Interactions (Italy, La Thuile, 2015-03-21 - 2015-03-28)
ARISF No. (2015)

On gamma N to gamma rho N at large gamma rho invariant mass
R. Boussarie, B. Pire, **L. Szymanowski**, S. Wallon
Photon 2015: International Conference on the Structure and Interactions of the Photon and the 21th International Workshop on Photon-Photon Collisions and International Workshop on High Energy Photon Linear Colliders (Russia, Novosibirsk, 2015-01-15 - 2015-01-19)
No. (2015)

Time Issue in Quantum Gravity
P. Małkiewicz
14th Marcel Grossmann Meeting (Italy, Rome, 2015-07-13 - 2015-07-18)

Oral Presentation

On integrability of the 1D Vlasov equation
P. Goldstein
8th Symposium on Integrable Systems (Poland, Łódź, 2015-07-03 - 2015-07-03)

LHC phenomenology of light pseudoscalars in the NMSSM
N.-E. Bomark, S. Moretti, S. Munir, **L. Roszkowski**
EPS-HEP 2015 (Austria, Vienna, 2015-07-22 - 2015-07-29)
Proceedings of Science (EPS-HEP2015) (2015)

Candidates for High-K Ground States in Super-heavy Nuclei
P. Jachimowicz, **M. Kowal**, **J. Skalski**
XXXIV Mazurian Lakes Conference on Physics (Poland, Piaski, 2015-09-06 - 2015-09-12)

LHC phenomenology of light pseudoscalarsin the NMSSM
N.E. Bomark, S. Moretti, S. Munir, **L. Roszkowski**
EPS-HEP 2015 (Austria, Vienna, 2015-07-22 - 2015-07-29)

GPDs in heavy mesons production and Compton scattering
J. Wagner, **L. Szymanowski**, D.Yu. Ivanov
6th International Conference on Physics Opportunities at an Electron-Ion Collider (France, Palaiseau, 2015-09-07 - 2015-09-11)

GUT-inspired SUSY and the g-2 anomaly: prospects for LHC 14 TeV
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **A.J. Williams**
PLANCK 2015 (Greece, Ioannina, 2015-05-25 - 2015-05-29)
PROCEEDINGS OF SCIENCE (PoS) (2015)

SUSY dark matter: Highlights from BayesFITS
E. Sessolo
Astrofizyka cząstek w Polsce 2015 (Poland, Warszawa, 2015-05-11 - 2015-05-13)

Sensistivity of CTA to dark matter annihilations in the Galactic Center
L. Roszkowski, **E. Sessolo**, **A.J. Williams**
EPS-HEP 2015 (Austria, Vienna, 2015-07-22 - 2015-07-29)
PROCEEDINGS OF SCIENCE (PoS) (2015)

SUSY dark matter, interplay of DD, ID, and the LHC
L. Roszkowski, **E. Sessolo**, **A.J. Williams**
COSMO-15: 19th annual International Conference on Particle Physics and Cosmology (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Results of the gluon Sivers asymmetry extraction from COMPASS data with transversely polarised targets
A. Szabelski
Quarks and Nuclear Physics (Chile, Valparaiso, 2015-03-02 - 2015-03-06)

Nuclear compressibility and excluded volume effects.
J. Rożynek
XXII Nuclear Physics Workshop "Marie & Pierre Curie" Kazimierz Dolny, Poland 2015 (Poland, Kazimierz Dolny, 2015-09-22 - 2015-09-27)

Axino and gravitino dark matter with low reheating temperature
L. Roszkowski, **S. Trojanowski**, K. Turzyński
EPS-HEP 2015 (Austria, Vienna, 2015-07-22 - 2015-07-29)
Proceedings of Science (EPS-HEP2015) Vol. 2015 (2015) 398

Sensitivity of CTA to dark matter annihilations in the galactic centre
A.J. Williams
Astrofizyka cząstek w Polsce 2015 (Poland, Warszawa, 2015-05-11 - 2015-05-13)

Spontaneous fission of odd-Z &/or odd-N nuclei
W. Brodziński, **J. Skalski**
XXII Nuclear Physics Workshop "Marie & Pierre Curie" Kazimierz Dolny, Poland 2015 (Poland, Kazimierz Dolny, 2015-09-22 - 2015-09-27)

The Relic Density of Heavy Neutralinos
A.J. Hryczuk, M. Beneke, A. Bharucha, F. Dighera, P. Ruiz-Femenia, S. Recksiegel
COSMO-15: 19th annual International Conference on Particle Physics and Cosmology (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Superstatistical cluster decay
G. Wilk, Z. Włodarczyk
XI Workshop on Particle Correlations and Femtoscopy (Poland, Warszawa, 2015-11-03 - 2015-11-07)

Poster

Supersymmetric dark matter with low reheating temperature
L. Roszkowski, **S. Trojanowski**, K. Turzyński
Astrofizyka cząstek w Polsce 2015 (Poland, Warszawa, 2015-05-11 - 2015-05-13)

Integrability analysis of the one-dimensional Vlasov equation
P. Goldstein
International Conference PLASMA-2015 (Poland, Warszawa, 2015-09-07 - 2015-09-11)

Supersymmetric dark matter with low reheating temperature
L. Roszkowski, **S. Trojanowski**, K. Turzyński
Understanding the early Universe (Switzerland, Geneva, 2015-01-06 - 2015-01-16)

Supersymmetric dark matter with low reheating temperature
L. Roszkowski, **S. Trojanowski**, K. Turzyński
Invisibles15 School (Spain, Miraflores de la Sierra (Madrid), 2015-06-15 - 2015-06-20)

Future impact of CTA on SUSY models
L. Roszkowski, **E.M. Sessolo**, **A.J. Williams**
COSMO-15: 19th annual International Conference on Particle Physics and Cosmology (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Dynamics and observational constraints on Brans-Dicke cosmological model
O. Hrycyna
Testing Gravity 2015 (Canada, Vancouver, 2015-01-15 - 2015-01-17)

Supersymmetric dark matter with low reheating temperature
L. Roszkowski, **S. Trojanowski**, K. Turzyński
COSMO-15: 19th annual International Conference on Particle Physics and Cosmology (Poland, Warsaw, 2015-09-07 - 2015-09-11)

LECTURES, COURSES AND EXTERNAL SEMINARS

Dark matter, a review with a view[a]
L. Roszkowski
Torun, Nicolaus Copernicus University, 2015-01-22

Possible Implication of a Single Nonextensive p_T Distribution for Hadron Production in High-Energy pp Collisions[b]
G. Wilk
Warszawa, University of Warsaw, Faculty of Physics, Institute of Theoretical Physics, 2015-01-26

Towards a usable source of atomic pairs: measurment of correlation functions of atoms scattered in the collision of Bose-Einstein consensates[b]
P. Ziń
Warsaw, Division of Optics Institute of Experimental Physics, Faculty of Physics, University of Warsaw, 2015-03-26

Time Issue in Quantum Gravity[b]
P. Małkiewicz
Warsaw, University of Warsaw, 2015-04-17

Impact of interaction between quasiparticles on the parametric amplification process in Bose-Einstein condensate[a]
P. Ziń
Kraków, Wydział Fizyki, Uniwersytet Jagieloński , 2015-10-15

Mixmaster Universe[b]
P. Małkiewicz
Paris, France, Astroparticle and Cosmology, Paris University Diderot, 2015-03-06

Discovery prospects of light pseudoscalars in the NMSSM[b]
N.E. Bomark
Norway, University of Oslo, 2015-04-24

Where is SUSY: implications of Higgs boson for SUSY and dark matter searches[b]
L. Roszkowski
Athens, University of Athens, 2015-05-19

What is Dynamics in Quantum Gravity?[b]
P. Małkiewicz
Rio de Janeiro, CBPF - Centro Brasileiro de Pesquisas Físicas, 2015-10-21

Neutralino dark matter: lessons from the LHC for direct and indirect detection searches[b]
E. Sessolo
Ann Arbor, MI, USA, University of Michigan, 2015-10-21

GUT-inspired SUSY and the g-2 anomaly: prospects for LHC 14 TeV[b]
E. Sessolo
Geneva, CERN, 2015-12-03

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

INTERNAL SEMINARS

Supersymmetry on the eve of the LHC Run 2[b]
E. Sessolo
Warsaw, Poland, NCBJ, 2015-01-14

From QCD based description of transverse momentum spectra to simple distributions based on nonextensive statistical mechanics[b]
G. Wilk
Warsaw, National Centre for Nuclear Research Department of Fundamental Research , 2015-02-11

Generalized Parton Distributions in Deeply Virtual Compton Scattering[b]
J. Wagner
Saclay, IRFU-SPhN, CEA, 2015-02-20

Fermiology and magnetic structure of gadolinium; ab-initio calculation supplemented with experimental data[a]
M. Pylak
Warsaw, National Centre for Nuclear Research, 2015-02-25

Cosmological singularity problem[b]
W. Piechocki
Warsaw, National Centre for Nuclear Research , 2015-03-11

Measurement of the charged-pion polarisability @ Compass[b]
K. Kurek
Warsaw, NCBJ, BP2, 2015-03-25

Correlation functions of atoms scattered in the collision of Bose-Einstein condensates[b]
P. Ziń
Warsaw, Centre For Theoretical Physics, Polish Academy of Science, 2015-04-01

Black hole physics and holography[b]
G. Plewa
Warsaw, NCBJ, 2015-05-27

Quantum Dynamics of Mixmaster Universe[b]
E. Czuchry
Warszawa, Narodowe Centrum Badań Jądrowych, 2015-10-28

Quantum Mixmaster[a]
E. Czuchry
Warszawa, Narodowe Centrum Badań Jądrowych, 2015-12-02

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

DIDACTIC ACTIVITY

P. Goldstein - Lectures in Statistical Physics (for Ph.D. students at NCBJ)

A. Sobiczewski - Care of Ph.D. student: Michał Palczewwski

A. Sobiczewski - Seminar on nuclear theory, conducted commonly with prof. J. Dąbrowski (NCBJ) and prof. S.G. Rohoziński (Warsaw University)

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

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

W. Piechocki
Member of the Polish Relativistic Society
Member of the Polish Physical Society
Member of NCBJ Scientific Council

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

J. Skalski
scientific Council of NCBJ

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

L. Szymanowski
member of PANDA Theory Advisoty Group

G. Wilk
National Center for Nuclear Research Chief of the PhD section
Institute of Theoretical Physics UW, Member of the commision for competitions for extraordinary professorship; Member of the commision for competitions for ordinary professorship (full professor of UW position)

A.J. Williams
Member of Organizing Committee on COSMO-15: 19th annual International Conference on Particle Physics and Cosmology in Warsaw, Poland

PERSONNEL

Research scientists

Jan Błocki, Professor
Nils-Erik Bomark, PhD
Ewa Czuchry, PhD
Dąbrowski Mariusz, Profesor
Antonio J.R. Figueiredo, 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*
Krzysztof Kurek, Assoc. Prof.
Przemysław Małkiewicz, PhD
Jakub Mielczarek, PhD
Zygmunt Patyk, Profesor
Marek Pawłowski, PhD
Włodzimierz Piechocki, Professor
Grzegorz Plewa, PhD
Maciej Pylak, 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, Assoc.Prof.
Lech Szymanowski, Assoc.Prof.
Sebastian Trojanowski, PhD
Jakub Wagner, PhD
Andrew Williams, PhD
Grzegorz Wilk, Professor
Sławomir Wycech, Professor
Paweł Ziń, PhD

PhD students
Varvara Batozskaya, MSc
Wojciech Brodziński, MSc
Palczewski Michal, MSc
Grzegorz Plewa, MS
Adam Szabelski, MSc
Sebastian Trojanowski, MSc

Technical and administrative staff
Anna Sidor

HIGH ENERGY PHYSICS DIVISION

Head of Division: Maciej Górski, PhD
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e-mail: maciej.gorski@ncbj.gov.pl

Overview

The Department is organized in two divisions: the Accelerator Physics Section and the Neutrino Physics Section.

Members of the Accelerator Section participate in large international collaborations at CERN (LHC accelerator, ALICE, CMS, LHCb experiments), SPS (COMPASS), COSY (Jülich) and KLOE (Frascati).

The CMS team continued work on studying the Higgs boson decays into a pair of tau leptons. Such analyses broaden the discovery scope of CMS providing information important for the establishment of the newly discovered particle's nature. Another domain is the continuation of the search for Heavy Stable Charged Particles predicted by various extensions of the Standard Model. The work was basically directed towards adaptation of the triggering system required by the present operation mode of the LHC to higher energy and luminosity. The Warsaw group is responsible for the first level muon trigger and worked on a new triggering scheme where all muon detectors are treated together. Our group specially worked on inclusion of new RPC detectors installed during the long LHC shutdown. There is also a subgroup working on Heavy Ion physics within CMS. One of theCMS members, dr Michal Szleper, obtained habilitation (Dr. Sci. degree) with distinction for his work on the scattering of W bosons. This work was chosen as one of the Department’s achievements.

The main interest of the ALICE group is of course Heavy Ion physics. The results concern principally the global characteristics of HI interactions, with special stress being put on the identification of produced particles, including strange and charmed ones. An important item is the reconstruction of the pi0 meson spectra from the electromagnetic calorimeter PHOS. A novel method of data unfolding has been developed by dr P. Kurashvili and was included in the Department's important results for the year 2015.

The LHCb team continued their physics analyses of CP violation effects and charm physics. One of the main results of LHCb was the measurement of the CP violating phase in the $B_s \to J/\Psi(\mu^+\mu^-)h^+h^-$ decays (φ_s=-0.036±0.001 radians) while our group worked on a complementary channel $B_s \to J/\Psi(e^+e^-)\Phi(KK)$ and the analysis is close to be finalized.

The COMPASS group continued studies of gluon polarization, and worked on the preparation of further studies of generalized parton distributions. Paweł Sznajder obtained this PhD for his work on "Investigation of azimuthal asymmetries in exclusive leptoproduction of vector mesons on transversely polarized protons and deuterons. "Low energy studies performed by the WASA detector group dealt with searches for rare decays, mostly of the η meson.

Studies are also being conducted on data from "old" experiments – namely ZEUS at the HERA proton-electron machine, where J/Ψ production is being studied.

The group led by prof. W. Wiślicki participates in the analysis of data from the KLOE concerning the interferometry of K^0 meson pairs from the Φ resonance decays.

Prof. S. Mrówczyński pursued his activities in the domain of theoretical aspects of the quark-gluon plasma physics.

The Neutrino Physics Section members analyzed data from the long-baseline neutrino experiment T2K. The main achievement of the Section is the participation in analysis leading to the establishment of limitations of the CP symmetry breaking in the lepton sector based on disappearance of ν_μ and appearance of ν_e. The group members were among those awarded the Breakthrough Prize for those results. This result was proposed as one of Institute's main achievements. Participation in the NA61/SHINE experiment at the CERN SPS is also pursued concentrating mainly on the strange particle production in SPS energy Heavy Ions interactions.

One should note as well the creation of the large computer centre (CiŚ) under supervision of one of BP3 employees, prof. Wojciech Wiślicki, although more information is presented elsewhere.

In 2015 Department members co-authored 224 publications in refereed journals and 7 popular publications. The Department members appeared 7 times on national TV and radio, gave several lecturea and participated in the "Science Festival" activities. They presented 33 invited talks at international conferences, 33 seminar talks, were referees of 19 articles, grant applications and PhD theses.

9 students pursued their PhD studies under the supervision of Department members and one of them obtained PhD degree in 2015.

Maciej Górski and. A. Sandacz

REPORTS

No english version
M. Gierlik, ... , **S. Borsuk**, **A. Burakowska**, **S. Burakowski**, **Z. Guzik**, **Ł. Kaźmierczak**, **T. Kaźmierczak**, **T. Krakowski**, **T. Lotz**, **J. Rzadkiewicz**, **P. Sobkowicz**, **M. Szeptycka**, **A. Urban**, ... et al.
NCBJ

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Review of LAr TPC event reconstruction: Progress and Challenges.
D. Stefan
International Workshop for the Next Generation Nucleon Decay and Neutrino Detector (NNN15) and Unification Day (UD2) (USA, Stony Brook, 2015-10-28 - 2015-10-31)

Searches for physics/particles beyond the Standard Model at the LHC
P. Zalewski
Matter To The Deepest, Recent Developments In Physics Of Fundamental Interactions, XXXIX International Conference of Theoretical Physics (Poland, Ustroń, 2015-09-13 - 2015-09-18)

Searches for long-lived massive particles in CMS
M. Kazana
SUSY 2015 - the 23rd International Conference on Supersymmetry and Unification of Fundamental Interactions (USA, Lake Tahoe, 2015-08-23 - 2015-08-29)

Heavy Stable Charged Particles
A. Ackert, T. Adams, G. Bruno, L. Quertenmont, J. Zobec, A. Meneguzzo, **M. Kazana**, **P. Zalewski**
CMS Exotica Workshop (Italy, Venezia, 2015-11-12 - 2015-11-14)

Searches for new physics in dijet and multijet in CMS
M. Kazana
SUSY 2015 - the 23rd International Conference on Supersymmetry and Unification of Fundamental Interactions (USA, Lake Tahoe, 2015-08-23 - 2015-08-29)

Probing neutrino physics with the T2K experiment
J. Zalipska
Astrofizyka Cząstek w Polsce (Poland, Warszawa, 2015-05-11 - 2015-05-13)

Searches for heavy stable charged particles and other exotic signatures with large ionization at the **LHC**
M. Kazana
LHCP 2015 - The Third Annual Large Hadron Collider Physics Conference (Russia, St. Petersburg, 2015-08-31 - 2015-09-05)

Nano-explosive detector for Dark Matter and Neutrinos
M. Górski, A.K. Drukier, K. Freese, A. Lopez
COSMO-15: 19th annual International Conference on Particle Physics and Cosmology (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Pomiary oscylacji neutrin
J. Zalipska
XLIII Zjazd Fizyków Polskich (Poland, Kielce, 2015-09-06 - 2015-09-11)

Photon and neutral pion production in pp and Pb-Pbcollisions at LHC energies in the ALICE experiment
P. Kurashvili
LISHEP 2015 (Brazil, Manaus, 2015-08-02 - 2015-08-09)

Modern Approach to Security of Software for Nuclear Facility in Świerk Computing Centre
K. Gomulski, **S. Potempski**, **K. Klimaszewski**, **P. Szwajkowski**
The International Conference on Computer Security in a Nuclear World: Expert Discussion and Exchange (Austria, , 2015-06-01 - 2015-06-05)

Exclusive meson production at COMPASS
P. Sznajder
23rd Workshop on Deep-Inelastic Scattering and Related Subjects (USA, Dallas, 2015-04-27 - 2015-05-01)
Proceedings of Science Vol. DIS2015 (2015) 215

My adventures with particle correlations and Janek
St. Mrówczyński
XI Workshop on Particle Correlations and Femtoscopy (Poland, Warszawa, 2015-11-03 - 2015-11-07)

Indirect searches for dark matter particles at Super-Kamiokande
P. Mijakowski
TAUP: XIV International Conference on Topics in Astroparticle and Underground Physics (Italy, Turin, 2015-09-07 - 2015-09-11)

Energy loss in unstable quark-gluon-plasma
St. Mrówczyński
INT Program `Equilibration Mechanisms in Weakly and Strongly Coupled Quantum Field Theory (USA, Seattle, 2015-08-03 - 2015-08-28)

Astroparticle searches at the Super-Kamiokande Detector
P. Mijakowski
Astrofizyka Cząstek w Polsce (Poland, Warszawa, 2015-05-11 - 2015-05-13)

High-Energy Parton in Unstable QGP
St. Mrówczyński
11-th Polish Workshop on Relativistic Heavy-Ion Collisions (Poland, Warszawa, 2015-01-17 - 2015-01-18)

LHCb results on CP violation
A. Ukleja
Warsaw Spring Workshop (Poland, Warszawa, 2015-04-14 - 2015-04-14)

Dark matter: How to kill a candidate and how to keep it alive
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, K. Turzynski, **A. Williams**
Understanding the early Universe (Switzerland, Geneva, 2015-01-06 - 2015-01-16)

Poszukiwania fizyki poza Modelem Standardowym w eksperymencie LHCb
A. Ukleja
XLIII Zjazd Fizyków Polskich (Poland, Kielce, 2015-09-06 - 2015-09-11)

Looking for supersymmetry: the power of complementarity in LHC and dark matter searches
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, **A. Williams**
Rencontres de Moriond: QCD and High Energy Interactions (Italy, La Thuile, 2015-03-21 - 2015-03-28)
ARISF No. (2015)

The GPD program at COMPASS
A. Sandacz
12th Conference on Intersections of Particle and Nuclear Physics (USA, Vail, Colorado, 2015-05-19 - 2015-05-24)

Recent results from T2K
J. Łagoda
25th International Workshop on Weak Interactions and Neutrinos (WIN2015) (Germany, Heidelberg, 2015-06-08 - 2015-06-13)

SUSY dark matter: lessons from and for the early Universe, and related issues
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, K. Turzynski, **A. Williams**
PLANCK 2015 (Greece, Ioannina, 2015-05-25 - 2015-05-29)

Recent results from COMPASS on exclusive muoproduction
A. Sandacz
XVI Workshop on High Energy Spin Physics (Russia, Dubna, 2015-09-08 - 2015-09-12)

Results from Long Baseline neutrino experiments
J. Łagoda
35th International Symposium on Physics in Collision (PIC 2015) (United Kingdom, Coventry, 2015-09-15 - 2015-09-19)
EConf (2015)

Smoking guns of supersymmetric dark matter
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, K. Turzynski, **A. Williams**
The Spacetime Odyssey Continues (Sweden, Stockholm, 2015-06-02 - 2015-06-05)

PAC trigger status
M. Kazana
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)

SUSY dark matter: lessons from and for the early Universe
K. Kowalska, **L. Roszkowski**, **E. Sessolo**, **S. Trojanowski**, K. Turzynski, **A. Williams**
DSU-15, Dark Side of the Universe (Japan, Kyoto, 2015-12-14 - 2015-12-18)

Search for dark matter at the LHC
P. Zalewski
XLIII Zjazd Fizyków Polskich (Poland, Kielce, 2015-09-06 - 2015-09-11)

Reconstructing CMSSM parameters at the LHC with $\sqrt{s}$=14 TeV via the golden decay channel
A. Fowlie, **L. Roszkowski**, **M. Kazana**
SUSY 2015 - the 23rd International Conference on Supersymmetry and Unification of Fundamental Interactions (USA, Lake Tahoe, 2015-08-23 - 2015-08-29)

Oral Presentation

J-PET – a novel TOF-PET scanner based on plastic scintillators
W. Krzemień
Congress of the 50 years of Polish Society of Medical Physics (Poland, Warszawa, 2015-09-03 - 2015-09-09)

Results on jet quenching from the CMS experiment
B. Boimska
11-th Polish Workshop on Relativistic Heavy-Ion Collisions (Poland, Warsaw, 2015-01-17 - 2015-01-18)

Search for eta-mesic He
W. Krzemień, P. Moskal, M. Skurzok
Hadrons and Hadron Interactions in QCD 2015 (Japan, Kyoto, 2015-02-15 - 2015-03-21)

Search for the 4He-η bound state in dd → (4He-η)bound → 3Henπ 0 and dd → (4He-η)bound → 3Hepπ − reactions with the WASA-at-COSY facility
W. Krzemień, M. Skurzok, P. Moskal
Jagiellonian Simposium on Fundamental and Applied Subatomic Physics (Poland, Kraków, 2015-06-07 - 2015-06-13)

Hadron Production Measurements from NA61/SHINE for Neutrino Flux Predictions
K. Kowalik
27th Rencontres de Blois (France, Blois, 2015-05-31 - 2015-06-05)

SU(5) Yukawa matrix unification in the General Flavour Violating MSSM
M. Iskrzyński, **K. Kowalska**
PLANCK 2015 (Greece, Ioannina, 2015-05-25 - 2015-05-29)

GUT-inspired SUSY and the g-2 anomaly: prospects for LHC 14 TeV
K. Kowalska, **L. Roszkowski**, E. Sessolo, **A.J. Williams**
PLANCK 2015 (Greece, Ioannina, 2015-05-25 - 2015-05-29)
PROCEEDINGS OF SCIENCE (PoS) (2015)

Poster

Physics of Higgs boson with the CMS detector
M. Bluj
Jubileuszowe sympozjum Narodowego Centrum Badań Jądrowych (Poland, Otwock, 2015-06-15 - 2015-06-15)

Heavy Ion Physics in the CMS Experiment: Highlights from the LHC Run-1
B. Boimska
Jubileuszowe sympozjum Narodowego Centrum Badań Jądrowych (Poland, Otwock, 2015-06-15 - 2015-06-15)

A novel TOF-PET scanner based on plastic scintillators
W. Krzemień
The 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)

Pi of the Sky system of robotic telescopes
A. Ćwiek, **T. Batsch**, M. Ćwiok, G. Kasprowicz, **A. Majcher**, L. Mankiewicz, **K. Nawrocki**, R. Opiela, L.W. Piotrowski, M. Siudek, **M. Sokołowski**, R. Wawrzaszek, **G. Wrochna**, **A. Zadrożny**, M. Zaremba, A.F. Żarnecki
Polish Scientific Networks (Poland, Warszawa, 2015-06-18 - 2015-06-20)

Dilepton pairs production in NA61/SHINE Experiment
J. Stepaniak, **T. Palczewski**
Electromagnetic Interactions with Nucleons and Nuclei (Cyprus, Pathos, 2015-11-01 - 2015-11-07)

LECTURES, COURSES AND EXTERNAL SEMINARS

New measurements of the CP-violating phase φ_s[b]
K. Klimaszewski
Warsaw, Institute of Experimental Physics, University of Warsaw, 2015-01-16

Experiments studying neutrino oscillations: news and future ideas[b]
P. Przewłocki
Wroclaw, Institute of Theoretical Physics, Univeristy of Wroclaw, 2015-04-20

Why do we need near detectors in long baseline neutrino experiments?[a]
J. Łagoda

Warsaw, University of Warsaw, Faculty of Physics, 2015-05-15

The latest news from neutrino physics[b]
J. Zalipska
Warsaw, Warsaw University, 2015-10-23

Nobel 2015 in physics: Neutrinos oscillate, so they have mass![b]
J. Łagoda
Warsaw, University of Warsaw, Faculty of Physics, 2015-11-16

Neutrinos oscillate, so they have mass – Nobel 2015 in physicsWspólne konwersatorium im. Jerzego Pniewskiego i im. Leopolda Infelda [b]
E. Rondio
Warszawa, Physics Department of Warsaw University, 2015-11-16

Towards understanding electroweak symmetry breaking[b]
M. Szleper
Kraków, IFJ PAN, 2015-11-24

Measurement of 2p2h interactions in the T2K experiment[a]
J. Zalipska
Wroclaw, Wroclaw University, 2015-11-30

What was the last Nobel Prize in physics given for[b]
J. Zalipska
Warsaw, Nicolaus Copernicus Astronomical Center of the Polish Academy of Science, 2015-12-16

Trigger and DAQ Readiness: Hardware and Online SoftwareHardware and Online Software[b]
M. Kazana
Geneve, CERN, 2015-01-28

Vector Boson Scattering at the LHC and beyond[b]
M. Szleper
Dresden, Technical University Dresden, 2015-04-23

Flavor of Supersymmetry[b]
K. Kowalska
Dortmund, Technische Universitat Dortmund , 2015-05-21

Some remarks on the cross section normalisation[b]
J. Stepaniak
Paris, University of Pierre and Marie Curie, 2015-05-21

Model-independent search for CPV in three-bodies charm baryon decays[b]
A. Ukleja
Geneve, CERN, 2015-06-03

CPT violations in phi->KLKS decays[b]
W. Krzemień
Genewa, CERN, 2015-06-25

LAr TPC data reconstruction.[b]
D. Stefan
Brookhaven, Brookhaven National Laboratory, 2015-11-05

Run2 data taking : Challenges for tau triggers[b]
M. Bluj
Hamburg, DESY, 2015-11-17

Nobel in physics 2015[a]
E. Rondio
Warszawa, Polska Akademia Nauk Wydział Matematyki, Fizyki i Chemii oraz Nauk o Ziemi PAN, 2015-11-05

Nobel in physics 2015[a]
E. Rondio
Warszawa, Polska Akademia Nauk, Zespół Fizyki, 2015-11-24

a) in Polish
b) in English

INTERNAL SEMINARS

New Features of Knedle[b]
W. Krzemień
Frascati, INFN, Frascati, 2015-01-16

Strategy of tau triggers validation in 2015[b]
M. Bluj
Geneva, CERN, 2015-01-19

First look at 2015 tau trigger efficiencies[b]
M. Bluj
Geneva, CERN, 2015-02-13

Status of tau triggers[b]
M. Bluj
Padova, INFN, 2015-03-10

Git and GitLab as a tool for group work in the CIŚ project.[a]
M. Karpiarz
Otwock-Świerk, National Centre for Nuclear Research, 2015-03-17

The measurements of CP violation in the LHCb experiment[a]
A. Ukleja
Krakow, AGH University of Science and Technology, 2015-05-15

Tau triggers: Tag-and-probe trigger validation - methods and tools[b]
M. Bluj
Geneva, CERN, 2015-06-01

Vector Boson Scattering at the LHC and beyond[b]
M. Szleper
Warszawa, NCBJ, 2015-06-10

Tau trigger offline DQM at beginning of LHC Run-2, Status report[b]
M. Bluj
Geneva, CERN, 2015-06-14

Muon Timing with first data 2015[b]
M. Kazana
Geneve, CERN, 2015-06-25

First look at tau triggers in the new 2015 data[b]
M. Bluj
Geneva, CERN, 2015-07-23

Discussion of ZTT/HTT publication plans for 2015/2016[b]
M. Bluj
Geneva, CERN, 2015-09-04

Tau trigger performance in 2015 Run C data[b]
M. Bluj
Geneva, CERN, 2015-09-14

The Nobel Prize in Physics 2015: discovery of neutrino oscillations[b]
P. Przewłocki
Warsaw, National Centre for Nuclear Research, 2015-10-21

The searches for physics beyond the Standard Model in the LHCb experiment[b]
A. Ukleja
Warsaw, University of Warsaw, 2015-11-27

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

DIDACTIC ACTIVITY

H. Białkowska - Head of Doctoral Studies NCBJ

M. Bluj - Auxiliary supervisor of master thesis of Andrzej Pyskir, a student at Physics Department of University of Warsaw

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

K. Klimaszewski - Support supervisor of the PhD thesis of Varvara Batozskaya, MSc. Thesis title 'Measurement of CP violation in B0s→J/ψϕ
decays at LHCb experiment'.

K. Kowalik - The supervision of the student laboratory exercise - "Study of particle production in proton-carbon interactions at the NA61/SHINE experiment"

J. Łagoda - Supervising of student's laboratory: "How to distinguish neutrino and antineutrino interactions in T2K near detector" (Aleksander Andrysiak)

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

P. Przewłocki - Supervising Andrzej Pyskir, a student from IFD UW

E. Rondio - supervision of mgr katarzyna Frankiewicz

E. Rondio - supervision of mgr. Monireh Kabirnezhad

A. Sandacz - Co-supervision with dr P. Sznajder of two students from Warsaw Technical University during their summer studies at NCBJ

A. Sandacz - Supervison of Ph.D.student Paweł Sznajder.
The defence of his thesis took place on 14.07.2015

T. Siemiarczuk - PhD students:
Rahul Nair,
Oleksandr Kovalenko,
Iryna Ilkiv

J. Stepaniak - Search for a New Light Boson in Meson Decays

M. Szeptycka - M. Kasztelan started to write the PhD thesis - subject: application of Geant in the study of low energy neutron interactions

< br />
I work with a PhD Warsaw University student

J. Zalipska - Lectures and laboratory for school students during Festival of Science, Sep. 2015

J. Zalipska - Supervising student during it's laboratory work, Grzegorz Żarnecki "Recosntruction of neutrino energy in the near detetor ND280 of the T2K experiment"

J. Zalipska - Supervising student for preparatoin of seminat at 5th year of master study at Warsaw University - Andrzej Pyskir, "Search for MEC interactions in ND280oa in T2K experiment"

J. Zalipska - Supervising student Marina Gerszewska during her laboratory work. Exercise is concentrated on "Reconstructing energy of interacting neutrinos and anti-neutrinos in the near detector of the T2K experiment". Winter semester of academic year 2015/2016

J. Zalipska - Supervising student, Justyna Cybowska, during her laboratory work "What is the energy of interacting neutrinos in T2K experiment".

J. Zalipska - Supervising Summer Student - ANdrzej Pyskir who was working for " Search for MEC interactions in ND280"

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

E. Rondio
Electron-Ion-Collider Advisory Committee
member of Scientific Advisory Committee Institute Cosmology and Physics of Americas (COFI)
Member of scientific Board

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
chairman National Center of Nuclear Research
Uniwersity of Warsaw Heavy Ion Laboratory, Member Heavy Ion Laboratory
Chairmen, National Center of Nuclear Research

A. Sandacz
Member of the Group Leaders Board of the COMPASS exoeriment
Co-chair of the Organising Committee of XVI Workshop on High Energy Spin Physics, Dubna, 2015

M. Szczekowski
member of Scientific Council NCBJ

W. Wiślicki
Pl-Grid National Consortium
Member of 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

G. Wrochna
Member of the Polish Nuclear Society
Member of the Committee on Nuclear Physics of the Council for Atomic Energy Matters
Coordinator of Polish Nuclear Technology Platform
Member of the Physics Committee PAN
President of the Council of Atomic Center consortium
President of the Council of Polish Astroparticle Physics Network
President of the Council of XFEL-Polska consortium
Societas Scientiarum Varsaviensis
Member of the Scientific Council of the Heavy Ion Laboratory, Warsaw University

P. Zalewski
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
Andrzej Deloff, Assoc.Prof.*
Tomasz Fruobes, PhD
Maciej Górski, PhD
Julia Hoffman, PhD — on leave
Mariusz Karpiarz, MSc — ½*
Małgorzata Kazana, PhD
Konrad Klimaszewski, PhD
Katarzyna Kowalik, PhD
Kamila Kowalska, PhD
Wojciech Krzemień, PhD
Andrzej Kupść, PhD — on leave
Podist Kurashvili, PhD
Justyna Łagoda, PhD
Piotr Mijakowski, PhD
Dmytro Melnychuk PhD
Stanisław Mrówczyński, Professor*
Krzysztof Nawrocki, PhD
Adam Nawrot, Eng*
Paweł Przewłocki, PhD
Ewa Rondio, Professor
Andrzej Sandacz, Professor
Teodor Siemiarczuk, Professor*
Ryszard Sosnowski, Professor
Dorota Stefan, PhD
Joanna Stepaniak, Professor*
Robert Sulej, PhD
Adam Szabelski, MSc
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
Wojciech Wiślicki, Professor
Grzegorz Wrochna, Professor
Piotr Zalewski, PhD
Joanna Zalipska, PhD

* part-time employee

Technical and administrative staff

Tadeusz Marszał
Paweł Marciniewski — on leave
Teresa Świerczyńska

ASTROPHYSICS DIVISION

Head of Division: Assoc. Prof. Agnieszka Pollo
phone: +48 22 55 32 265
e-mail: agnieszka.pollo@ncbj.gov.pl

Overview

The Division of Astrophysics was formed in 2014 by merging the former Division of Cosmic Ray Physics (BP4) in Łódź and Laboratory of Astrophysics belonging to the High Energy Physics Division (BP3) in Warsaw. The aim was to create a unified and strong unit dedicated to astrophysical research and participation in ground-based and space astrophysical missions, both technologically and scientifically. Currently, 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 performs active research in observational cosmology, high-energy astrophysics, and the search for astrophysical transient sources of different origins – from gravitational wave sources to gamma ray bursts (GRBs).

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, VVDS, AKARI, WISE. In 2015, we co-organized the 1st International Cosmology Summer School "Introduction to Cosmology" in Kielce and the Roman Juszkiewicz Cosmological Symposium 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, modernization and optimization of observational sites, as well as the data centre, were continued. Transients which can be potentially connected with sources of gravitational waves are of particular interest. In 2014 Pi of the Sky signed a Memorandum of Understanding with an international consortium to search for gravitational waves, LSC-VIRGO, and in 2015 observations in the framework of this MoU were carried out.

Our teams were involved in two space mission proposals submitted to the ESA M4 call in 2015: CORE+, aiming at measurements of the polarisation of the CMB, and LOFT, filling the niche in high energy astrophysics. The proposals were not successful but their resubmission at the next M5 ESA call is planned.

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

Finding the sources of the highest energy Cosmic Rays is the main goal of the satellite experiment JEM-EUSO which will observe EASs from the International Space Station. We are participating in the preparation of the hardware (sophisticated high voltage power suppliers) for the mission. In 2015, we participated in the test measurements in Utah (USA) and continued theoretical work aimed at the interpretation of the future data.

POLAR is a joint Swiss-Polish-Chinese mission whose goal will be a measurement of the X-ray polarisation of GRBs. We have designed, developed and made an engineering model of a high voltage power supply unit for POLAR. The satellite is now being prepared for launch which is expected in 2016. As part of the preparatory phase we participated in vacuum and thermal tests of the detector. We are preparing software for data analysis based on Geant 4 simulations.

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 is developing radio techniques for EAS measurements in Karlsruhe. These experiments, in which our group has participated from their beginning, have finished data-taking, but we continue data analysis publishing results in the top journals with high impact factors.

The Laboratory in Łódź also concentrates on methodological studies of the detection of neutrons and interpretation of multiple neutron registrations in underground laboratories. Among other tasks, we completed the ISOTTA project, for which we performed GEANT4 simulations of neutron transport.

Presentation of Cosmic Ray registration to high school students has become a popular way to introduce particle physics detectors and elementary particle detection techniques to young people. We organize in Łódź and Poznań workshops on particle physics for high school students, in the framework of international IPPOG's Masterclasses – Hands on Particle Physics.

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. The 2015 publication, which presented the final results of a 30 year effort to describe the internal proton structure was the subject of a DESY press release.

Agnieszka Pollo

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Advanced LIGO and Virgo projects
A. Królak
Astrofizyka cząstek w Polsce (Poland, Warszawa, 2015-05-11 - 2015-05-13)

Properties of galaxies
A. Pollo
First Cosmology School in Kielce (Poland, Kielce, 2015-07-15 - 2015-07-25)

Wszechświat 3D, czyli kosmiczna sieć
A. Pollo
VIII Międzynarodowa Konferencja (Poland, Niepołomice, 2015-10-16 - 2015-10-18)

Towards multi-messenger astronomy: electromagnetic follow-up of gravitational wave transient candidates from Advanced LIGO/Virgo detectors
A. Zadrożny
The 2nd Conference of the Polish Society on Relativity: 100 Years of General Relativity (Poland, Warszawa, 2015-11-23 - 2015-11-27)

KASCADE-Grande experiment measurements of the cosmic ray spectrum and large scale anisotropy
A. Chiavassa, **P. Łuczak**, **J. Zabierowski**
CRIS 2015 - Cosmic Ray International Seminar (Italy, Gallipoli, 2015-09-11 - 2015-09-16)
Nucl. Phys. B Proc. Sup. (in press)

The VIPERS survey
A. Pollo, **K. Małek**
1st Roman Juszkiewicz Symposium "The non-linear Universe" (Poland, Warszawa, 2015-08-24 - 2015-08-28)

Oral Presentation

Cosmology and large scale structure from existing and future deep sky surveys
A. Pollo
Astrofizyka cząstek w Polsce 2015 (Poland, Warszawa, 2015-05-11 - 2015-05-13)

Results of the Time Domain F-statistic all-skyMDC search
O. Dorosh, **A. Królak**, M. Bejger, M. Piętk
LSC-Virgo 2015 Collaboration Meeting (Hungary, Budapest, 2015-08-31 - 2015-09-03)

Learning algorithms at the service of WISE survey
K. Małek, **T. Krakowski**, M. Bilicki, **A. Pollo**, A. Solarz, M. Krupa, A. Kurcz, W. Hellwing, J. Peacock, T. Jarrett
WISE at 5: Legacy and Prospects (USA, Pasadena, 2015-02-10 - 2015-02-12)

Właściwości optyczne rentgenowskiego układu symbiotycznego GX1+4
A. Majczyna, J. Madej, M. Należyty
XXXVII Zjazd Polskiego Towarzystwa Astronomicznego (Poland, Poznań, 2015-09-07 - 2015-09-10)

Upper limits on the diffuse gamma-rays measured with KASCADE-Grande
D. Kang, **P. Łuczak**, **J. Zabierowski**
34^{th} International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 810

NL AGNs - VIPERS data
K. Małek, **A. Pollo**, B. Garilli
VIPERS science meeting (Italy, Turin, 2015-03-09 - 2015-03-13)

Star formation history of early-type galaxies
M. Siudek, **K. Małek**, M. Scodeggio, B. Garilli, A. Fritz
VIPERS science meeting (Italy, Turin, 2015-03-09 - 2015-03-13)

Cross talk fluctuations in POLAR test data.
J. Szabelski, **A. Zwolińska**
The First POLAR Collaboration Meeting (Chile, Pekin, 2015-11-16 - 2015-11-20)

WISE as the cornerstone for all-sky photometric redshift samples
M. Bilicki, T. Jarrett, J. Peacock, M. Cluver, L. Steward, **K. Małek**, M. Krupa, A. Kurcz, **T. Krakowski**, **A. Pollo**, A. Solarz
WISE at 5: Legacy and Prospects (USA, Pasadena, 2015-02-10 - 2015-02-12)

Improving the Mass Resolution of Primary CRin Underground Measurements with a Surface Array
J. Szabelski
EMMA Meeting (Finland, Pyhasalmi / Oulu, 2015-05-10 - 2015-05-14)

Marked correlation functions in VIPERS
A. Pollo, A. Nadkańska
VIPERS science meeting (Italy, Turin, 2015-03-09 - 2015-03-13)

Calibration of POLAR Flight Model Gamma Ray Burst Polarimeter
H. Xiao, R.M. Marcinkowski, W. Hajdas, **D. Rybka**, I. TraseiraRodriguez, M.R. Kole, N. Produit, C. Lechanoine-Leluc, S. Orsi, M. Pohl, M. Paniccia, D. Rapin, T. Bao, J. Chai, Y. Dong, M. Kong, L. Li, J. Liu, X. Liu, H. Shi, J. Sun, R. Wang, X. Wen, B. Wu, H. Xu, L. Zhang, S. Zhang, X. Zhang, Y. Zhang, **T. Batsch**, **A. Rutczyńska**, **J. Szabelski**, **T. Krakowski**, **A. Zwolińska**
Joint Annual Meeting of the Austrian Physical Society and the Swiss Physical Society (Austria, Vienna, 2015-09-01 - 2015-09-04)

The energy spectrum of cosmic rays in the rangefrom 1014 to 1018eV
S. Schoo, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 263

A support vector machine classification at the service of VIPERS survey
K. Małek, A. Solarz, **A. Pollo**, A. Fritz, B. Garilli, M. Scodeggio, A. Iovino, , B. Grannet
1st Roman Juszkiewicz Symposium "The non-linear Universe" (Poland, Warszawa, 2015-08-24 - 2015-08-28)

VIPERS: marked correlation functions
A. Nadkańska, **A. Pollo**
VIPERS science meeting (Italy, Milan, 2015-11-02 - 2015-11-06)

POLAR: Gamma-Ray Burst Polarimetry onboard the Chinese Spacelab
M.R. Kole, H. Xiao, R.M. Marcinkowski, W. Hajdas, **D. Rybka**, I. TraseiraRodriguez, N. Produit, C. Lechanoine-Leluc, S. Orsi, M. Pohl, M. Paniccia, D. Rapin, T. Bao, J. Chai, Y. Dong, M. Kong, L. Li, J. Liu, X. Liu, H. Shi, J. Sun, R. Wang, X. Wen, B. Wu, H. Xu, L. Zhang, S. Zhang, X. Zhang, Y. Zhang, **T. Batsch**, A. Rutczyńska, **J. Szabelski**, **T. Krakowski**, **A. Zwolińska**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)

Star formation history of early-type galaxies
M. Siudek, **K. Małek**, M. Scodeggio, B. Garilli, A. Fritz, **A. Pollo**
1st Roman Juszkiewicz Symposium "The non-linear Universe" (Poland, Warszawa, 2015-08-24 - 2015-08-28)

New results of the digital radio interferometer LOPES
F.G. Schroeder, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
Proceedings of Science (PoS) Vol. ICRC2015 (2015) 317

Properties and evolution of galaxy clustering at z =[2-5] based on VIMOS Ultra Deep Survey
A. Durkalec, **A. Pollo**
1st Roman Juszkiewicz Symposium "The non-linear Universe" (Poland, Warszawa, 2015-08-24 - 2015-08-28)

POLAR Trigger - Experimental Verification
H. Xiao, R.M. Marcinkowski, W. Hajdas, **D. Rybka**, I. TraseiraRodriguez, M.R. Kole, N. Produit, C. Lechanoine-Leluc, S. Orsi, M. Pohl, M. Paniccia, D. Rapin, T. Bao, J. Chai, Y. Dong, M. Kong, L. Li, J. Liu, X. Liu, H. Shi, J. Sun, R. Wang, X. Wen, B. Wu, H. Xu, L. Zhang, S. Zhang, X. Zhang, Y. Zhang, **T. Batsch**, A. Rutczyńska, **J. Szabelski**, **T. Krakowski**, **A. Zwolińska**
2015 IEEE Nuclear Science Syhmposium & Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)
IEEE, The Conference Record, (2015) No. (2015)

Clustering of mid-infrared selected galaxies in AKARI NEP Deep Field
A. Solarz, **A. Pollo**, T.T. Takeuchi
1st Roman Juszkiewicz Symposium "The non-linear Universe" (Poland, Warszawa, 2015-08-24 - 2015-08-28)

KASCADE-Grande results on the energy spectrum of high energy cosmic rays
J. Zabierowski
Astrofizyka Cząstek w Polsce (Poland, Warszawa, 2015-05-11 - 2015-05-13)

Clustering of mid-infrared selected galaxies in AKARI NEP Deep Field
A. Solarz, **A. Pollo**, T.T. Takeuchi
XXXVII Zjazd Polskiego Towarzystwa Astronomicznego (Poland, Poznań, 2015-09-07 - 2015-09-10)

Pi of the Sky telescope contribution to the LSC-Virgo Electromagnetic Follow-up project
A. Zadrożny
Astrofizyka cząstek w Polsce 2015 (Poland, Warszawa, 2015-05-11 - 2015-05-13)

KASCADE-Grande energy spectrum interpreted with post-LHC hadronic interaction models
M. Bertaina, **P. Łuczak**, **J. Zabierowski**
TAUP 2015 XIV International Conference on Topics in Astrophysics and Underground Physics (Italy, Torino, 2015-09-07 - 2015-09-11)
J. Phys.: Conf. Ser. (in press)

A unified description of Broad-Line and Narrow-Line AGN in VIPERS - update
K. Małek, **A. Pollo**
VIPERS science meeting (Italy, Milan, 2015-11-02 - 2015-11-06)

Legal Hacking
A. Zadrożny
Offtopicarium 6th (Poland, Warszawa, 2015-04-17 - 2015-04-19)

A study of the first harmonic of the large scale anisotropies with the KASCADE-Grande experiment
A. Chiavassa, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 281

Star formation history of early-type galaxies - results
M. Siudek, **K. Małek**, M. Scodeggio, B. Garilli, **A. Pollo**, A. Fritz
VIPERS science meeting (Italy, Milan, 2015-11-02 - 2015-11-06)

Prawo jako struktura matematyczna
A. Zadrożny
Polish Scientific Networks (Poland, Warszawa, 2015-06-18 - 2015-06-20)

Update on Time-Domain F-statistic all-sky MDC studies(Stage3)
O. Dorosh, **A. Królak**, M. Bejger
LSC-Virgo March 2015 Meeting (USA, Pasadena, 2015-03-16 - 2015-03-19)

Two Decades of KASCADE and KASCADE-Grande Measurements: Some Achievements
A. Haungs, **P. Łuczak**, **J. Zabierowski**,
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 278

Pi of the Sky preparations for LSC-Virgo\'s electromagnetic follow-up project
A. Zadrożny, **M. Sokołowski**, **A. Majcher**, R. Opiela, Ł. Obara
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)
Proc. SPIE Vol. 9662 (2015) 96621F

Poster

By atmosphere to the core of the neutron star
A. Majczyna, A. Różańska, J. Madej, M. Należyty
Astrofizyka Cząstek w Polsce (Poland, Warszawa, 2015-05-11 - 2015-05-13)

KASCADE-Grande energy spectrum of cosmic rays interpreted with post-LHC hadronic interaction **models**
M. Bertaina, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 359

Clustering of Infrared Galaxies in the AKARI Surveys
A. Pollo, T.T. Takeuchi, **A. Solarz**, **K. Małek**, T.L. Suzuki, S. Oyabu, A. Pępiak
Gas, Dust, and Star-Formation in Galaxies from the Local to Far Universe (Greece, Platanias , 2015-05-25 - 2015-05-29)

Search for gamma-ray point sources with KASCADE
D. Kang, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 812

Primary energy reconstruction from the S(500) observable recorded with the KASCADE-Grande
A. Gherghel-Lascu, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 301

Learning algorithms at the service of WISE survey
K. Małek, **T. Krakowski**, M. Bilicki, **A. Pollo**, A. Solarz, M. Krupa, A. Kurcz, W. Hellwing
Gas, Dust, and Star-Formation in Galaxies from the Local to Far Universe (Greece, Platanias , 2015-05-25 - 2015-05-29)

The KASCADECosmic Ray Data Centre (KCDC)
S. Schoo, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 262

Proposition of a method for optical transient externally triggered searches using data from ground based telescopes
A. Zadrożny, G. Djorgovski, A. Drake, A. Mahabal, M. Graham
LSC-Virgo March 2015 Meeting (USA, Pasadena, 2015-03-16 - 2015-03-19)

Calibration of Gamma-ray Burst Polarimeter POLAR
H. Xiao, R.M. Marcinkowski, W. Hajdas, **D. Rybka**, I. TraseiraRodriguez, M.R. Kole, N. Produit, C. Lechanoine-Leluc, S. Orsi, M. Pohl, M. Paniccia, D. Rapin, T. Bao, J. Chai, Y. Dong, M. Kong, L. Li, J. Liu, X. Liu, H. Shi, J. Sun, R. Wang, X. Wen, B. Wu, H. Xu, L. Zhang, S. Zhang, X. Zhang, Y. Zhang, **T. Batsch**, **A. Rutczyńska**, **J. Szabelski**, **T. Krakowski**, **A. Zwolińska**
2015 IEEE Nuclear Science Syhmposium & Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)
IEEE, The Conference Record No. (2015)

Law as a graph
A. Zadrożny, M. Zadrożna
Science: Polish Perspectives (United Kingdom, Cambridge, 2015-10-29 - 2015-10-31)

Revised absolute amplitude calibration of the LOPES experiment
K. Link, T. Huege, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 311

Effects of the new hadronic interaction models on the reconstruction of KASCADE-Grande observables
A. Gherghel-Lascu, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 302

Longitudinal development of EAS muon component - comparison of data from the Muon Tracking Detector in KASCADE-Grande with model predictions
P. Łuczak, **J. Zabierowski**, S. Schoo
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 386

Limits on the isotropic diffuse γ-rays at ultra high energies measured with KASCADE
W.D. Apel, Z. Feng, **P. Łuczak**, **J. Zabierowski**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)
PROCEEDINGS OF SCIENCE (PoS) Vol. ICRC2015 (2015) 823

Pi of the Sky system of robotic telescopes
A. Ćwiek, **T. Batsch**, M. Ćwiok, G. Kasprowicz, **A. Majcher**, L. Mankiewicz, **K. Nawrocki**, R. Opiela, L.W. Piotrowski, M. Siudek, **M. Sokołowski**, R. Wawrzaszek, **G. Wrochna**, **A. Zadrożny**, M. Zaremba, A.F. Żarnecki
Polish Scientific Networks (Poland, Warszawa, 2015-06-18 - 2015-06-20)

LECTURES, COURSES AND EXTERNAL SEMINARS

Prospects of detection of gravitational waves[a]
A. Królak
Kraków, Faculty of Physics, Jagiellonian University , 2015-05-06

VIPERS: a 3D web of 90,000 galaxies at z z ~ 1[b]
A. Pollo
Warsaw, Warsaw University, Physics Department, 2015-12-01

All-sky search for almost monochromatic gravitational waves using massively parallel algorithms[b]
A. Królak
Karlsruhe, Karlsruhe Institute of Technology, 2015-11-17

a) in Polish
b) in English

INTERNAL SEMINARS

By the atmosphere to the core of the neutron star[a]
A. Majczyna
Warsaw, National Centre for Nuclear Research, 2015-04-21

Properties and evolution of galaxy clustering at z~3 based on VIMOS Ultra Deep Survey[b]
A. Durkalec
Warszawa, Narodowe Centrum Badań Jądrowych, 2015-06-09

Classification and clustering of mid-infrared selected galaxies in AKARI NEP Deep Field[b]
A. Solarz
Warszawa, NCBJ, 2015-10-20

a) in Polish
b) in English

DIDACTIC ACTIVITY

A. Królak - Supervision of PhD thesis of Mr. Adam Zadrożny entitled
Search for gravitational waves in coincidence with optical observations.

Public defence of the thesis took place on 23.06.2015 at NCBJ

A. Pollo - OA UJ, lecture "Stellar and galactic astronomy II"

A. Pollo - OA UJ, mgr Agata Pępiak

A. Pollo - OA UJ, mgr Agnieszka Kurcz

A. Pollo - OA UJ, mgr Aleksander Kurek

A. Pollo - OA UJ, mgr Aleksandra Nadkańska

A. Pollo - OA UJ, mgr Katarzyna Wierzbicka, title: "Wpływ otoczenia na aktywność [U]LIRG-ów" (The role of environmental effects in [U]LIRG's activity)

A. Pollo - OA UJ, mgr Magdalena Krupa

A. Pollo - OA UJ, mgr Małgorzata Bankowicz

A. Pollo - OA UJ, mgr Michał Wypych

A. Pollo - OA UJ, mgr Oskar Kopczyński

A. Pollo - OA UJ, mgr Oskar Kopczyński, title: Multi-parameter classification of galaxies at z $\sim$ 1

A. Pollo - OA UJ, mgr Tobiasz Górecki

A. Pollo - OA UJ, monograph lecture (in English) "Observational cosmology"

J. Szabelski - A photomultiplier model for computer simulations of electric circuits.

J. Szabelski - Cosmic ray muon measurements and their application in detection systems.

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

A. Pollo
Member of Organizing Committee on 1st Roman Juszkiewicz Symposium "The non-linear Universe" in Warszawa, Poland
Member of Organizing Committee on First Cosmology School in Kielce in Kielce, Poland
Member of Advisory Board on 1st Roman Juszkiewicz Symposium "The non-linear Universe" in Warszawa, Poland
Member of Advisory Board on First Cosmology School in Kielce 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
Advances in High Energy Physics, Special Issue, Advances in High Energy Physics, Hindawi Publishing Corporation
member of Scientific Advisory Board

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
in Łódź:
Pluciński Paweł, PhD, Assistant Professor, on leave
Szabelski Jacek, PhD, Assistant Professor
Tymieniecka Teresa (*), Associate Professor
Wibig Tadeusz (*), Associate Professor
Zabierowski Janusz, Professor

in Warsaw:
Durkalec Anna, PhD Assistant Professor
Królak Andrzej (*), Associate Professor
Majczyna Agnieszka, Dr. Assistant Professor
Małek Katarzyna, PhD, Assistant Professor
Pollo Agnieszka, Professor
Sokołowski Marcin, PhD, Assistant Professor, on leave
Solarz Aleksandra, PhD Assistant Professor
Zadrożny Piotr, PhD Assistant Professor

PhD students
in Łódź
Plebaniak Zbigniew, Msc Eng
Zwolińska Anna, MSc Eng

Technical research staff
in Łódź:
Jędrzejczak Karol, PhD, on leave
Kasztelan Marcin, Msc.
Szabelska Barbara, PhD (*)

in Warsaw:
Ćwiek Arkadiusz, Msc.
Łuczak Paweł, PhD
Majcher Ariel, Msc.

Technical and admnistrative staff
in Łódź:
Dębicki Zdzisław
Karczmarczyk Jacek
Lewandowski Ryszard
Orzechowski Jerzy, MSc.Eng.
Skowronek Wojciech
Tokarski Przemysław, MSc.Eng.
in Warsaw:
Kutynia Adam, MSc.Eng.
Nikliborc Krzysztof , MSc.Eng.

Admnistrative staff (in Łódź):
Feder Jadwiga (*)

(*) part-time employee

NUCLEAR TECHNIQUES &EQUIPMENT DEPARTMENT

Head of Department: Jacek Rzadkiewicz, PhD
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e-mail: jacek.rzadkiewicz@ncbj.gov.pl

Overview

The Department of Nuclear Techniques and Equipment has ~100 employees, including 2 professors, 5 associate professors and 30+ employees with a PhD degree. The new structure of the Department was established in 2015 and includes four divisions:

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

Most of the scientific achievements of the department were summarized in top level peer reviewed publications, published in the Journal of Instrumentation, Plasma Sources Science & Technology, Nuclear Fusion, Journal of Physics B, Physical Review C and many others.
In 2015 the department's activities were strongly 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. In particular, the commercialization process of the **Coline 6** medical accelerator and **CANIS** accelerator system dedicated to the identification of smuggled goods like cigarettes or weapons was conducted by the **BRIdge Mentor** project implemented by the National Centre for Research and Development (an agency of the Ministry of Science and Higher Education) and the PWC consulting company. The intraoperative medical accelerator INTRALINE was developed within the **INTRA-DOSE** project realized in collaboration with the Wielkopolskie Cancer Centre (WCO) and UJP Hitec Systems S.A.

Our commercial projects were devoted to the development of:

- Technology based on the fast neutron activation and XRF methods dedicated to the mining industry (Cu-NAA and Cu-XRF project) in collaboration with the KGHM company,
- Systems control of the chemical composition of raw materials for cement production operated in the continuous mode (online), based on neutron activation analysis and a neutron generator in collaboration with the SysKon and OTJ Polon-Wrocław companies (RaM-scaN project),
- High-resolution large area detectors for radiography in collaboration with the ImagineRT company,
- Mobile monitoring systems for particulate matter pollution including PM10 and PM2.5 (particulate matter with diameters smaller than 10 mm and 2.5 mm, respectively) in collaboration with the local authorities of Pruszcz Gdański.

In 2015 our research groups participated in large European projects (selected):

- GBAR - construction of a 9-MV accelerator for the GBAR experiment at CERN, in particular microwave measurements and tuning accelerating structures and bunker shielding calculations,
- EUROFUSION– development of a diagnostic technique based on a Cherenkov-type detector, designed especially for an FTU and COMPASS and a gamma ray diagnostic technique based on scintillation detectors for the JET tokamak,
- C-BORD - participation in the development of technologies for inspection 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,
- XFEL - in the framework of the in-kind contribution provided by NCBJ to the European XFEL Project simulations and calculations of beam dynamics were performer the whole Higher Order Modes (HOM) suppression system was developed and delivered to XFEL-GmbH DESY,
- ESS - preparation for the construction of the accelerating structures and their construction, mechanical designs systems, design of the Gamma Blocker and moving collimators,
- BioQuaRT– participation in the EURAMET project "Biologically weighted quantities in radiotherapy". Nanodosimetry studies of carbon ions using the Jet Counter technique.

Jacek Rzadkiewicz

PARTICLE ACCELERATION PHYSICS & TECHNOLOGY DIVISION

Head of Division: Sławomir Wronka PhD Eng
phone: +48 22 2731539
e-mail: s.wronka@ncbj.gov.pl

Overview

The activity of the TJ1 department is focused on the development of new acceleration techniques and technologies, as well as on applications of particle accelerators. Our main competenties are concentrated in cavity optimisation, calculations 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 activity of the TJ1 department in 2015 was related to the continuation of the XFEL project, measurements of the accelerators for the AiD project: IORT and cargo screening (CANIS), calculations for the ESS (European Spallation Source) and participation in the GBAR experiment.

The Medical Physics group (previously affiliated at Applied Physics Department), has been recently included in TJ1 with the aim of continuing new developments in nanodosimetry.

Some of these topics are described in detail in separate articles.

The TJ1 department is quite well equipped with experimental accelerator stands. During a year, typically at least a few different configurations of linacs are tested. High energy X-ray and electron beams are continuously available, thus external users are commercially invited for industrial irradiations or specific scientific tests.

Radiographic detectors are also available due to the development of radiation-resistant technology for imaging sensors, therefore an industrial 2D radiography service as well as high energy CT is offered.

Thanks to the AiD project and the CANIS demonstrator, the development of cargo scanning techniques is continued both in the high energy region and classical X rays. Interlaced energy linacs for a wide energy range have been continuously under progressive developed in the TJ1 department.

In 2015 the prototype of a high resolution radiographic detector was successfully completed , therefore some results are presented elseware.

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

Also summer practices are offered to students, typically from Warsaw University and Warsaw University of Technology.

Sławomir Wronka

RADIATION DETECTORS DIVISION

Head of Division: Łukasz Świderski PhD
phone: +48 22 2731603
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:

- study of the influence of slow scintillation components in CsI:Tl crystals on their non-proportionality and energy resolution
- characterization of high density Silicon Photomultiplier (SiPM) performance in gamma- and X-ray spectrometry using scintillators
- development of new photomultipliers with screening grid at the anode for TOF PET block detectors
- characterization of a large volume $CeBr_3$ detector operated with an Active Anti-Compton shield
- characterization of basic properties of scintillators, including non-proportional response to the deposited energy and its relation to energy resolution, decay time, timing resolution and detection efficiency
- development of the Ion Sputtering (Al, B, Sb) method for production of new type semiconductor radiation detectors

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

- C-BORD, Neutron activation: we are 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 are studied by means of a linear accelerator.
- RaM-ScaN: the aim of this project is to develop a system for controlling the chemical composition of raw materials used in cement production. The method of scanning will be based on Neutron Activation Analysis.
- TAWARA_RTM: we are involved in the development of a multi-step platform for detection and identification of trace activities in water processed in Waterworks. In the past year, laboratory characterization of the SPEC identification system performance was completed.
- EUROfusion: in cooperation with the Division of Electronics and Detection Systems (TJ4), we are involved in the construction of a gamma camera for inspection of thermofusion reactions. In recent years, two prototypes based on $CeBr_3$ scintillators coupled to MPPCs have been constructed and installed at the Joint European Torus at CCFE.
- COST network: COST is a programme oriented for experience exchange between scientists involved in projects related to nuclear medicine.

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, Journal of Instrumentation and High Energy Density Physics. In addition, our scientists presented 23 contributions at international conferences – including 4 presentations at the IEEE Nuclear Science Symposium and Medical Imaging Conference 2015 in San Diego, USA and 3 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, France, ISC Kharkov, Ukraine, LNL INFN, Italy, Tohoku University, Japan, Wake Forest University, USA, the Heavy Ion Laboratory, Poland and companies such as Saint-Gobain, France, Scionix B.V., Holland, Siemens Healthcare, USA, Syskon, OTJ Polon Wroclaw, 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 dedicated records of this Annual Report.

Łukasz Świderski

REPORTS

Drugi podetap pracy, część „b" z realizacji programu pt. „Oznaczanie składu pierwiastkowego rudy miedzi w warunkach dołowych w oparciu o metody rentgenowskie – etap I"
P. Mazerewicz, ... , **A. Burakowska**, **A. Gójska**, **K. Grodzicki**, **T. Lotz**, **P. Markowski**, **P. Matuszczak**, **J. Rzadkiewicz**, **M. Słapa**, **P. Sobkowicz**, **J. Szymanowski**, **M. Laskus**, **M. Snopek**, **Z. Wojciechowski**, ... et al.
NCBJ

Introductory measurements of particulate matter concentration in ambient air in the vicinity of a potential location of a nuclear power plant (Krokowa commune)
M. Bogusz, **J. Bzdak**, **M. Lasiewicz**, **B. Mysłek-Laurikainen**, **M. Sowiński**, **H. Trzaskowska**
Narodowe Centrum Badań Jądrowych

No english version
M. Gierlik, ... , **S. Borsuk**, **A. Burakowska**, **S. Burakowski**, **Z. Guzik**, **Ł. Kaźmierczak**, **T. Kaźmierczak**, **T. Krakowski**, **T. Lotz**, **J. Rzadkiewicz**, **P. Sobkowicz**, **M. Szeptycka**, **A. Urban**, ... et al.
NCBJ

Oznaczanie składu pierwiastkowego rudy miedzi w warunkach dołowych w oparciu o metody rentgenowskie – etap I
P. Mazerewicz, ... , **A. Burakowska**, **A. Gójska**, **K. Grodzicki**, **T. Lotz**, **P. Markowski**, **P. Matuszczak**, **J. Rzadkiewicz**, **M. Słapa**, **P. Sobkowicz**, **J. Szymanowski**, **M. Laskus**, **M. Snopek**, ... et al.
NCBJ

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Influence of slow components on energy resolution of scintillators
M. Moszyński, **A. Syntfeld-Każuch**, **Ł. Świderski**
Applications of Novel Scintillators for Research and Industry (Ireland, Dublin, 2015-01-12 - 2015-01-14)

Thin layer Pb photocathode deposition for improved performance of SRF guns (status in May 2015)
R. Nietubyć, **J. Lorkiewicz**, J. Sekutowicz, **M. Barlak**, D. Kostin, **A. Kosińska**, R. Barday, R. Xiang, **R. Mirowski**, **M. Frelek**, **W. Pawlak**, **T. Sworobowicz**, **J. Witkowski**, **W. Grabowski**
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)

Diagnosing and understanding heavy impurity accumulation in JET
A.E. Shumack, **J. Rzadkiewicz**, T. Nakano, M. Chernyshova, T. Czarski, S. Dalley, N. Hawkes, K. Jakubowska, G. Kasprowicz, E. Kowalska-Strzeciwilk, K. Pozniak, S. Tyrrell, W. Zabolotny
The 27th edition of the Symposium series on Plasma Physics and Radiation Technology (Netherlands, Lunteren, 2015-03-10 - 2015-03-11)

Study of ^{8}He beta decay using OTPC chamber.
S. Mianowski, Z. Janas
The XIX International Scientific Conference of Young Scientists and Specialists (Russia, Dubna, 2015-02-16 - 2015-02-20)

Oral Presentation

Photomultipliers with the screening grid at the anode for TOF PET block detectors
M. Moszyński, **T. Szczęśniak**, **M. Grodzicka**, R. Leclercq, A. West, **M. Kapusta**,
2015 IEEE Nuclear Science Syhmposium & Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)

Temperature dependence of non-proportionality components in doped CsI
A. Syntfeld-Każuch, **M. Grodzicka**, **T. Szczęśniak**, **Ł. Świderski**, **M. Moszyński**, A. Gektin
2015 SCINT, 13th International Conference on Inorganic Scintillators and Their Applications (USA, Berkeley, 2015-06-07 - 2015-06-12)

Energy Resolution and Slow Components in Undoped CsI Crystals
M. Moszyński, **A. Syntfeld-Każuch**, **Ł. Świderski**, **P. Sibczyński**, , **M. Grodzicka**, **T. Szczęśniak**, A.V. Gektin, P. Schotanus, N. Shiran, R.T. Williams
2015 SCINT, 13th International Conference on Inorganic Scintillators and Their Applications (USA, Berkeley, 2015-06-07 - 2015-06-12)

Digital Approach To High Rate Gamma-Ray Spectrometry
S. Korolczuk, **S. Mianowski**, **J. Rzadkiewicz**, **P. Sibczyński**, **Ł. Świderski**, **J. Szewiński**, **I. Zychor**
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)
IEEE Trans. Nucl. Sci. (2015)

Poster

ED-XRF method in analysis of historical polish coins elemental composition
A. Gójska, **K. Grodzicki**, **P. Matuszczak**, **P. Markowski**, **P. Mazerewicz**, **J. Rzadkiewicz**, **P. Sibczyński**, **M. Słapa**, **M. Snopek**, **J. Szymanowski**, **K. Wincel**, **B. Zaręba**
TECHNART2015 Non-destructive and microanalytical techniques in art and cultural heritage (Italy, Katania, 2015-04-27 - 2015-04-30)

Modeling of the soft x-ray spectra from tungsten radiation for different WEST scenarios
Ł. Syrocki, K. Słabkowska, E. Szymańska, M. Polasik, **J. Rzadkiewicz**
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)
Phys. Scr. (2015)

Scintillators for high temperature plasma diagnostics
Ł. Świderski, **A. Gójska**, **M. Grodzicka**, **S. Korolczuk**, **S. Mianowski**, **M. Moszyński**, **J. Rzadkiewicz**, **P. Sibczyński**, **A. Syntfeld-Każuch**, **M. Szawłowski**, **T. Szczęśniak**, **J. Szewiński**, **A. Szydłowski**, **I. Zychor**
1st EPS Conference on Plasma Diagnostics (Italy, Frascati, 2015-04-14 - 2015-04-17)

The individual M x-ray line subshell contributions originating from Cu- and Co-like tungsten for various plasma temperature
K. Słabkowska, Ł. Syrocki, E. Szymańska, M. Polasik, **J. Rzadkiewicz**
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)
Phys. Scr. (2015)

The K x-ray line structures of the 3d-transition metals in warm dense plasma
E. Szymańska, **J. Rzadkiewicz**, Ł. Syrocki, K. Słabkowska, M. Polasik
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)
Phys. Scr. (2015)

Characterization of scintillators for gamma-ray spectrometry of fusion plasma
P. Sibczyński, **A. Gójska**, V. Kiptily, **S. Korolczuk**, **S. Mianowski**, **M. Moszyński**, **J. Rzadkiewicz**, **Ł. Świderski**, **A. Szydłowski**, **I. Zychor**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

X-ray spectra of tungsten and molybdenum in high temperature plasmas
K. Słabkowska, Ł. Syrocki, E. Szymańska, M. Polasik, **J. Rzadkiewicz**
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Silicon photomultiplier as a potential photodetector in scintillation detectors used for plasma diagnostics
T. Szczęśniak, **M. Grodzicka**, **M. Moszyński**, **Ł. Świderski**, **M. Szawłowski**
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Plasma temperature determination during the time of maximum K-shell X-ray emission of Cu impurities in PF1000 device
J. Rzadkiewicz, **A. Gójska**, M. Paduch, M. Polasik, O. Rosmej, K. Słabkowska, Ł. Syrocki, E. Szymańska, M. Scholz, E. Zielińska
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Gamma Spectrometer Based on $CeBr_3$ Scintillator with Compton Suppression for Identification of Trace Activities in Water
Ł. Świderski, **T. Batsch**, **J. Iwanowska-Hanke**, **M. Moszyński**
The 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)
IEEE NSS Conf. Rec. (2015)

New IORT machine:the IntraLine accelerator research and development project
A. Wysocka-Rabin, **P. Adrich**, **A. Baczewski**, **M. Baran**, **E. Jankowski**, **J. Kopeć**, **K. Kosiński**, **P. Krawczyk**, **E. Kulczycka**, **A. Masternak**, B. Meglicki, **A. Misiarz**, E. Plawski, **M. Staszczak**, **A. Syntfeld-Każuch**, **K. Swat**, **A. Wasilewski**, **M. Wojciechowski**, **M. Wójtowicz**, **S. Wronka**, J. Wysokiński, S. Adamczyk, M. Kruszyna, D. Murawa
3rd ESTRO FORUM (Spain, Barcelona, 2015-04-24 - 2015-04-28)

Study of fluorine-based plastic scintillators for fast neutron detection by means of ^{19}F activation
P. Sibczyński, **J. Kownacki**, **M. Moszyński**, **A. Syntfeld-Każuch**, **J. Iwanowska**, **M. Gierlik**, **A. Urban**, M. Hamel, F. Carrel, E. Montbarbon, A. Grabowski, P. Schotanus, A. Iovene, C. Tintori
The 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)

New IORT machine: the IntraLine accelerator project.
A. Wysocka_Rabin, **P. Adrich**, **A. Baczewski**, **M. Baran**, **E. Jankowski**, **J. Kopeć**, J. Kopec, **K. Kosiński**, **P. Krawczyk**, **E. Kulczycka**, **A. Masternak**, B. Meglicki, **A. Misiarz**, **E. Pławski**, **M. Staszczak**, **A. Syntfeld-Każuch**, **K. Swat**, **A. Wasilewski**, **M. Wojciechowski**, **M. Wójtowicz**, **S. Wronka**, J. Wysokinski
Jubileuszowe Sympozjum Narodowego Centrum Badań Jądrowych (Poland, Otwock-Świerk, 2015-06-15 - 2015-06-15)

Silicon Photomultipliers in Scintillation Detectors Used For Gamma-Ray Energies Up to 6.1 MeV
M. Grodzicka, **T. Szczęśniak**, **M. Moszyński**, **Ł. Świderski**, **M. Szawłowski**
2015 IEEE Nuclear Science Syhmposium & Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)

Temperature compensation device MTCD@NCBJ for MPPC in plasma diagnostics
G. Bołtruczyk, **M. Gosk**, **S. Mianowski**, **M. Szawłowski**, **I. Zychor**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Temperature compensation device MTCD@NCBJ for MPPC in plasma diagnostics
G. Bołtruczyk, **M. Gosk**, **S. Mianowski**, **M. Szawłowski**, **I. Zychor**
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)

ED-XRF method in analysis of historical polish coins elemental composition
A. Gójska, **K. Grodzicki**, **M. Laskus**, **P. Matuszczak**, **P. Markowski**, **P. Mazerewicz**, **J. Rzadkiewicz**, **P. Sibczyński**, **M. Słapa**, **M. Snopek**, **J. Szymanowski**, **K. Wincel**, **B. Zaręba**
Jubileuszowe Sympozjum Narodowego Centrum Badań Jądrowych (Poland, Otwock, 2015-06-15 - 2015-06-15)

INTERNAL SEMINARS

Monitor Temperature Compensation Device (MTCD@NCBJ) for MPPC based detectors[a]
S. Mianowski
Otwock, National Centre for Nuclear Reaserch, 2015-05-06

a) in Polish

DIDACTIC ACTIVITY

A. Syntfeld-Każuch - "Photofission of nuclear materials and fission signatures detection with application in border monitoring."

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

M. Moszyński
Session chairman on Applications of Novel Scintillators for Research and Industry in Dublin, Ireland
Session chairman on 2015 SCINT, 13th International Conference on Inorganic Scintillators and Their Applications in Berkeley, USA
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
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)

Ł. Świderski
Member of IEEE Nuclear and Plasma Sciences Society

A. Syntfeld-Każuch
Member of IEEE Nuclear and Plasma Sciences Society
member of scientific council, National Centre for Nuclear Research

PERSONNEL

Scientific staff
Belcarz Eugeniusz, MSc Eng
Czarnacki Wiesław PhD
Grodzicka-Kobyłka Martyna, PhD Eng
Iwanowska-Hanke Joanna, MSc
Kotlarski Andrzej, MSc Eng (until Oct. 2015)
Kownacki Jan, Professor
Mianowska Zuzanna, MSc
Mianowski Sławomir, MSc
Moszyński Marek, Professor
Rzadkiewicz Jacek, PhD
Sibczyński Paweł, MSc
Syntfeld-Każuch Agnieszka, PhD
Szawłowski Marek, MSc Eng
Szczęśniak Tomasz, PhD
Świderski Łukasz, PhD
Wolski Dariusz, MSc Eng
Kapusta Maciej, PhD
Zychor Izabella, Assoc. Prof. (until Sep. 2015)

Technical and administrative staff
Dziedzic Andrzej
Kostrzewa Krzysztof
Kos Monika, MSc
Sworobowicz Tadeusz
Trzaskowska Halina

ELECTRONICS AND DETECTION SYSTEMS DIVISION

Head of Division: Michał Gierlik, PhD
phone: +48 22 2731299
e-mail: michal.gierlik@ncbj.gov.pl

Overview

The end of 2015 marks the fourth year of existence and activity of the Division Electronics and Detection Systems. In the Autumn of this year, after the reorganization of the structure of NCBJ the TJ4 Division gained two new laboratories; the Laboratory of Environment Protection Physics, lead by Dr. Janusz Licki, and the Laboratory of X-ray Radiation Physics, led by Msc. Eng. Piotr Mazerewicz. All previous members of the TJ4 Division have now beenincluded in the Laboratory of Spectrometry and Nuclear Electronics.

The division participates in various projects, providing expertise and support whenever the need for high end electronics arises. Our goal remains unchanged. It is to maintain our technological edge by participating in challenging projects and collaborations while actively seeking commercial opportunities and applications for our solutions..

In 2015 the division's efforts were focused on the following topics.

Laboratory of Spectrometry and Nuclear Electronics (dr. Michał Gierlik)

- R&D contract with KGHM "Polska Miedź" S. A
  The technology of neutron activation analysis, refined during the years of the A&D project, is meeting with increasing interest from industry. This year completed an R&D project for the mining company KGHM "Polska Miedź" S. A. The details of the contract are classified. However, the research programme is in general related to appraising ore quality at various stages of extraction and excavation.
- PLC Crates for the first six XFEL experiments
  Within the Polish in-kind contribution to the X-FEL project NCBJ will deliver 200 modules containing PLC Terminals for slow control support for the first six experiments at X-FEL. Design of the modules has been approved by the physicists responsible for each experimental station. Preparation of each module requires ordering of components, specification cross-check, labelling, wiring, testing, packing, and shipment to Hamburg. For the purposes of preparation of a large number of devices (200) a dedicated laboratory has been prepared. The laboratory has four workstions, storage area and the necessary tools and equipment. At the end of 2015, about a quarter of all required PLC terminals had been ordered, all procedures like parts ordering, module assembly, testing and shipment had been accomplished, and the first batch of devices was delivered and successfully accepted by X-FEL GMBH.
- EUROfusion_NCBJ_JET4
  We are involved in the JET4 Enhancement Project dealing with modernisation 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 the planned deuterium-tritium campaign measurements at high count rates are expected. Information provided by the upgraded Gamma-ray Camera will complement high resolution spectroscopy measurements with the Gamma Spectrometer. We tested the use of $CeBr_3$ scintillators, characterized by good energy resolution, short decay time and relatively high detection efficiency for a few MeV gamma-rays. $CeBr_3$ crystals are considered as one of the best scintillators for the upgraded gamma-ray diagnostics at JET.
- Multichannel Analyzer Tukan
  New improvements in the energy determination algorithm were introduced. The effective accepted event rate has been increased up to 200 kHz as a result of the changes implemented.
- Astrophysics
  The development of astrophysical apparatus in the TJ4 division was supported in 2015 by two grants: SWISS – part of the Swiss Contribution programme and the national IDEAS+ grant. Termination of the SWISS grant was originally planned for 30.09.2014. To date the project indicators have been achieved. With savings of funds on both Beneficiary and Partner sides it was possible to apply for an extension of the grant period. Our two applications concerning this case, each asking for extension by 2 quarters, obtained the consent of the Joint Research Committee. As a result the deadline for the grant was set at 31.12.2015. The deadline of the IDEAS+ grant was 16.12.2015.
- "Pi of the Sky" project
  All necessary components for the new robot are prepared and purchased. A work associated with the use of equipment and software of "Pi" project for the observation of gravitational waves was initiated.

- "Polar" project
  The detector flight model was handed over to the Chinese side. We are working on getting the approval of the Chinese Space Agency.
- Clustering VIPERS data
  The focus was mainly on maintaining and testing tools for data clustering (SWISS – Task 107). Software for data processing in was tested and improved.

It is worth to notice that a new astrophysical project with the Swiss partner is being started. The project initiated by Dr. Nicolas Produit, the principal investigator in the SWISS grant on Partners side, has to use the equipment and experience gathered in POLAR project. Actually the work relates to the construction of the pilot set-up in order to check the correctness of the assumptions. The work on astrophysical apparatus is done in close collaboration with BP4, Astrophysics division led by prof. Agnieszka Pollo.

- PANDA

This year activities linked to the PANDA experiment were focused on the following tasks:

- Involvement in the preparation of essential documents for the in-kind contract "The Development, Production and Delivery of the Slow Control System for the Cluster-Jet Target of the PANDA detector":
  - hardware scheme for the Slow Control System,
  - communication scheme with the supervisory system (EPICS),
  - detailed technical specification,
  - list of tasks and time schedule (draft),
  - milestones definition (draft),
  - hardware and software purchases cost estimation,
  - travels and salaries cost calculations (draft).
- Continuation of the state machine development in conjunction with the CompactRIO's FPGA for the beam-dump part of the Cluster-Jet Target using the LabVIEW software.
- The version 2.0 Bidirectional Universal RS232-RS485 Signals Converter (BURGER) development. Besides all the so far produced BURGERs can be used to emulate target devices such as pump controllers (inverters) or Vacuum Gauge Controllers (CENTER THREE) after reprogramming it with the firmwares especially written for that purposes. This allows to test and debug the LabVIEW software with purchased hardware before installing it in the Cluster-Jet Target.

Laboratory of Environment Preservation Physics (Dr. Janusz Licki)

The hybrid process of the electron beam flue gas treatment process combined with the seawater scrubber enhanced with $NaClO_2$ solution was applied for purification of the exhaust gases with high NO_x concentration above 1000 ppmv. The first study of this process was carried out at the laboratory plant in the Institute of Nuclear Chemistry and Technology in Warsaw. The high NO_x removal efficiency above 90% was obtained.

The NCBJ mobile laboratory for environmental measurements participated in the ambient air quality determination at ten different city localizations. The measurements of the PM_{10} and $PM_{2.5}$ mass fraction of suspended particulate matter in ambient air were performed in each localization. In some cities were recorded the 24-hour average PM_{10} concentrations exceeded the Directive 2008/50/EC limit value of 50 $\mu g/m^3$.

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

– The R&D contract with KGHM "Polska Miedź" S. A.

The ability of X-ray fluorescence analysis (ED-XRF) to appraise the ore quality has been demonstrate. XRF technology provides fast and simplest analytical methods for the determination of the chemical composition of materials. The team developed instruments and measurement techniques dedicated for mining industry. The details of the contract are classified.

– The application of microanalytical, non-destructive techniques in art and cultural heritage.

The Laboratory of X-ray Radiation Physics started a collaboration, the aim of which is to determine the elemental composition of archaeological artifacts by means of XRF techniques. XFR archaeometry is a non-destructive method, which is considered its main advantage over other methods that may damage valuable examined artifacts. In 2015 we examined artifacts from the archaeological site at Kosewo (gm. Mrągowo), dated to the Migration Period (480-550 AD). We are currently investigating artifacts dated to the IX-XI century, such as silvered and silver coins, and bronze and silver jewelry.

Michał Gierlik

REPORTS

Introductory measurements of particulate matter concentration in ambient air in the vicinity of a potential location of a nuclear power plant (Krokowa commune)
M. Bogusz, **J. Bzdak**, **M. Lasiewicz**, **B. Mysłek-Laurikainen**, **M. Sowiński**, **H. Trzaskowska**
NCBJ

Wykorzystanie technologii neutronowej analizy aktywacyjnej do określenia zawartości pierwiastków użytecznych w rudzie miedzi in situ oraz na różnych etapach jej urabiania i transportu - etap 1.
M. Gierlik, ... , **S. Borsuk**, **A. Burakowska**, **S. Burakowski**, **Z. Guzik**, **Ł. Kaźmierczak**, **T. Kaźmierczak**, **T. Krakowski**, **T. Lotz**, **J. Rzadkiewicz**, **P. Sobkowicz**, **M. Szeptycka**, **A. Urban**, ... et al.
NCBJ

Oznaczanie składu pierwiastkowego rudy miedzi w warunkach dołowych w oparciu o metody rentgenowskie – etap I
P. Mazerewicz, ... , **A. Burakowska**, **A. Gójska**, **K. Grodzicki**, **T. Lotz**, **P. Markowski**, **P. Matuszczak**, **J. Rzadkiewicz**, **M. Słapa**, **P. Sobkowicz**, **J. Szymanowski**, **M. Laskus**, **M. Snopek**, ... et al.
NCBJ

Kosewo. Archiwalne cmentarzysko z okresu wędrówek ludów Kossewen III, book
A. Gójska
NCBJ

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Oferta technologiczna: Mobilne Laboratorium Pomiarów Środowiskowych - możliwości i osiągnięcia
<u>**J. Licki**</u>, **J. Sernicki**, **M.T. Kowalski**, **M. Lasiewicz**, **A. Bigos**, **M. Laskus**
IV Konferencja „Nowe Technologie dla Mazowsza". Sposoby i problemy komercjalizacji wyników badań naukowych (Poland, Józefów, 2015-02-04 - 2015-02-04)

Detectors for Gamma-ray Diagnostics in Plasma
<u>**I. Zychor**</u>
Coordinated Working Group Meeting (CWGM) (Poland, Warsaw, 2015-06-17 - 2015-06-19)

Skarby Pojezierza Mazurskiego w świetle badań starozytnych aliaży
<u>**E. Miśta**</u>, **A. Gójska**
Odkryte na nowo – archeolodzy i historycy na tropach tajemnic Warmii i Mazur (Poland, Mrągowo, 2015-12-09 - 2015-12-10)

Oral Presentation

Calibration of POLAR Flight Model Gamma Ray Burst Polarimeter
<u>H. Xiao</u>, R.M. Marcinkowski, W. Hajdas, **D. Rybka**, I. TraseiraRodriguez, M.R. Kole, N. Produit, C. Lechanoine-Leluc, S. Orsi, M. Pohl, M. Paniccia, D. Rapin, T. Bao, J. Chai, Y. Dong, M. Kong, L. Li, J. Liu, X. Liu, H. Shi, J. Sun, R. Wang, X. Wen, B. Wu, H. Xu, L. Zhang, S. Zhang, X. Zhang, Y. Zhang, **T. Batsch**, **A. Rutczyńska**, **J. Szabelski**, **T. Krakowski**, **A. Zwolińska**
Joint Annual Meeting of the Austrian Physical Society and the Swiss Physical Society (Austria, Vienna, 2015-09-01 - 2015-09-04)

POLAR: Gamma-Ray Burst Polarimetry onboard the Chinese Spacelab
<u>M.R. Kole</u>, H. Xiao, R.M. Marcinkowski, W. Hajdas, **D. Rybka**, I. Traseira Rodriguez, N. Produit, C. Lechanoine-Leluc, S. Orsi, M. Pohl, M. Paniccia, D. Rapin, T. Bao, J. Chai, Y. Dong, M. Kong, L. Li,

J. Liu, X. Liu, H. Shi, J. Sun, R. Wang, X. Wen, B. Wu, H. Xu, L. Zhang, S. Zhang, X. Zhang, Y. Zhang, **T. Batsch**, A. Rutczyńska, **J. Szabelski**, **T. Krakowski**, **A. Zwolińska**
34th International Cosmic Ray Conference - ICRC2015 (Netherlands, Hague, 2015-07-30 - 2015-08-06)

Digital Approach To High Rate Gamma-Ray Spectrometry
S. Korolczuk, **S. Mianowski**, **J. Rzadkiewicz**, **P. Sibczyński**, **Ł. Świderski**, **J. Szewiński**, **I. Zychor**
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)
IEEE Trans. Nucl. Sci. (2015)

High performance detectors for upgraded gamma ray diagnostics for JET DT campaigns
I. Zychor
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

POLAR Trigger - Experimental Verification
H. Xiao, R.M. Marcinkowski, W. Hajdas, **D. Rybka**, I. TraseiraRodriguez, M.R. Kole, N. Produit, C. Lechanoine-Leluc, S. Orsi, M. Pohl, M. Paniccia, D. Rapin, T. Bao, J. Chai, Y. Dong, M. Kong, L. Li, J. Liu, X. Liu, H. Shi, J. Sun, R. Wang, X. Wen, B. Wu, H. Xu, L. Zhang, S. Zhang, X. Zhang, Y. Zhang, **T. Batsch**, A. Rutczyńska, **J. Szabelski**, **T. Krakowski**, **A. Zwolińska**
2015 IEEE Nuclear Science Syhmposium & Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)
IEEE, The Conference Record, (2015) No. (2015)

NCBJ - IPPLM Activities in Gamma Diagnostics Upgrade at JET
I. Zychor
4th Italy-Poland Workshop (Italy, Frascati, 2015-07-06 - 2015-07-07)

Learning algorithms at the service of WISE survey
K. Małek, **T. Krakowski**, M. Bilicki, **A. Pollo**, A. Solarz, M. Krupa, A. Kurcz, W. Hellwing, J. Peacock, T. Jarrett
WISE at 5: Legacy and Prospects (USA, Pasadena, 2015-02-10 - 2015-02-12)

WISE as the cornerstone for all-sky photometric redshift samples
M. Bilicki, T. Jarrett, J. Peacock, M. Cluver, L. Steward, **K. Małek**, M. Krupa, A. Kurcz, **T. Krakowski**, **A. Pollo**, A. Solarz
WISE at 5: Legacy and Prospects (USA, Pasadena, 2015-02-10 - 2015-02-12)

Poster

Pi of the Sky system of robotic telescopes
A. Ćwiek, **T. Batsch**, M. Ćwiok, G. Kasprowicz, **A. Majcher**, L. Mankiewicz, **K. Nawrocki**, R. Opiela, L.W. Piotrowski, M. Siudek, **M. Sokołowski**, R. Wawrzaszek, **G. Wrochna**, **A. Zadrożny**, M. Zaremba, A.F. Żarnecki
Polish Scientific Networks (Poland, Warszawa, 2015-06-18 - 2015-06-20)

Pomiary stężeń masowych pyłu zawieszonego w powietrzu atmosferycznym
J. Sernicki, **J. Licki**, **M. Lasiewicz**, **M.T. Kowalski**, **A. Bigos**, **M. Laskus**
Jubileuszowe Sympozjum Narodowego Centrum Badań Jądrowych (Poland, Otwock-Świerk, 2015-06-15 - 2015-06-15)

Calibration of Gamma-ray Burst Polarimeter POLAR
H. Xiao, R.M. Marcinkowski, W. Hajdas, **D. Rybka**, I. TraseiraRodriguez, M.R. Kole, N. Produit, C. Lechanoine-Leluc, S. Orsi, M. Pohl, M. Paniccia, D. Rapin, T. Bao, J. Chai, Y. Dong, M. Kong, L. Li, J. Liu, X. Liu, H. Shi, J. Sun, R. Wang, X. Wen, B. Wu, H. Xu, L. Zhang, S. Zhang, X. Zhang, Y. Zhang, **T. Batsch**, **A. Rutczyńska**, **J. Szabelski**, **T. Krakowski**, **A. Zwolińska**
2015 IEEE Nuclear Science Syhmposium & Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)
IEEE, The Conference Record No. (2015)

Temperature compensation device MTCD@NCBJ for MPPC in plasma diagnostics
G. Bołtruczyk, **M. Gosk**, **S. Mianowski**, **M. Szawłowski**, **I. Zychor**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Gamma Spectrometer Based on $CeBr_3$ Scintillator with Compton Suppression for Identification of Trace Activities in Water
Ł. Świderski, **T. Batsch**, **J. Iwanowska-Hanke**, **M. Moszyński**
The 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)
IEEE NSS Conf. Rec. (2015)

Study of fluorine-based plastic scintillators for fast neutron detection by means of ^{19}F activation
P. Sibczyński, **J. Kownacki**, **M. Moszyński**, **A. Syntfeld-Każuch**, **J. Iwanowska**, **M. Gierlik**, **A. Urban**, M. Hamel, F. Carrel, E. Montbarbon, A. Grabowski, P. Schotanus, A. Iovene, C. Tintori
The 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (USA, San Diego, 2015-10-31 - 2015-11-07)

Scintillators for high temperature plasma diagnostics
Ł. Świderski, **A. Gójska**, **M. Grodzicka**, **S. Korolczuk**, **S. Mianowski**, **M. Moszyński**, **J. Rzadkiewicz**, **P. Sibczyński**, **A. Syntfeld-Każuch**, **M. Szawłowski**, **T. Szczęśniak**, **J. Szewiński**, **A. Szydłowski**, **I. Zychor**
1st EPS Conference on Plasma Diagnostics (Italy, Frascati, 2015-04-14 - 2015-04-17)

Temperature compensation device MTCD@NCBJ for MPPC in plasma diagnostics
G. Bołtruczyk, **M. Gosk**, **S. Mianowski**, **M. Szawłowski**, **I. Zychor**
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)

ED-xrf method in analysis of historical polish coins elemental composition
A. Gójska, **K. Grodzicki**, **M. Laskus**, **P. Matuszczak**, **P. Markowski**, **P. Mazerewicz**, **J. Rzadkiewicz**, **P. Sibczyński**, **M. Słapa**, **M. Snopek**, **J. Szymanowski**, **K. Wincel**, **B. Zaręba**
Jubileuszowe Sympozjum Narodowego Centrum Badań Jądrowych (Poland, Otwock, 2015-06-15 - 2015-06-15)

ED-XRF method in analysis of historical polish coins elemental composition
A. Gójska, **K. Grodzicki**, **P. Matuszczak**, **P. Markowski**, **P. Mazerewicz**, **J. Rzadkiewicz**, **P. Sibczyński**, **M. Słapa**, **M. Snopek**, **J. Szymanowski**, **K. Wincel**, **B. Zaręba**
TECHNART2015 Non-destructive and microanalytical techniques in art and cultural heritage (Italy, Katania, 2015-04-27 - 2015-04-30)

Characterization of scintillators for gamma-ray spectrometry of fusion plasma
P. Sibczyński, **A. Gójska**, V. Kiptily, **S. Korolczuk**, **S. Mianowski**, **M. Moszyński**, **J. Rzadkiewicz**, **Ł. Świderski**, **A. Szydłowski**, **I. Zychor**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Learning algorithms at the service of WISE survey
K. Małek, **T. Krakowski**, M. Bilicki, **A. Pollo**, A. Solarz, M. Krupa, A. Kurcz, W. Hellwing
Gas, Dust, and Star-Formation in Galaxies from the Local to Far Universe (Greece, Platanias , 2015-05-25 - 2015-05-29)

Non-thermal plasma technology for multipollutant emissions control from coal-fired boiler
J. Licki, A.G. Chmielewski, Z. Zimek
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)
Nukleonika (in press)

Plasma temperature determination during the time of maximum K-shell X-ray emission of Cu impurities in PF1000 device
J. Rzadkiewicz, **A. Gójska**, M. Paduch, M. Polasik, O. Rosmej, K. Słabkowska, Ł. Syrocki, E. Szymańska, M. Scholz, E. Zielińska
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)

What we know about Oslo meteorite from cosmogenic isotope analysis
Z. Tymiński, M. Stolarz, T. Kubalczak, **K. Tymińska**, **E. Kołakowska**, **T. Dziel**, **A. Burakowska**, **E. Miśta**, **P. Saganowski**
European Planetary Science Congress (France, Nantes, 2015-09-27 - 2015-10-02)

LECTURES, COURSES AND EXTERNAL SEMINARS

Design and optimization of High-Dose Rate (HDR) Applicator for Skin Irradiation, based on Monte Carlo simulation,[a]
P. Mazerewicz
Otwock, NCBJ, 2015-06-10

[a)] in Polish

INTERNAL SEMINARS

NCBJ contribution in detector constructing within the European Joint Programme underthe Council Regulation (EURATOM) No 1314/2013 of 16 December 2013 on theResearch and Training Programme of the European Atomic Community (2014-2018)Complementing the Horizon 2020 - The Framework Programme for Research and Innovation[a]
I. Zychor
Świerk, National Centre for Nuclear Research (NCBJ), 2015-02-11

Competences of Environmental Analysis Laboratory[b]
A. Burakowska, J. Bzdak, M. Bogusz
Otwock-Świerk, NCBJ, 2015-02-24

Design of a device for simultaneous measurements with more than one detector[a]
G. Bołtruczyk
Świerk/Otwock, NCBJ, 2015-10-14

MTCD@NCBJ for silicon photomultiplier (MPPC) control[a]
M. Gosk
Otwock/Świerk, National Centre for Nuclear Research, 2015-10-14

Digital Approach To High Rate
Gamma-Ray Spectrometry[a]
S. Korolczuk
Otwock/Świerk, NCBJ, 2015-10-14

EUROfusion_NCBJ_JET4 project in 2015[a]
I. Zychor
Świerk, National Centre for Nuclear Research (NCBJ), 2015-10-14

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

DIDACTIC ACTIVITY

P. Mazerewicz - A slideshow of the results of research "Nuclear physics for medicine" (Open Days in NCBJ Świerk).

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

A. Gójska
Polish Physical Society

Z. Guzik
POLSKIE NORMY, POLISH STANDARDS Polish Stanardization Committee
Member of Scientific Council in National Centre of Nuckear Research

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
Session chairman on International Conference on Research and Application of Plasmas PLASMA-2015 in Warsaw, Poland
PhD Proceedings Admission Committee Member, National Centre for Nuclear Research (NCBJ) Scientific Council

PERSONNEL

Scientific staff
Tadeusz Batsch, PhD
Grzegorz Bołtruczyk, MSc Eng
Stanisław Borsuk, MSc Eng
Andrzej Brosławski, MSc
Agnieszka Burakowska, PhD
Arkadiusz Chłopik, MSc Eng
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PLASMA STUDIES DIVISION

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Overview

In 2015 the two main scientific tasks of the Plasma Studies Division (TJ5) were continued:

- 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;
- Investigations of high-temperature plasma streams and their interactions with solid targets.

Within the framework of the EUROfusion Consortium, the detailed studies to determine the conditions of runaway electron generation, and to investigate mitigation techniques, were continued in 2015 as part of the MST2 package. This research was carried at the COMPASS tokamak, under the leadership of the IPP AS CR in Prague. New single- and multi-channel Cherenkov detectors were installed during the spring- and autumn-campaigns 2015. During the first campaign, in addition to frequently observed long-lasting signals, some very short Cherenkov signals were recorded. For the autumn campaign a new multichannel Cherenkov probe equipped with three channels with radiators made of filtered diamond crystals in order to establish different lower-energy thresholds (58 keV, 145 keV and 221 keV) was employed. Using this probe some preliminary results were obtained. In another part of this research the results of earlier experimental campaigns, which were carried out within the FTU tokamak (in Frascati) with the single-channel detector, were summarized. A new kind of modulated Cherenkov signals has been found and interpreted. Important correlations between runaway electrons and evolution of magnetic islands, as well as disruptions caused by injection of deuterium pellets, were also investigated.

As regards the applications of solid-state nuclear track detectors (SSNTDs) for studies of fast ions and fusion reaction products, TJ5 scientists continued their involvement in an experiment at the PALS laser laboratory (in Prague), where $^{11}B + p \rightarrow 3\alpha + 8.7$ MeV nuclear reactions were studied. It should be mentioned that such laser-induced nuclear-fusion reactions are nowadays investigated as an alternative approach for the production of fusion energy. Changes in the sensitivity of the nuclear track detectors after their long-term storage were also investigated.

During the whole of 2015 the NCBJ team, in close scientific collaboration with the IFPiLM in Warsaw, has continued experimental studies of X-rays, ion and electron emission from PF-type discharges. Particular attention was paid to X-ray pinhole images which demonstrated the appearance of plasma filaments or "hot-spots" in discharges realised within the PF-1000U facility. The team also performed a very detailed analysis of the recorded time-integrated X-ray images, and the time-resolved measurements performed with four PIN diodes located behind filtered pinholes. Much experimental efforts was also devoted to measurements of fast electron beams emitted from a modified PF-360U facility, mostly in the upward direction, through a central channel in the anode. For this purpose use was made of magnetic analysers equipped with miniature Cherenkov or scintillation detectors.

As regards investigations of high-temperature plasma streams, experimental efforts have been devoted to studies of intense plasma streams interactions with targets made of tungsten. Results of the studies of optical emission spectra, obtained within the PF-1000U facility, were analyzed by a joint Polish-Ukrainian team. Particular attention was focused on identification of tungsten spectral lines and determination of mass-losses caused by the irradiation of the investigated W-samples. Another task was research on interactions of plasma streams with CFC targets within an RPI-IBIS (rod plasma injector) facility. Analysis of the D_β line enabled temporal changes of the plasma electron density to be determined. Temporal changes of spectral lines originating from exited atoms and ions, which were produced from the irradiated targets, enabled the target erosion dynamics to be studied. In addition to optical spectra surface changes of the irradiated targets were also investigated.

Jarosław Żebrowski

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Dense magnetized plasma activity in IPP NSC KIPT
I.E. Garkusha, N.N. Aksenov, O.V. Byrka, V.A. Makhlai, S.S. Herashchenko, S.V. Malykhin, S.V. Surovitskiy, S.V. Bazdyrieva, **M.J. Sadowski**, **E. Składnik-Sadowska**
ICDMP Annual Meeting and Workshop (Poland, Warsaw, 2015-09-11 - 2015-09-13)

OES studies of plasmoids distribution during the coating deposition with the use of the IPD method controlled by the gas injection
K. Nowakowska-Langier, R. Chodun, K. Zdunek, S. Okrasa, **R. Kwiatkowski**, **K. Malinowski**, **E. Składnik-Sadowska**, **M.J. Sadowski**
9-th Symposium on Vacuum based Science and Technology in conjunction with the 14-th Annual Meeting of the German Vacuum Society (DVG) (Poland, Kolobrzeg, 2015-11-17 - 2015-11-19)

Recent high-temperature plasma studies by the NCBJ team, Poland
M.J. Sadowski, **E. Składnik-Sadowska**, **R. Kwiatkowski**, **K. Malinowski**, **K. Nowakowska-Langier**, **J. Żebrowski**, **K. Czaus**, **W. Surała**, **D. Załoga**, M. Kubkowska, M. Paduch, E. Zielinska, P. Kubes, I. Garkusha, V. Makhlay, M. Ladygina
ICDMP Annual Meeting and Workshop (Poland, Warsaw, 2015-09-11 - 2015-09-13)

Thin layer Pb photocathode deposition for improved performance of SRF guns (status in May 2015)
R. Nietubyć, **J. Lorkiewicz**, J. Sekutowicz, **M. Barlak**, D. Kostin, **A. Kosińska**, R. Barday, R. Xiang, **R. Mirowski**, **M. Frelek**, **W. Pawlak**, **T. Sworobowicz**, **J. Witkowski**, **W. Grabowski**
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)

Soft X-ray studies of microstructures in dense plasma pinches
M.J. Sadowski
Summer School of Plasma Diagnostics: PhDiaFusion - Soft X-ray Diagnostics for Fusion Plasma (Poland, Bezmiechowa, 2015-06-16 - 2015-06-20)

Physics of neutron production in dense plasma focus experiments
P. Kubes, D. Klir, J. Cikhardt, J. Kravarik, K. Rezac, B. Cikhartova, M. Paduch, E. Zielinska, **W. Surała**, **D. Załoga**, **M.J. Sadowski**, V. Krauz, K. Mitrofanov
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Stan i perspektywy badań nad opanowaniem kontrolowanych reakcji syntezy jądrowej w gorącej plazmie
M.J. Sadowski
XLIII Zjazd Fizyków Polskich (Poland, Kielce, 2015-09-06 - 2015-09-11)

PF-1000 studies, 2013 – 2015
P. Kubes, D. Klir, J. Cikhardt, J. Kravarik, K. Rezac, B. Cikhartova, M. Paduch, E. Zielinska, **W. Surała**, **D. Załoga**, **M.J. Sadowski**, H.J. Kunze
ICDMP Annual Meeting and Workshop (Poland, Warsaw, 2015-09-11 - 2015-09-13)

Oral Presentation

Energy- and time-resolved measurements of fast ions from Plasma-Focus discharges by means of a Thomson-type spectrometer
R. Kwiatkowski, **K. Czaus**, M. Paduch, **M.J. Sadowski**, **E. Składnik-Sadowska**, **D. Załoga**, E. Zielinska, **J. Żebrowski**
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)

Important issues from X-ray studies of high-current pulse discharges of the plasma-focus type
M.J. Sadowski, M. Paduch, **E. Składnik-Sadowska**, **W. Surała**, **D. Załoga**, R. Miklaszewski, E. Zielinska, K. Tomaszewski
International Conference on Plasma Science ICOPS-2015 (Turkey, Antalya, 2015-05-24 - 2015-05-28)

Development of the Cherenkov-type diagnostic system to study runaway electrons in tokamaks
L. Jakubowski, **K. Malinowski**, **R. Mirowski**, **M. Rabiński**, **M.J. Sadowski**, **J. Żebrowski**, **M.J. Jakubowski**
1st EPS Conference on Plasma Diagnostics (Italy, Frascati, 2015-04-14 - 2015-04-17)

Time-integrated and time-resolved measurements of X-rays from high-current Plasma-Focus discharges
D. Załoga, **W. Surała**, **M.J. Sadowski**, M. Paduch, **E. Składnik-Sadowska**, K. Tomaszewski, E. Zielinska
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)

Study of X-ray emission and fine structure of a Plasma-Focus pinch column
W. Surała, **M.J. Sadowski**, **R. Kwiatkowski**, **L. Jakubowski**, **J. Żebrowski**, M. Paduch, E. Zielinska, K. Tomaszewski
Summer School of Plasma Diagnostics: PhDiaFusion - Soft X-ray Diagnostics for Fusion Plasma (Poland, Bezmiechowa, 2015-06-16 - 2015-06-20)

Application of QSPA plasma streams for simulation of plasma surface interaction in fusion reactor; Recent results and prospects
I.E. Garkusha, N.N. Aksenov, O.V. Byrka, V.A. Makhlai, S.S. Herashchenko, S.V. Malykhin, S.V. Surovitskiy, S.V. Bazdyrieva, M. Wirtz, J. Linke, **M.J. Sadowski**, **E. Składnik-Sadowska**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Numerical studies of fast ion motion within a plasma pinch column
R. Kwiatkowski, **M.J. Sadowski**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Signal acquisition in Cherenkov-type diagnostics of electron beams within tokamak facilities
M. Rabiński, **L. Jakubowski**, **M.J. Sadowski**, **J. Żebrowski**, **M.J. Jakubowski**, **K. Malinowski**, **R. Mirowski**
XXXVI-th IEEE-SPIE Joint Symposium Wilga 2015 (Poland, Wilga, 2015-05-25 - 2015-05-30)

Advanced scheme for high-yield laser driven proton-boron fusion reaction
D. Margarone, A. Picciotto, V. Velyhan, J. Krasa, M. Kucharik, M. Morrissey, A. Mangione, **A. Szydłowski**, **A. Malinowska**, G. Bertuccio, Y. Shi, M. Crivellari, J. Ullschmied, P. Bellutti, G. Korn
High Power Lasers for Fusion Research III (USA, San Francisco, 2015-02-07 - 2015-02-12)
SPIE No 9345 (2015) 93450F-1

Wzrost zainteresowania reakcją syntezy $^{11}B(p, \alpha)2\alpha$, czy uda się powrócić do koncepcji zbudowania ultra czystego reaktora jądrowego? Polski wkład w badania.
A. Malinowska, **A. Szydłowski**, **M. Jaskóła**
XLIII Zjazd Fizyków Polskich (Poland, Kielce, 2015-09-06 - 2015-09-11)

Poster

Time- and energy-resolved measurements of ion beams emitted from Plasma-Focus type discharges
R. Kwiatkowski, **K. Czaus**, M. Paduch, **M.J. Sadowski**, **E. Składnik-Sadowska**, E. Zielinska
1st EPS Conference on Plasma Diagnostics (Italy, Frascati, 2015-04-14 - 2015-04-17)

Optical spectra of plasma-streams and plasma from targets in plasma-focus experiments
D. Załoga, **E. Składnik-Sadowska**, **K. Malinowski**, **R. Kwiatkowski**, **M.J. Sadowski**, **J. Żebrowski**, M. Kubkowska, M. Paduch, V.A. Gribkov, M.S. Ladygina
2015 Joint ICTP-IAEA Advanced School and Workshop on Modern Methods in Plasma Spectroscopy (Italy, Trieste, 2015-03-16 - 2015-03-27)

Studies of pulsed plasma-ion streams during their free propagation and interaction with SiC-targets
E. Składnik-Sadowska, **R. Kwiatkowski**, **K. Malinowski**, **M.J. Sadowski**, **K. Czaus**, **D. Załoga**, **J. Żebrowski**, **K. Nowakowska-Langier**
International Conference on Plasma Science ICOPS-2015 (Turkey, Antalya, 2015-05-24 - 2015-05-28)

Scintillators for high temperature plasma diagnostics
Ł. Świderski, **A. Gójska**, **M. Grodzicka**, **S. Korolczuk**, **S. Mianowski**, **M. Moszyński**, **J. Rzadkiewicz**, **P. Sibczyński**, **A. Syntfeld-Każuch**, **M. Szawłowski**, **T. Szczęśniak**, **J. Szewiński**, **A. Szydłowski**, **I. Zychor**
1st EPS Conference on Plasma Diagnostics (Italy, Frascati, 2015-04-14 - 2015-04-17)

Energy balance studies of IPD plasma accelerator working with fast valve
M. Rabiński, K. Zdunek
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Characterization of scintillators for gamma-ray spectrometry of fusion plasma
P. Sibczyński, **A. Gójska**, V. Kiptily, **S. Korolczuk**, **S. Mianowski**, **M. Moszyński**, **J. Rzadkiewicz**, **Ł. Świderski**, **A. Szydłowski**, **I. Zychor**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Coating and processing of thin lead layers on niobium for photocathodes in superconducting RF electron injectors
R. Nietubyć, **J. Lorkiewicz**, **A. Kosińska**, **M. Barlak**, J. Sekutowicz, D. Kostin, R. Barday, R. Xiang, **R. Mirowski**, **J. Witkowski**, **W. Grabowski**
PLASMA 2015; International Conference on Research and Applications of Plasmas (Poland, Warsaw, 2015-09-07 - 2015-09-11)
Phys. Scr. (2015)

Advances in the development of a Cherenkov diagnostic system to study runaway electron losses
F. Causa, G. Pucella, B. Esposito, P. Buratti, E. Giovannozzi, FTUTeam, **L. Jakubowski**, **K. Malinowski**, **M. Rabiński**, **M.J. Sadowski**, **J. Żebrowski**
1st EPS Conference on Plasma Diagnostics (Italy, Frascati, 2015-04-14 - 2015-04-17)

Cherenkov diagnostic observations of fast electron losses in FTU and interpretation with gyrokinetic simulations
F. Causa, S. Briguglio, P. Buratti, B. Esposito, G. Fogaccia, V. Fusco, E. Giovannozzi, G. Pucella, G. Vlad, FTUTeam, **L. Jakubowski**, **K. Malinowski**, **M. Rabiński**, **M.J. Sadowski**, **J. Żebrowski**
42nd EPS Conference on Plasma Physics (Portugal, Lisbon, 2015-06-22 - 2015-06-26)
EPS Conference Abstracts Vol. 39E (2015) O4.134

Measurements of electron beams in Plasma-Focus experiments
W. Surała, **M.J. Sadowski**, **R. Kwiatkowski**, **L. Jakubowski**, **J. Żebrowski**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

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**
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

Effects of Plasma Control on Runaway Electrons in the COMPASS Tokamak
J. Mlynar, O. Ficker, M. Vlainic, V. Weinzettl, M. Imrisek, R. Paprok, **M. Rabiński**, **M.J. Jakubowski**, M. Tomes, M. Peterka, R. Panek, COMPASSTeam
42nd EPS Conference on Plasma Physics (Portugal, Lisbon, 2015-06-22 - 2015-06-26)
EPS Conference Abstracts Vol. 39E (2015) P4.102

Studies of plasma interactions with tungsten targets in PF-1000U facility
M.S. Ladygina, **E. Składnik-Sadowska**, **M.J. Sadowski**, **D. Załoga**, M. Kubkowska, E. Kowalska-Strzęciwilk, N. Krawczyk, M. Paduch, I.E. Garkusha, R. Miklaszewski
International Conference on Research and Application of Plasmas PLASMA-2015 (Poland, Warsaw, 2015-09-07 - 2015-09-11)

LECTURES, COURSES AND EXTERNAL SEMINARS

Measurements of fast electrons by means of a cherenkov-type single-channel detector in COMPASS tokamak[b]
K. Malinowski
Prague, Institute of Plasma Physics ASCR, 2015-05-21

Chernobyl - facts and myths[a]
M. Rabiński
Góra Kalwaria, University of the Third Age, 2015-11-12

a) in Polish
b) in English

INTERNAL SEMINARS

Analysis of recent results on ions, electrons and visual radiation of plasma generated within PF-360 and PF-1000 facilities[b]
R. Kwiatkowski
Warsaw, National Centre for Nuclear Research, 2015-05-12

b) in English

DIDACTIC ACTIVITY

A. Malinowska - Care for a master's thesis entitled: Model of personnel neutron detector.

M. Rabiński - "Thermonuclear Fusion" - Warsaw University of Technology

M.J. Sadowski - Superviser of a Ph.D. thesis of Kamil Szewczak on "Assessment of radiological hazards during fusion studies with the PF-1000 facility", defended in July 2015.

M.J. Sadowski - Superviser of a Ph.D. thesis of Roch Kwiatkowski on "Analysis of results of the newest measurements of ions, electrons and visible radiation from plasma in PF-360 and PF-1000 facilities", defended in March 2015.

M.J. Sadowski - Supervision of Ph.D. studies of Dobromil Zaloga, M.Sc. (IV year of studies).

M.J. Sadowski - Supervision of Ph.D. studies of Wladyslaw Surala, M.Sc. (V year of studies).

E. Składnik-Sadowska - Assistance and supervision of experiments carried out withi a frame of Ph.D. studies of Dobromil Zaloga, M.Sc., in the field of x-ray diagnostics and optical spectroscopy (IV year of studies).

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
member of Scientific Council

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
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
Member of the Polish Physical Society.

A. Szydłowski
International Nuclear Track Society, member

PERSONNEL

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Gawrońska Alicja
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Jakubowski Lech, PhD
Jędrzejczyk Marek
Karpiński Paweł
Kwiatkowski Roch, PhD
Malinowska Aneta, PhD
Malinowski Karol, PhD
Rabiński Marek, PhD
Sadowski Marek, Professor
Składnik-Sadowska Elżbieta, PhD
Szydłowski Adam, Asocc. Prof.
Witkowski Jan, B.Sc.E.E.
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NUCLEAR EQUIPMENT DIVISION - HITEC

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Overview

The Division of Nuclear Equipment - HITEC specializes in applications of accelerator technologies in research medicine and industrial radiography. It combines research and development with manufacturing activities.

In 2015, HITEC concentrated on performing R&D works that continued the efforts of Project No. POIG.01.01-14-012/08-00 (known under the short name of *Accelerators and Detectors*) completed the previous year. Decisive progress was made towards building a full prototype of a low energy medical accelerator, Coline 6, derived from the results of this Project, in particular from the work on a medical accelerator for advanced radiotherapy.

Work was also continued on a mobile accelerator for intra-operative radiation therapy. The aim of these efforts undertaken within the project *INTRA-DOSE*, founded by NCBiR in the framework of the *Applied Research* call, is to develop a complete intra-operative radiotherapy system with a functionality optimally fitting the needs of medical users. For this purpose, *INTRA-DOSE* has been a collaborative effort involving an oncological clinic, Wielkopolskie Centrum Onkologii, as well as commercial partners. The resulting unit will exhibit enhanced mobility features and a user friendly mode of operation.

Full speed development work was undertaken on the linac intended for use by the GBAR experiment, aimed at measuring the gravitational behaviour of antimatter. This effort was performed together with NCBJ TJ1 Division as part of a Collaboration Agreement with CERN. Upon successful installation of the accelerator, the project will involve participation of NCBJ researchers in the experiment.

In 2015, HITEC almost finished manufacturing the PI-Mode Structure (PIMS) accelerating cavities for Linac 4 in the framework of an earlier Collaboration Agreement with CERN aimed at upgrading the performance of the CERN Large Hadron Collider (LHC). The structures are being gradually installed in the Linac 4 tunnel. All the collaborators are waiting for the accelerator’s first beam which will provide the ultimate evidence of the quality of this extensive work.

2015 also saw the opening of HITEC’s new Accelerating Structure Laboratory. The Laboratory, consisting of a building and 2 bunkers capable of housing high energy (up to 18 MeV) accelerators, will greatly improve HITEC’s R&D capabilities. The Laboratory was built as part of the *4LABs* project (Project No. RPMA.01.01.00-14-030/10-00, co-funded by the EU Regional Development Funds). Within the same project HITEC designed and manufactured an accelerator based radiographic system for the Radiographic Laboratory. As with other development of linear accelerators, this work was done in collaboration with NCBJ TJ1 Division.

HITEC is proud of its contribution to the SOLARIS synchrotron system at the Narodowe Centrum Promieniowania Synchrotronowego in Kraków. HITEC specialists were contracted to perform the vacuum installation for the system.

Finally, it is worth mentioning that in 2015 HITEC contracted two radiographic accelerators for foreign customers. They are scheduled for delivery in 2016.

Paweł Krawczyk

DEPARTMENT OF COMPLEX SYSTEM

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Overview

In connection with signing an annex to the agreement to finance the Świerk Computer Centre (CIS) project, some significant additional investment in hardware was possible in the second half of 2015. The CIS precision air conditioning system was expanded with a row of server cabinets each equipped with its own 50 kW capacity cooling module and an additional 400 kW capacity cooling/pumping unit. The combined cooling power of all three units can now reach 1,200 kW. Two disk systems have been purchased to expand the capacity of the storage system: a 7 PB EMC-manufactured NAS array supports NFS and CIFS protocols, while 16 disk servers each equipped with 84 NL-SAS disks and 2 application controllers support a fully redundant, high-performance Lustre file system. In addition, 2 new servers with fast SSD disks store metadata. The combined capacity of the latter disk system amounts to 8 PB. CIS' computing power was also significantly increased: a cluster of 470 machines powered by Intel Xeon E5-2680v3 processors directly liquid-cooled (combined power 450 TFLOPS) and computers equipped with Nvidia Tesla K80 accelerators dedicated to running CUDA architecture applications (combined power 94 TFLOPS) were installed. Hardware acquisitions in 2015 have doubled the total computing power of the supercomputer developed within the CIS project to more than 1 PFLOPS.

Research conducted in the Centre for Hazard Analysis was focussed on the following three areas: (i) applications of Computational Fluid Dynamics (CFD) models/methods; (ii) probabilistic safety analyses (PSA); (iii) selected topics in environmental protection.

- CFD models/methods were applied to: analyses of oscillations in the flow of coolant through densely packed nuclear fuel assemblies; analyses of the cooling of spherical beds in HTR reactors; thermal-flow calculations for the BNCT converter/molybdenum containers for the MARIA reactor; thermal-flow calculations of the hydraulic manifold installed in the CIS supercomputer cooling loop.
- Research on PSA models/methods included: calculation of the probability of nuclear power plant failure caused by human error; assessment of the risk of failure caused by external factors (forces of nature); plant supply system reliability; impact of very rare/extreme cases of *force majeure* on plant safety systems.
- Research related to environmental protection included: a search for optimal strategies applicable in Polish circumstances to treat contaminated food/to decontaminate urban areas after severe nuclear accidents (within the RODOS system developed to support decision-makers after such accidents); implementation of water modules dedicated to the Vistula/Odra river drainage basins in the RODOS system; application of the Bayesian methodology to stochastic reconstruction of events – case study: release of hazardous substances into the atmosphere; implementation of the SMOKE emission model in the WRF-Chem air quality model.

Research topics in the Interdisciplinary Division for Energy Analyses (which evolved from the NCBJ Complex Systems Department) included: refinement of energy market zoning algorithms; power mix models; unit commitment; development of a node model for high- and very-high voltage grids in Europe; optimization of cross-border transmission lines.

Research conducted in the Reactor Analyses Section was focussed on the following two areas: (i) nuclear safety assessment; (ii) nuclear fuel cycle analyses.

[1] Research on assessment of nuclear safety included: refinement of the MARIA research reactor model with the use of the RELAP5 and CATHARE2 thermal-flow software codes; simulation of fuel element drying phenomena (within the FP7 Euratom NURESAFE project framework); modelling the consequences of severe nuclear accidents (formation of a pool in the lower part of the reactor safety containment after melt-down of the reactor core; exchange of heat in the metallic layers of the molten material; cooling of the reactor vessel walls); participation in the H2020 Euratom IVMR (In-Vessel Melt Retention) project. In addition, some new software tools were implemented in the CIS cluster and some user interfaces of already implemented applications were refined. A Regional workshop of the International Atomic Energy Agency on severe nuclear accidents (software codes to simulate reactor core melt down) was organized at Świerk in November 2015.

[2] Research on the nuclear fuel cycle included: experiments on the utilization of spent fuel by irradiating QUINTA assemblies containing natural uranium with neutrons (participation in the E+T RAW project run at Dubna, Russia); simulation of migration of helium atoms through fuel containing uranium dioxide; studies of the concept of liquid-fuel molten-salt reactors (in particular modelling of their extractors).

Within the framework of cooperation with the Jagiellonian University in Krakow (May 2015–June 2016) CIS/DUZ performed simulations helping to develop a state-of-the-art Positron Emission Tomography Strip Scanner (the J-PET project coordinated by Professor Paweł Moskal). 200- and 384-strip versions were tested from the random coincidence/scattering point of view. NEMA characteristics were tentatively determined for a single-layer version of the scanner. The results of Compton scattering studies were published (*Scatter Fraction of the J-PET Tomography Scanner*, P. Kowalski et al., Acta Physica Polonica B, 2016). A method to restore voltage signals on outputs of J-PET photomultipliers was developed; the results were presented at the *IEEE Engineering in Medicine and Biology Conference*, August 2015, Milan, Italy. Studies of the limits of time resolution of J-PET scanners (based on the time jitter of voltage signals observed at the photomultiplier outputs) are in progress

Wojciech Wiślicki

LABORATORY FOR ANALYSES OF COMPLEX SYSTEMS

Head of division: Karol Wawrzyniak, PhD Eng

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Overview

The Division for Analyses of Complex Systems consists of two groups involving multidisciplinary personnel working on different kind of complex systems: energy markets, power transfer distribution, medical application of J-PET tomography and radiopharmaceuticals. After the Świerk Computing Centre Project (CIŚ) was completed, part of the personnel involved in the project became part of this division.

Group for Energy Analysis

Profile:

- mathematical modelling of power systems using High Performance Computing (HPC)
- generation, transmission, distribution and energy cross-border exchange
- problems related to security of energy supply, such as redispatching in addition to the risk of failure of the power system (unsatisfied criteria *n-1*, *g-1*)
- modelling power flow in the transmission grid, including the European transmission network – UCTE system
- energy mix forecasts
- energy market structures: nodal model and zonal models of the European energy market, designing zonal division for the future European energy market
- determining prices on the energy market and the volume of cross-border exchange using a Market Coupling algorithm
- multi-agent approach for modelling market participant's behaviour in the energy market and in econo- and social sciences

Group for Bio-Medical Applications

The Group for Bio-Medical Applications is part of the J-PET collaboration that aims to construct a PET scanner from plastic scintillators which would allow for simultaneous imaging of the whole human body. The coordinator of the group, prof. Paweł Moskal, as well as the majority of the participants are from Cracow, from the Jagiellonian University, Faculty of Physics, Astronomy and Applied Computer Science.

Profile:

- study ofa modern J-PET tomograph (Jagiellonian Positron Emission Tomography) based on plastic scintillation detectors
- simulation of various geometries and characteristics of the J-PET tomograph based on the computing environment GATE (Geant4 Application for Tomographic Emission)
- analytical methods of reconstructing the signals from photomultipliers, the places of annihilations along scintillation strips and the tomographic images
- application of density functional theory (DFT) to quantum-chemical calculations
- molecular modelling using ab initio methods
- theoretical investigations (using methods based on molecular electronic structure theory) of radiopharmaceutical structures
- studies of the electronic structure of Fe-S clusters
- modelling of Nuclear Magnetic Resonance (NMR) parameters of compounds containing transition metal atoms

Karol Wawrzyniak

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Nowa struktura europejskiego rynku energii - rynek strefowy
K. Wawrzyniak, **M. Kłos**, **M. Jakubek**, **M. Blachnik**, **A. Kadłubowska**, **Sz. Kitowski**
ZET 2015 - Zarządzanie Energią i Teleinformatyka (Poland, Nałęczów, 2015-02-18 - 2015-02-20)

Integracja krajowego rynku rynku energii w ramach paneuropejskiego rynku strefowego - kontekst polityczno-gospodarczy
K. Wawrzyniak
Bezpieczeństwo energetyczne na wspólnym rynku energii UE (Poland, Rzeszów, 2015-04-28 - 2015-04-28)

Integracja rynku elektroenergetycznego - szanse czy zagrożenia dla bezpieczeństwa energetycznego UE
K. Wawrzyniak
Bezpieczeństwo energetyczne na wspólnym rynku energii UE (Poland, Rzeszów, 2015-04-28 - 2015-04-28)

Optimization of Levels of Voltage Thresholds in a Novel J-PET Device
L. Raczyński
Warsaw Medical Physics Meeting (Poland, Warszawa, 2015-05-14 - 2015-05-16)

Poster

Reconstruction of Signal in Plastic Scintillator of PETusing Tikhonov Regularization
L. Raczyński
37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (Italy, Milano, 2015-08-25 - 2015-08-29)

LECTURES, COURSES AND EXTERNAL SEMINARS

Market Coupling in Europe - pros and cons for Poland[a]
K. Wawrzyniak
Warszawa, Lewiatan - Federacja Przedsiębiorców Polskich, 2015-08-20

Intuitive introduction to grid clustering according to Power Transfer Distribution Factors[b]
M. Kłos
Duesseldorf, European Network of Transmission System Operators for Electricity, 2015-06-12

a) in Polish
b) in English

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

M. Kłos
Complex Systems Society

L. Raczyński
Session chairman on International Conference Cybernetic Modelling of Biological Systems in Kraków, Poland

K. Wawrzyniak
Complex Systems Society
Top 500 Innovators

PERSONNEL

Karol Wawrzyniak, PhD Eng
Marcin Jakubek, MSc
Wojciech Jaworski, PhD
Anna Kadłubowska, MSc
Szymon Kitowski
Micha l Kłos, MSc
Paweł Kowalski, MSc Eng
Krzysztof Królikowski
Lech Raczyński, PhD Eng
Artur Wodyński, PhD

Technical and administrative staff
Michał Findeisen, PhD ?
Agnieszka Gajownik, MSc
Magdalena Kośla, MSc

LABORATORY OF NUCLEAR ENERGY AND ENVIRONMENTAL STUDIES

Head of the Division (since OCT2015): Mariusz Dąbrowski, Professor
phone: (22) 273-14-30
e-mail: Mariusz.Dabrowski@ncbj.gov.pl

Head of the Nuclear Energy Division
(till OCT2015): Tomasz Jackowski
phone: (22) 273-11-01
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Overview

The Division of Nuclear Energy and Environmental Studies was created in October 2015 from the Nuclear Energy Division moved to the newly established Department of Complex Systems with a new structure. All the presented activities were undertaken within the former structure of NCBJ.

Main scientific and technical achievements.

The **Neutronics and New Reactor Technologies Section** was engaged in a number of activities – the most important are the following:

1. Modelling of the MARIA research reactor:

• Burnup calculations of the MARIA research reactor fuel elements and poisoning in beryllium blocks using the APOLLO and MCNP codes.

2. Power reactor analysis:
• Implementation of the SCALE code package for neutron-physics analysis (codes KENO-VI, NEWT).
• Investigations of Accident Tolerant Fuel with different fuel cladding materials, based on PWR core calculations. Calculations were carried out using the MCNP code.

3. Participation in the HTR-PL Project "Development of High Temperature Reactors for industrial purposes":
• Modelling of HTR core with various distributions of fuel and dummy elements using the MCNP code.
• Verification of the safety characteristics of the Chinese pebble bed reactor HTR-10. For the purpose of this studya SCALE/KENO-VI two high fidelity Monte Carlo models of HTR-10 were developed based on the IAEA benchmark specifications and experimental data: the first with regular and the second with random distribution of pebbles in the core. A diffusion theory model for practical applications is under development.

4. Participation in the International Benchmark Phase-I: *Reflector Effect of SiO_2 for Direct Disposal of Used Nuclear Fuel.* Calculations were performed using the SCALE/KENO-VI, SERPENT and MCNP codes.

5. Activities related to development ofGas Cooled Reactor Technology:
• participation in ALLIANCE - ALLegro Implementing Advanced Nuclear Fuel Cycle in Central Europe. Information was providedabout R&D needs and potential research facilities in NCBJ for testing GFR materials and components.
• participation in ESNII PLUS - Preparing ESNII for HORIZON 2020. ALLEGRO is developed as one of four fast reactor demonstrators under this EU programme. Common and coordinated activities were created by a "Project Coordination Team"from Poland, Slovakia, Hungary, the Czech Republic and France as a result of which a strategy document "ALLEGRO Roadmap" was published,
• participation in the IAEA Technical Meeting on the Economic Analysis of High Temperature Gas Cooled Reactors and Small and Medium Sized Reactors – contribution to future requirements and objectives for HTR deployment strategy was provided.

6. Activities related to nuclear cogeneration:
• Management NC2I-R - Nuclear Cogeneration Industrial Initiative – to Research into and provide reports about implementation of nuclear cogeneration in Poland. Legal forms of demonstrator facilities, safety requirements, etc. were analysed.
• Participation in IAEA Coordinated Research Projects Application of Advanced Low Temperature Desalination Systems to Support Nuclear Power Plants and Non-Electric Applications – proposal calculations for very low and waste heat use applications.

7. Education and science popularization:

• Organizing a conference with workshops: VIIIth International School on Nuclear Power, 26-30.10.2015
• Training with the MARIA reactor simulator for students of Warsaw University of Technology
• Scientific supervision of bachelor and master papers.

The Reactor Analyses Section was created by combining the Deterministic Safety Analyses Team and Fuel Cycle Laboratory.
The main activities in the field of safety assessment focused on the following:

1. Continuation of work on modelling of the MARIA research reactor. The model takes into account various fuel assembly types, the whole primary and secondary cooling circuit and the pool. The core can be configured as a set of single fuel assemblies or groups of assemblies according to their power. Selected transients were simulated and the results are in good correlation with earlier analyses. The model in RELAP5 is included as part of a project on improved modelling with ANL. The model fuel assemblies in the CATHARE2 code are finished and are further developed to include cooling circuits.
2. The task related to participation in the NURESAFE FP7 project was finished. Verification of existing models of nuclear fuel dry-out phenomena was performed. A new model that predicts parameters much better has been developed and introduced into the CATHARE-3 code.
3. In the area of severe accident phenomena modelling studies and development were undertaken, specifically studies of corium pool formation in the lower plenum of reactor vessel, heat transfer in the metallic layer of the corium pool, uncertainty studies of phenomena and models and cooling of the reactor vessel wall. Participation in the EU Horizon 2020 project In-Vessel Melt Retention (IVMR) was initiated.
4. Implementation of computational tools (codes) on the computer cluster and development of user interfaces and tools that improve the application workspace. This concerns:
    a. Development of software for carrying out calculations using the code RELAP5 with graphical presentation of the results on-line and the ability to simulate operator actions,
    b. A new program for determining changes in the concentration of radionuclides in fuel,
    c. Development of computing platform for the HPC environment "Notebook ZAR",
    d. Continuation of development of database, workspace and user interface for the REBUS code model of the MARIA reactor, to improve the capability of the reactor staff in planning future fuel cycles.
5. Organization of the TC Project RER9129 “Regional Workshop (Forum) on Core Metldown Calculations and Related Software”, 02 – 06 November 2015.

In the field of the fuel cycle the following tasks were continued:

1. The involvement in an International Research Project “E+T RAW” was continued. The project is carried out at JINR Dubna Russia (Cooperation protocol 4382-1-14/16). Its aim is an investigation of nuclear waste utilization with spallation neutrons produced in a natural uranium assembly QUINTA during irradiation with a high energy accelerator beam. A series of experiments was carried out in 2012, 2013 and 2014. Y-89 sample activation method was used for neutron field parameter determination and the actinides Np-237 and Am-241 for fission and neutron capture rate determination. Analyses of results were performed.
2. Modelling of helium atom migration in uranium dioxide fuel during neutron irradiation and during annealing has been continued.
3. Studies of molten salts reactors - modelling extractor

The work of the **Centre for Hazard Analyses MANHAZ** (the previous Probabilistic Safety Analysis Team) was concentrated mainly on the analysis of environmental issues and risk analyses.
The most important activities were:

1. Development of computing tools for the safety analysis and exploitation of the MARIA research reactor:
    - High fidelity thermo-hydraulic analyses using CFD codes for the planned BNCT (boron-neutron capture therapy) converter: determination of critical values and safety margins dependence on operational pressure, heat flux and geometry.
2. Development of computing tools for the safety analysis and optimization of the exploitation of light water reactors:
    - Preparatory work on the international experiment “CFD prediction and Uncertainty Quantification of a GEMIX mixing layer test”: calibration of the models.
    - Development of a methodology for performing probabilistic calculations for accidents caused by human error, including uncertainties.
    - Development of a methodology for including rare external hazards (natural and man-made) in probabilistic safety assessments. Participation in the EU ASAMPSA_E project (Advanced Safety Assessment : Extended PSA ").

3. Analyses of IV generation nuclear reactors:
    - Analyses of cooling for HTR of pebble bed type using CFD techniques for various turbulence models, meshes and different treatment of boundary-wall layer.
    - Development of a multi-physics model for integration of thermal and mechanical phenomena.
    - Development of a methodology for probabilistic safety analysis for HTR.
4. High fidelity models for energetic reactors suited for high performance computing.
    - Analysis of oscillations of the flux around fuel rods (the Hooper case), possibly leading to vibration, by means of CFD techniques.
5. Development of tools for the analysis of the impact of nuclear installations on the environment
    - Implementation of countermeasure modules of the RODOS (Real-time On-line DeciOn Support) system for urban areas and agriculture.
    - Preparatory work on the implementation of the hydrological path for transport and dispersion of radionuclides for the RODOS system.
    - Development of models, algorithms and programs for identification of source term parameters in case of the release of dangerous material to the atmosphere using information from environmental monitoring stations based on a Bayesian approach.

Mariusz Dąbrowski and Tomasz Jackowski

REPORTS

Needs of R&D in support of the safety demonstrations - delivarable D3.32 (NC2I-R)
Ł. Koszuk, C. Pohl, O. Baudrand
Narodowe Centrum Badań Jądrowych

Production of neutrons in heavy spallation targets by electrons of energy from 200 to 1000 MeV and realativistic protons
A. Polański, **B. Słowiński**, **T. Jackowski**, A. Pacan
NCBJ, Świerk Annual Report 2014, p.186

Requirements for the demonstrator program of a co-generation system - deliverable D3.31 (NC2I-R)
A. Strupczewski, **Ł. Koszuk**
Narodowe Centrum Badań Jądrowych

Technical Report: Maria Research Reactor Model in RELAP5 code
M. Skrzypek, **E. Skrzypek**
NCBJ

Introductory measurements of particulate matter concentration in ambient air in the vicinity of a potential location of a nuclear power plant (Krokowa commune)
M. Bogusz, **J. Bzdak**, **M. Lasiewicz**, **B. Mysłek-Laurikainen**, **M. Sowiński**, **H. Trzaskowska**
Narodowe Centrum Badań Jądrowych

PARTICIPATION IN CONFERENCES AND WORKSHOPS

<u>Invited Talk</u>

Gas Cooled Reactor Technology: Current status and R&D needs
<u>**A. Przybyszewska**</u>, **T. Jackowski**, **K. Różycki**
AER Working Group F Meeting (Slovakia, Modra, 2015-05-04 - 2015-05-06)

Energy in Poland
<u>**T. Jackowski**</u>, **T. Machtyl**, **A. Przybyszewska**, **K. Różycki**, **K. Samul**, **A. Strupczewski**
OECD NEA meeting (France, Paris, 2015-06-29 - 2015-07-02)

Wpływ technologii reaktorów chłodzonych gazem na zrównoważony rozwój energetyki jądrowej w Europie
<u>**A. Przybyszewska**</u>, **K. Różycki**
Energia i Paliwa (Poland, Kraków, 2015-06-09 - 2015-06-11)
AGH, Kraków No. (2016)

Contribution of Nuclear Energy to EU Energy Mix
<u>**T. Jackowski**</u>, **A. Przybyszewska**, **T. Machtyl**, **K. Samul**, **M. Spirzewski**
Nuclear Power Plant Life Management and Extension 2015 (France, Paris, 2015-10-04 - 2015-10-05)

Modern Approach to Security of Software for Nuclear Facility in Świerk Computing Centre
<u>**K. Gomulski**</u>, **S. Potempski**, **K. Klimaszewski**, **P. Szwajkowski**
The International Conference on Computer Security in a Nuclear World: Expert Discussion and Exchange (Austria, , 2015-06-01 - 2015-06-05)

Perspectives on Polish Involvement in Development of Nuclear Cogeneration: HTR-PL and NC2I
<u>**A. Przybyszewska**</u>
Technical Meeting on the Economic Analysis of High Temperature Gas Cooled Reactors and Small and Medium Sized Reactors, IAEA (Austria, Wiedeń, 2015-08-25 - 2015-08-28)

Centrum obliczeń reaktorowych i analiz bezpieczeństwa NCBJ
T. Jackowski, **T. Machtyl**, **K. Samul**, **M. Spirzewski**
Analizy bezpieczeństwa elektrowni jądrowych z reaktorami BWR (Poland, Szczyrk, 2015-02-17 - 2015-02-18)

Hypothetical modeling of helium atom migration in the uranium dioxide fuel during neutron irradiation and during annealing.
M. Szuta, **L. Dąbrowski**
Fifth Meeting of the Expert Group on Reactor Fuel Performance (EGRFP) of Working Party on Scientific Issues of Reactor Systems (WPRS); 17 February 2015; NEA Headquarters, France.) (France, Paryż, 2015-02-17 - 2015-02-19)

The need of development Gas Cooled Reactor Technology in Europe
A. Przybyszewska, **K. Różycki**
24th International Conference Nuclear Energy for New Europe-NENE2015 (Slovenia, Portoroz, 2015-09-14 - 2015-09-17)

Modelling of helium release from the highly burned fuel during annealing and impact on its migration in the uranium dioxide fuel during neutron irradiation.
M. Szuta, **L. Dąbrowski**
11th International Conference on WWER Fuel Performace , Modelling and Experimental support, (Bulgaria, Varna, 2015-09-26 - 2015-10-03)

Process heat application of GFR high temperature coolant
A. Przybyszewska
ALLEGRO Workshop and 21st GIF GFR System Meeting (Hungary, Budapest, 2015-10-14 - 2015-10-15)

Using heat from the Maria Reactor as a heat source for heat pump
A. Przybyszewska
Application of Advanced Low Temperature Desalination Systems to Support Nuclear Power Plants and Non-electric Applications, IAEA (Austria, Wiedeń, 2015-12-01 - 2015-12-03)

Use of CATHARE at NCBJ
T. Machtyl, **M. Spirzewski**
26th CATHARE Users Club (France, Paris, 2015-10-05 - 2015-10-07)

In Vessel Corium Propagation Sensitivity Study Of Reactor Pressure Vessel Rupture Time With PROCOR Platform.
M. Skrzypek, **E. Skrzypek**
24th International Conference Nuclear Energy for New Europe-NENE2015 (Slovenia, Portoroz, 2015-09-14 - 2015-09-17)
NENE2015 24rd International Conference Nuclear Energy for New Europe No. (2015)

Dynamiczne stałe fizyki i koncepcja Multiwszechświata
M.P. Dąbrowski
43 Zjazd Fizyków Polskich (Poland, Kielce, 2015-09-07 - 2015-09-11)

Feasibility study of minor actinide application as a neutron fluency and average neutron energy detector in the place of their location.
M. Szuta, **S. Kilim**, **E. Strugalska-Gola**, **M. Bielewicz**, S. Tiutiunnikov
Fifth Meeting of the Expert Group on Reactor Physics and Advanced Nuclear System (EGRPANS) of Working Party on Scientific Issues of Reactor Systems (WPRS); 21 February 2015; NEA Headquarters, Paris, France (France, Paryż, 2015-02-17 - 2015-02-20)

The In Vessel Melt Retention Strategy for the high power Pressurized Water Reactors – selected issues and modelling.
E. Skrzypek, **M. Skrzypek**
XII Konferencja Problemy badawcze energetyki cieplnej (Poland, Warszawa, 2015-12-08 - 2015-12-11)

Simulations of Large Break Loss of Coolant Accident without Safety Injection for EPR Reactor using MELCOR Computer Code
P. Darnowski, **E. Skrzypek**, P. Mazgaj, M. Gatkowski
ERMSAR 2015 (France, Marsylia, 2015-03-24 - 2015-03-26)
ERMSAR2015 No. (2016)

Renesans energetyki jądrowej na świecie
Ł. Koszuk
VIIIth International School on Nuclear Power (Poland, Warszawa, 2015-10-26 - 2015-10-30)

Współpraca naukowa Polski i Francji na przykładzie NCBJ, Zakładu Energetyki Jądrowej i Analiz Środowiska
E. Skrzypek
Mądralin-2015 (Poland, Warszawa, 2015-11-24 - 2015-11-25)

Allegro and HTR Reactors
T. Jackowski, **A. Przybyszewska**, **E. Skrzypek**
ARCADIA Seminar "SELECTED ASPECTS OF IMPLEMENTATION OF GENIII/IV IN NMS (Poland, Warszawa, 2015-10-01 - 2015-12-01)

HTGR as a source of process heat for the European and U.S. industry
T. Jackowski, **T. Machtyl**, **A. Przybyszewska**, **K. Różycki**, M. Gradecka, C. Auriault, A. Kiss
Technical Meeting on Advances in Non-Electric of Nuclear Energy and on Efficiency Improvement at Nuclear Power Plants (Turkey, Istanbul, 2015-06-15 - 2015-06-17)

Oral Presentation

Development and experimental qualification of a calculation scheme for the evaluation of gamma heating in experimental reactors. Application to MARIA and Jules Horowitz (JHR) MTR Reactors
M. Tarchalski, **K. Pytel**, P. Siréta, A. Lyoussi, C. Reynard-Carette, **J. Jagielski**, **M. Wróblewska**, D. Fourmentel, L. Barbot, J. Brun, **Z. Marcinkowska**, C. Gonnier, G. Bignan, J.F. Villard, C. Destouches, **A. Boettcher**, **R. Prokopowicz**, A. Luks
Advancements in Nuclear InstrumentationMeasurement Methods and their Applications (Portugal, Lizbona, 2015-04-20 - 2015-04-24)

Application of QUIC and EULAG to UDINEE
P. Kopka, **M. Korycki**, **S. Potempski**
Urban Dispersion International Evaluation Exercise Workshop (Italy, Ispra, 2015-12-14 - 2015-12-15)

Evolution of spatial heterogeneity in reactive flow in mineral-cemented fractures
T. Kwiatkowski, K. Kwiatkowski, P. Szymczak
7th International Conference on Porous Media & Annual Meeting (Italy, Padova, 2015-05-18 - 2015-05-21)

Loss of offsite power caused by tornado in Surry NPP – a case study
A. Kaszko, **K. Kowal**
48th ESReDA Seminar on Critical Infrastructures Preparedness:Status of Data for Resilience Modelling, Simulation and Analysis (MS&A) (Poland, Wroclaw, 2015-05-28 - 2015-05-29)

Calibration of High Fidelity Bare Rod Bundle Simulations for Various Prandtl Fluids
T. CardosodeSouza, **T. Kwiatkowski**, A. Shams, F. Roelofs
16th International Topical Meeting on Nuclear Reactor Thermalhydraulics (USA, Chicago, 2015-08-30 - 2015-12-04)

Time-dependent PSA model for emergency power system of nuclear power plant
M. Borysiewicz, **A. Kaszko**, **K. Kowal**, **S. Potempski**
25th European Safety and Reliability Conference, ESREL 2015 (Switzerland, Zürich, 2015-09-07 - 2015-09-10)

The formation and growth of wormholes in mineral-cemented fractures
T. Kwiatkowski, K. Kwiatkowski, P. Szymczak
European Geosciences Union General Assembly 2015 (Austria, Vienna, 2015-04-12 - 2015-04-17)

Probabilistic Safety Assessment (PSA) – methodology and applications
K. Kowal, **A. Kaszko**
Safety analysis of BWR type nuclear power reactors (Poland, Szczyrk, 2015-02-17 - 2015-02-18)

Update on Time-Domain F-statistic all-sky MDC studies(Stage3)
O. Dorosh, **A. Królak**, M. Bejger
LSC-Virgo March 2015 Meeting (USA, Pasadena, 2015-03-16 - 2015-03-19)

Results of the Time Domain F-statistic all-skyMDC search
O. Dorosh, **A. Królak**, M. Bejger, M. Piętk
LSC-Virgo 2015 Collaboration Meeting (Hungary, Budapest, 2015-08-31 - 2015-09-03)

New tests of the variability of the speed of light
M.P. Dąbrowski, V. Salzano, A. Balcerzak, R. Lazkoz
4th International Conference on New Frontiers in Physics ICFNP2015 (Greece, Kolymbari, 2015-08-23 - 2015-08-31)
Eur. Phys. J. C (2016)

Experimental study of the physical properties of ADS systems - measurement of high energy neutron fields by using the Y-89 threshold detectors
M. Bielewicz, **E. Strugalska-Gola**, **S. Kilim**, **M. Szuta**
24th International Conference Nuclear Energy for New Europe-NENE2015 (Slovenia, Portoroz, 2015-09-14 - 2015-09-17)
Nuclear Society of Slovenia (2015)

Charakterystyki procesu recyklingu wypalonego paliwa jądrowego w reaktorach na neutronach prędkich
S. Chwaszczewski, **A. Boettcher**, M. Syta
MADRALIN- 2015 Wybrane aspekty bezpieczeństwa jądrowego w Polsce (Poland, Warszawa, 2015-11-24 - 2015-11-25)

Implementation of radioecological regions in Poland
H. Wojciechowicz, **S. Potempski**, R. Dąbrowski, A. Jaroszek
RODOS User Group Meeting 2015 (Germany, Niedersachsen, 2015-04-22 - 2015-04-23)

Gospodarka wypalonym paliwem jądrowym. Analiza opcji dla Polskiego Programu Energetyki Jądrowej.
S. Chwaszczewski, **A. Boettcher**
Badania materiałowe na potrzeby elektrowni konwencjonalnych i jądrowych oraz przemysłu energetycznego (Poland, Zakopane, 2015-06-17 - 2015-06-19)
LBM NCBJ, Otwock-Świerk No.XXII (2015) p. 57-93

The needs for improvement of atmospheric dispersion capabilities for decision support systems
S. Potempski, S. Galmarini
NERIS Workshop 2015 (Italy, Milano, 2015-04-27 - 2015-04-29)

Koszulki paliwa jądrowego odporne na awarie.
A. Boettcher
Badania materiałowe na potrzeby elektrowni konwencjonalnych i jądrowych oraz przemysłu energetycznego (Poland, Zakopane, 2015-06-17 - 2015-06-19)
LBM NCBJ, Otwock-Świerk No.XXII (2015) p. 103-115

Methodology for Estimating Extreme Weather Events for the Safety of NPPs
S. Potempski
IAEA Technical Meeting on Probabilistic Safety Assessment Framework for External Events (Austria, Wiedeń, 2015-08-03 - 2015-08-06)

Dynamic modeling of MSR and its reprocessing unit – progress report

S. Kilim
20th meeting of the AER Working Group E (Hungary, Paks, 2015-05-28 - 2015-05-29)

Poster

Mathematical aspects of assessing extreme events for the safety of nuclear plants
M. Borysiewicz, **S. Potempski**
European Geoscience Union Conference 2015 (Austria, Wiedeń, 2015-04-12 - 2015-04-17)

Hypothetical model of helium migration in the UO2 fuel during irradiation
M. Szuta, **L. Dąbrowski**
MADRALIN- 2015 Wybrane aspekty bezpieczeństwa jądrowego w Polsce (Poland, Warszawa, 2015-11-24 - 2015-11-25)

Safety Aspects of High Temperature Gas Cooled Reactors
A. Przybyszewska, **C. Kowalczyk**
2nd ARCHER EUROCOURSE (Netherlands, Petten, 2015-01-19 - 2015-01-21)

Dyfuzyjny model do obliczeń neutronowo – fizycznych reaktora HTR-10
K. Andrzejewski, **A. Bujas**
MADRALIN- 2015 Wybrane aspekty bezpieczeństwa jądrowego w Polsce (Poland, Warszawa, 2015-11-24 - 2015-11-25)

The neutronic calculations for safety analysis of high-temperature reactors with pebble bed core on the example of HTR-10
Ł. Koszuk, **M. Klisińska**
European Nuclear Young Generation Forum 2015 (France, Paris, 2015-06-22 - 2015-06-26)

The safety analysis of HTR-10 reactor with pebble bed core using KENO-VI/SCALE code
Ł. Koszuk, **M. Klisińska**
MADRALIN- 2015 Wybrane aspekty bezpieczeństwa jądrowego w Polsce (Poland, Warszawa, 2015-11-24 - 2015-11-25)

Actinides incineration investigation on Np-237 example
S. Kilim, **E. Strugalska-Gola**, **M. Szuta**, **M. Bielewicz**
Mądralin-2015 (Poland, Warszawa, 2015-11-24 - 2015-11-25)

LECTURES, COURSES AND EXTERNAL SEMINARS

Modelling of the metallic layer thermal-hydraulics in the PWR reactor under severe accident conditions.[a]
E. Skrzypek
Otwock-Świerk, National Center for Nuclear Research, 2015-01-21

RODOS - Real-time On-line Decision Support System for nuclear emergencies[a]
S. Potempski
Warsaw, Main School of Fire Service, 2015-02-19

Simplified thermo-mechanical modelling of the core support plate in a PWR under severe accident conditions[a]
M. Skrzypek
Warsaw, Politechnika Warszawska, 2015-05-13

A numerical study of stably stratified atmospheric flow around a tall building of a complex shape[b]
M. Korycki
Warsaw, University of Warsaw, 2015-05-29

Why do we need nuclear power in Poland?[a]
Ł. Koszuk
Zakopanie, National Centre for Nuclear Research, 2015-06-17

The efficient use of Trio_U code at NCBJ[b]
P. Prusiński
Saclay, CEA - French Atomic Energy Commission, 2015-01-28

Management of Spent Nuclear Fuel- options for nuclear power programme in Poland [b]
S. Chwaszczewski, A. Boettcher
Slovakia, Modra, VUJE, 2015-05-06

JRODOS as an example for a model decision support system for nuclear emergencies[b]
S. Potempski
Warsaw, Main School of Fire Service, 2015-05-12

Source term reconstruction through inverse modelling[b]
P. Kopka
Munich, The Federal Office for Radiation Protection (BfS) , 2015-05-15

Simulation of 6-inch break LOCA accidentin EPR using RELAP5 and CATHARE[b]
K. Samul
Prague, Code Applications and Maintenance Program - NRC, 2015-05-26

Simulation of 6-inch break LOCA accidentin EPR using RELAP5 and CATHARE[b]
M. Skrzypek
Prague, Nuclear Regulation Support Section (TSO), Research Centre Rez, 2015-05-26

Implementation of entrainment and deposition models by Okawa into CATHARE-3 system code.[b]
M. Spirzewski
Lappenranta, Lappeenranta University of Technology, 2015-06-11

Regional Workshop on the Use of Core Meltdown Calculating Software and Related Practical Matters[a]
J. Malesa
Otwock-Świerk, International Atomic Energy Agency, National Centre for Nuclear Research, 2015-11-02

Cathare3 entrainment and deposition models analysis.[b]
M. Spirzewski
Bruksela, NURESAFE Workgroup meeting, 2015-11-02

Management of Spent Nuclear Fuel- OPTIONS FOR NUCLEAR POWER PROGRAMME IN POLAND[b]
S. Chwaszczewski, A. Boettcher:
Modra- Harmónia, Slovakia, VUJE, 2015-05-06

Spent Nuclear Fuel Management. Analysis for Polish Nuclear Power Prigramme[a]
S. Chwaszczewski
Warsaw, National Nuclear Agency, 2015-02-13

Spent nuclear fuel management. Options analysis for Polish Nuclear Programme[a]
S. Chwaszczewski
Świerk, National Center for Nuclear Research, 2015-04-30

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

INTERNAL SEMINARS

Simplified thermo-mechanical modelling of the core support plate in a PWR under severe accident conditions[a]
M. Skrzypek
Otwock, Swierk, National Centre for Nuclear Research, 2015-01-21

Deterministic Safety Analyses, Safety Assessment, Severe Accidents[b]
T. Machtyl
Świerk, National Centre for Nuclear Research, 2015-02-24

Deterministic Safety Analyses, Safety assessment, Severe accidents[b]
K. Samul
Świerk, National Center for Nuclear Research, 2015-02-24

Turbulence modelling in two-phase flows using FLUENT CFD code.[a]
M. Spirzewski
Warszawa, Instytut Techniki Cieplnej, 2015-03-25

Assessing extreme natural events for the safety of nuclear power plants with the use of PSA[a]
T. Kwiatkowski
Warsaw, Institute of Theoretical Physics, Faculty of Physics, UW, 2015-04-29

Numerical simulation of flow structures around tall buildings in stable stratification.[a]
M. Korycki
Jablonna, Warsaw University of Technology, 2015-05-15

Modelling of the phase change process for the metallic layer on the top of the corium pool for the PWR reactor under severe accident conditions.[a]
E. Skrzypek
Warszawa, Warsaw University of Technology, 2015-05-20

Changes in seal capacity of fractured claystone caprocks induced by dissolved and gaseous CO_2 seepage[a]
T. Kwiatkowski
Warsaw, Institute of Theoretical Physics, Faculty of Physics, UW, 2015-06-03

Application of emission data from SMOKE preprocessor in air quality forecast by WRF model[a]
M. Korycki
Wroclaw, Wroclaw University, 2015-07-03

ALLEGRO projects[b]
A. Przybyszewska
Otwock, NCBJ, 2015-09-23

Weather forecast for emergency response[a]
M. Korycki
Warsaw, Polish Atomic Agency, 2015-11-09

DARIA - deterministic analyses of MARIA reactor[a]
T. Machtyl
Świerk, National Centre for Nuclear Research, 2015-11-10

Roadmap ALLEGRO[a]
A. Przybyszewska
Otwock, NCBJ, 2015-11-17

Only in Polisch[a]
M. Bielewicz
Otwock - Świerk, National centre for Nuclear Research, 2015-11-23

Environmental studies in the localization of future nuclear power plant - the current status[a]
S. Potempski
Otwock-Swierk, National Centre for Nuclear Research, 2015-11-30

Conclusions from Next Generation Nuclear Plant Program in Idaho National Engineering and Environmental Laboratory[a]
K. Andrzejewski
Świerk, National Centre for Nuclear Research, 2015-12-07

Preparation of data and examples of modeling using SMOKE package[a]
H. Wojciechowicz
Wroclaw, University of Wroclaw, 2015-07-01

When can we build a nuclear power plant in Poland?[a]
K. Różycki
Świerk, National Centre for Nuclear Research, 2015-09-24

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

DIDACTIC ACTIVITY

K. Andrzejewski - 3-month internship of two students from Warsaw Polytechnical Institute, Faculty of Mechanics, Electrotechnics and Aeronautics:
Dominik Rauchut,
Dominik Muszyński

P. Kopka - 2015-02-01 2015-06-30 lab "Probabilistic reliability methods and safety for complex technological systems", specialization - supercomputers and simulations, Faculty of Physics and Applied Informatics, University of Lodz.

Ł. Koszuk - Training with MARIA reactor simulator for students of Warsaw University of Technology

K. Kowal - Basic physics laboratory courses with carrying out of selected experiments in different branches of physics (mechanics, magnetism, optics, radiation) for students of Bachelor's degree program (1st cycle mode) in electrical engineering at Faculty of Electrical Engineering and Computer Science.

K. Kowal - Lectures on probabilistic methods for safety and reliability assessment of complex technological systems for students of the Master's degree programme (2nd cycle mode) in computer science (majoring in supercomputers and simulations) at the Faculty of Physics and Applied Informatics.

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.

T. Machtyl - Introductory course for Python programming language with web application - iWebApps

S. Potempski - Fundamentals of risk analysis and management for transportation accidents, Lodz University of Technology

S. Potempski - High Performance Computing,
Lodz University, Faculty of Physics and Applied Informatics

S. Potempski - Implementation of emmission model SMOKE and air quality model WRF in voievodship dolnoslaskie

S. Potempski - Industrial facilities for the protection and mitigation of consequences of industrial accidents, Main School for Fire Service

S. Potempski - Numerical methods suitable for HPC, Lodz University, Faculty of Physics and Applied Informatics

P. Prusiński - Internship students supervision

G. Siess - The certified Risk Management Manager - Module 3 "Methodology and technique of the risk analysis"

B. Słowiński - Development of electromagnetic cascades in segmented amorphous media

B. Słowiński - Global development of energetics - one semester lectures (30h) for M.Sc. students. Faculty of production technology, Warsaw University of Life Science.

B. Słowiński - Ph.D. student J.Bzdak, Physics Faculty, Warsaw University of Technology. Subject: Space-time dynamics of air pollution

B. Słowiński - Physics background of nuclear power - one semester lectures (30h) for underground and Ph.D. students of Facylty of Physics, Warsaw University of Technology

B. Słowiński - Physics phenomena in spallation targets of reactor systems driven by electrons and protons beams

B. Słowiński - Radiation modification of materials - one semester lectures (30h) for M.Sc. students of Faculty of Physics, Warsaw University of Technology

B. Słowiński - The use of high-themperature heat in industry and economy. University of Live Science, Warsaw

M. Spirzewski - Introductory course for Python programming language with web application - iWebApps

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

K. Andrzejewski
Nukleonika, Institute of Nuclear Chemistry and Technology

M. Bielewicz
Polish Astronomical Society

M. Borysiewicz
Member of the European Safety, Reliability and Data Association (ESReDA)

M.P. Dąbrowski
Session chairman on VIII Międzynarodowa Szkoła Energetyki Jądrowej W Warszawie, Świerku i Różanie. in Warsaw, Poland
Session chairman on Mądralin-2015 in Warszawa, Poland
Member of Organizing Committee on COSMO-15: 19th annual International Conference on Particle Physics and Cosmology in Warsaw, Poland
Polish Physical Society

Ł. Koszuk
Member of Organizing Committee on VIIIth International School on Nuclear Power in Warszawa, Poland
ATOMIC FORUM Foundation, President
Polish Nuclear Society, member
Forum Atomowe, Atomic Forum, ATOMIC FORUM Foundation

S. Potempski
Member: specialist in numerical analysis and informatics

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
Faculty Council, Physics Faculty, Warsaw University of Technology

E. Strugalska-Gola
member,Association of Polish Electricians, Committee of Nuclear Power

S. Chwaszczewski
Member of Polish Commitee
Polish Nuclear Society
Member in Polish Commitee of World Energy Council

T. Jackowski
Polish Nuclear Society
Steering Commitee member of IAEA TSO Forum
SNETP Executive Committee

D. Mączka
a member of the Polish Physical Society
Lublin Society of Science, a mumber
a member of the Faculty of Math.Inf.Phys., MCS University, Lublin

B. Mysłek-Laurikainen
Member, Polish Physical Society
Polish Nuclear Society
Member of Polish Nucleonic Society
Member of Women in Nuclear Poland
National Centre for Nuclear Research
Member of Scientific Counsil of NCBJ

K. Różycki
Polish Committee for Standardization, Chairman of Technical Committee No. 266 (Nuclear Instrumentation)

M. Szuta
OECD/NEA

PERSONNEL

Research scientists

Krzysztof	Andrzejewski, PhD
Rafał	Baranowski, MSc Eng
Marcin	Bielewicz, PhD
Agnieszka	Boettcher, MSc
Małgorzata	Bogusz, MSc Eng
Mieczysław	Borysiewicz, PhD
Adrian	Bujas, MSc Eng
Agnieszka	Burakowska, PhD
Jacek	Bzdak, MSc Eng
Mariusz	Dąbrowski, Professor
Orest	Dorosh, PhD
Krzysztof	Gomulski, MSc Eng
Tomasz	Jackowski, MSc Eng
Henryk	Jędrzejec, PhD
Aleksej	Kaszko, MSc Eng
Małgorzata	Klisińska, MSc
Piotr	Kopka, MSc
Michał	Korycki, MSc
Łukasz	Koszuk, MSc
Karol	Kowal, MSc Eng
Tomasz	Kwiatkowski, MSc Eng
Mariusz	Łuszcz, MSc Eng
Tomasz	Machtyl, MSc
Janusz	Malesa, MSc Eng
Dariusz	Mączka, Professor
Magdalena	Mądry, MSc
Ewelina	Miśta, MSc
Rafał	Możdżonek, MSc Eng
Bogumiła	Mysłek-Laurikainen, PhD
Sławomir	Potempski, PhD
Piotr	Prusiński, MSc Eng
Anna	Przybyszewska, MSc Eng
Kajetan	Różycki, MSc Eng
Kacper	Samul, 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
Jan	Szczurek, DSc Eng
Marcin	Szuta, PhD Eng. Assoc. Prof.
Anna	Wawrzyńczak-Szaban, PhD
Henryk	Wojciechowicz, MSc
Andrzej	Wojciechowski, PhD
Małgorzata	Wróblewska, MSc Eng
Dariusz	Zgorzelski, Eng

Technical and administrative Staff

Jolanta Przyłuska
Anna Wasiuk

EDUCATION AND TRAINING DIVISION

Head of Division: Professor Ludwik Dobrzyński
phone: +48 22 2731570
e-mail: Ludwik.Dobrzynski@ncbj.gov.pl

Overview

The Department of Education and Training leads a number of activities. A summary of its work and achievements in 2015 may be presented as follows:

- Close to 5300 visitors from high schools, universities (from Gdańsk and Warsaw), and industrial and scientific institutions from many towns and villages were served by the Department. The ages of our visitors ranged from about 12 to 85 years. Special courses were organised for firemen and residents of areas near the Baltic coast (Gniewino, Choczewo), possible sites for the construction of a nuclear power plant.
- Two Open Days were organized on 30^{th} and 31^{st} of May as one of a few event connected with 60th anniversary of the Institute of Nuclear Research - predecessor of NCBJ. The events took place during a week-end and gathered over 3000 visitors who had the chance to tour various laboratories on the Świerk site including, naturally, the MARIA reactor. In addition, special games and activities were organised for children. It became apparent that such events should be organised more frequently.
- From the scientific point of view, special attention should be drawn to an international project led by Japan, France, Belarus and Poland. The Project aim was to measure the natural radiation in the participating countries and see how much the radiation levels around Fukushima differed from those observed in other countries. In Poland 8 schools participated. The students had to carry out careful measurements during two weeks and note where they were during the day, almost every hour. As a result, a common scientific paper was published in the Journal of Radiological Protection. The paper showed that the differences between the countries are rather small – a result of great importance, especially for the Japanese students.
- As usual, the Department was very active during the Science Picnic and the Science Festival, both held in Warsaw. During the period of the Science Festival (22-24 September) about 200 people visited the MARIA reactor at Świerk.
- Organisation of the competition “The Paths of Physics” was continued. This was the 10^{th} edition of this competition.
- L. Dobrzyński served as an expert in the preparation of the IAEA report on the Fukushima event.

Ludwik Dobrzyński

PERSONNEL

Ludwik Dobrzyński Professor
Ewa Droste, MSc (2/5)
Łukasz Adamowski, MSc Eng
Marek Matych
Robert Wołkiewicz (2/5 from 01.09.2013)
Grażyna Swiboda, MSc
Anna Rędaszek, MSc
Gabryela Kosicka
Marek Kirejczyk, PhD
Maja Marcinkowska-Sanner, MSc
Marcin Sadowski, MSc
Marcin Sierpiński, MSc (4/5)
Władysław Szymczyk, PhD (3/5)
Krzysztof Masłowski, MSc
Katarzyna Deja, MSc
Artur Skwarek, MSc

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Ryzyko nowotworowe związane z niewielkimi dawkami promieniowania jonizującego
L. Dobrzyński
I. Międzynarodowa Konferencja Nuklearna (Poland, Poznań, 2015-12-07 - 2015-12-08)

Story of Nuclear Physics
M. Kirejczyk
Letnia Szkoła „Fizyka Jądrowa – Nauka i Zastosowania (Poland, Poznań, 2015-06-24 - 2015-07-04)

Poster

Partons energy loss in an ustable QGP
K. Deja, **S. Mrówczyński**, M. Carrington
Hard Probes 2015 (Canada, Montreal, 2015-06-29 - 2015-07-03)

LECTURES, COURSES AND EXTERNAL SEMINARS

On health problems due to radioactivity of food[b]
L. Dobrzyński
Tokyo, University of Tokyo, 2015-02-04

How to survive the presentation?[a]
M.P. Sadowski
Wrocław, Wyższa Szkoła Oficerska Wojsk Lądowych im. Tadeusza Kościuszki, 2015-02-22

How to survive a multimedia presentation?[a]
M.P. Sadowski
Warszawa, Uniwersytet Warszawski, 2015-03-09

The energy around us[a]
M.P. Sadowski
Świerk, Narodowe Centrum Badań Jądrowych, 2015-03-17

a) in Polish
b) in English

INTERNAL SEMINARS

Low doses and health effects[b]
L. Dobrzyński
Chiba, Japan, National Institute for Radiological Sciences, 2015-02-05

Highlights from the travel to Fukushima and Chiba in Japan[a]
L. Dobrzyński
Swierk, National centre for Nuclear Research, 2015-02-19

a) in Polish
b) in English

DIDACTIC ACTIVITY

Ł. Adamowski - Lectures for visitors in NCBJ Education and Training Division.

Ł. Adamowski - Preparing and conducting practical laboratory exercises for School of Nuclear Energy.

K. Deja - Teaching classes and laboratory for groups of middle school and high school students.

E. Droste - Popular lectures and demonstration of experiments concerning various aspects of atomic and nuclear physics organized for visitors of National Centre for Nuclear Research.

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 - Lecture "Biological efects of ionising radiation" for the students of Wrocław Technical University

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. Marcinkowska-Sanner - Laboratory classes for high school students.

M. Marcinkowska-Sanner - Lectures for visitors in National Centre for Nuclear Reasearch (Department of Education and Trainings).

M.P. Sadowski - Lectures and workshops for students, young people and other visitors to the Department of Education and Training

A. Skwarek - Conducting practical laboratory exercises for International School on Nuclear Power

A. Skwarek - Lectures for NCBJ visitors.

R. Wołkiewicz - Teaching in NCBJ

PARTICIPATION IN SCIENTIFIC COUNCILS, ASSOCIATIONS AND ORGANIZING COMMITTEES

L. Dobrzyński
Adviser of the Polish Delegation to UNSCEAR, alternate of the delegate of Polish delegation since 2011
Polish Atomic Agency, member of the Advisory Board, Chairman of the Commission of Social Education and Information
National centre for Nuclear Research

M.P. Sadowski
Polish Physical Society
National Club of Physics Demonstrators

VIIIth International School on Nuclear Power

A. Strupczewski, Ł. Koszuk, E. Szlichcińska
National Centre for Nuclear Research, Otwock-Swierk, Poland

The eighth edition of the International School on Nuclear Power took place in Warsaw and Swierk in from 26-30 October 2015.A team of eminent experts from 12 countries, each highly regarded in his field of expertise, presented lectures on subjects of most interest for further development of nuclear power, and there were 200 participants from various regions and organizations in Poland.

Lecture Hall in the Novotel Warszawa Airport hotel

As in previous years, the School was organized by the National Centre for Nuclear Research (NCBJ) in cooperation with the Radioactive Waste Management Plant (ZUOP) and the Department of Nuclear Energy in the Ministry of Economics. The main investor of nuclear power plants in Poland, PGE EJ1 was the leading partner and provided strong support for the School.On the lecture days of the School lecturers from 3 continents presented 24 lectures. This was possible owing to the support provided by organizations active in the field of nuclear power. Besides the above mentioned Ministry of Economics and PGE EJ1, the list of sponsors of the School included the following organizations, shown below in alphabetical order: AMEC, AREVA, China General Nuclear Power, EDF, General Electric Hitachi, KGHM, Westinghouse.

The work in the School lasted for five days. On the first day the team of Prof. Dobrzynski from NCBJ conducted a “Preschool of Nuclear Power” with three lectures about ionizing radiation and its biological effects and several hands-on experiments in which the participants were divided into small groups and could individually perform experiments with radiation. They studied the radioactive decay of the radon/thorium series, characteristics of Geiger Mueller detectors, the relationship of radiation intensity to distance from the source, the effectiveness of radiation shielding and a simulator of reactor core operation. The lectures and exercises met with high appreciation from the participants, which is no wonder, as prof. Dobrzynski is a permanent member of UNSCEAR and for many decades has been conducting radiation studies at NCBJ.

On the second and fifth days of the School (October 27 and 30) workshops were held in Świerk – at NCBJ and ZUOP and in the National radioactive waste repository in Różan. The participants visited the MARIA reactor and learned about its applications in industry and medicine, visited a new generation plasma gun, visited the Laboratory of Health Physics and the Department of radioactive waste management. They made a number of practical exercises, including whole body counter and external radiation monitoring. In parallel the workshops were held in the National Radioactive Waste Repository in Różan, about 90 km away from Warsaw. The organizers provided special bus transportation to the repository, and provided guidance and leadership of exercises in the repository.

Two days - October 28 and 29 – were filled up with lectures and workshops in Warsaw, in the lecture hall of the Novotel Warszawa Airport hotel.

The first session presenting the nuclear power development program in Poland featured presentations by the Ministry of Economics, PGE EJ1 as the main investor, and AMEC acting as the project technical advisor. The lecturers reviewed the work done so far and the timetable of future work, necessary for program implementation. The lecture of Mr. Jacek Cichosz, the chairman of PGE EJ1, stressed the necessity of parallel work on several key tasks so as to be able to fulfill the program within reasonable time limits.

Workshop at the Maria research reactor

Workshop at the National radioactive waste repository in Różan

The second session, chaired by dr. Krajewski, Director of the Central Laboratory for Radiation Protection, featured two papers dealing with low level radiation. In the first lecture, Mr. Bruno Comby, the chairman of Environmentalists for Nuclear Energy (EFN) showed why true environmentalists are FOR nuclear energy, and in the second, prof. Wade Allison from Oxford described evidence that low radiation doses are not harmful to living organisms including human beings. The afternoon session about clean energy sources was led by dr. Duda, the chief advisor to the chairman of the Polish Energy Market (ARE).

Mr. Bruno Comby, the chairman of Environmentalists for Nuclear Energy

The first paper was presented by dr. Misak, former chairman of the Nuclear Safety Authority of the Slovak Republic, later the leader of the Nuclear Safety Department in the IAEA and recently the leader of work connected with new reactors for Temelin and Dukovany NPPs in the Czech Republic. He discussed the reasons which had led the Czech government to choose the nuclear option as the mainstay of the Czech power industry. The second paper by prof. Voss from Germany showed the achievements and shortcomings of the Energiewende program, concluding that the change to renewables as the mainstay of power generation cannot be made in a market economy but would necessitate central government decisions.

The next session dealt with the nuclear power renaissance, with the main presentation delivered by Ms. Fiona Reilly of Price Water Cooper from the UK, acting as the representative of EDF. She described the principles of financing NPP construction in the UK and gave some details concerning contracts for difference CfD.

In the following part of the afternoon session prof. Strupczewski conducted a workshop on siting problems, and director Stryjecki from PGE EJ1 presented the actual state of work on choosing the site for the first Polish NPP.

In the second day of lectures the first session dealt with fuel cycle problems. Prof. Strupczewski gave a presentation on health hazards due to uranium mining and compared them with the hazards arising in coal mining in the USA and in Poland, showing the relative advantages of uranium versus coal.

In the second paper prof. Prasser from Zurich High Technical High School described how sup-plies of uranium can be assured for future NPPs, and added a discussion of the Polish possibilities of uranium recovery from copper mining waste. Then followed a workshop, in which the participants listened a the lecture on radioactive waste management and then had to play a game of questions and answers concerning a future radioactive waste repository planned for Poland. The game turned out to be very successful, arousing high interest from the participants.

Participants of the School during the special workshop devoted to radioactive waste management

After that, in the Special session, the first presentation was by prof. Wróblewski from Warsaw University, who spoke about the discovery of Roentgen radiation to celebrate the 120th anniversary of that discovery. The second paper was presented by Mr. C. Hueso Ordoñez from the Spanish company IDOM dealing with fuel cycle facilities, an activity which can assure fuel for the energy needs of mankind for hundreds of years. These two papers showed how much work has been done within the last century.

In the afternoon session the participants could choose one of two parallel series of lectures. In one room several lectures were presented by Polish professors of medicine, discussing radiation health problems in medical treatments. This session was chaired by prof. Janiak, a permanent member of UNSCEAR and leader of experimental studies of radiation effects in a Warsaw University.

In the second room four presentations dealt with new III generation reactors which can be offered to Poland. As three of these reactors had been designed in countries having radiation protection rules different than those which are in force in Poland and in several EU countries, the session was aimed at showing how each of the proposed reactors can meet EU safety requirements.

Prof. Renata Mikołajczak, POLATOM Radioisotope Centre

An expert from AREVA. Mr. C. Mayoral, Licensing Manager, presented a paper on the Robust-ness of the EPR reactor design – Analysis through the Multinational Design Evaluation Program. As the EPR had been from the very beginning designed according to EU safety requirements, demonstrating its safety was an easy task.

Mr. Mayoral addressed mainly the comparison of the inherent safety features of EPR with the requirements of regulatory bodies in the UK and those assembled in WENRA and showed that the safety of EPR is convincingly demonstrated. He also described the results of a design evaluation made within the international program MDEP, and in particular in the OECD working group on EPR. The results of stress tests after the Fukushima accident have shown that EPR remains safe even in conditions of a double natural catastrophe of earthquake and flooding such as in Japan in 2011.

The second paper was presented by the Chinese expert, Mr. Y. Maochun, from the China General Nuclear Power Corporation. The title of his paper was “Advanced Chinese Reactor meets EU requirements”. Mr. Maochun presented the profile of GNPC activities, demonstrating its extensive experience in construction and operation of NPPs in China.

The main achievement of GNPC is the development of the design of the Chinese HPR 1000 reactor, which has

a system of in-vessel retention of molten corium like the AP1000 reactor. It also has a post-accident heat removal system with heat exchangers situated outside containment like in the Russian WWERs.

The nuclear safety parameters of the HPR 1000 are very good, with a calculated frequency of core damage below 10-6/year and the frequency of large releases below 10-7/year. Other parameters are also better than the EU requirements.

The third paper was presented by Mr. David Powell, vice-chairman of Nuclear Power Plant Sales Europe, GE Hitachi Nuclear Energy. He described ”Innovations in GE Hitachi’s nuclear reactor designs”, in particular those implemented in ABWR and ESBWR reactors. After presenting the General Electric and Hitachi companies, which together have over 225 years of experience and manage a staff of 660 000 employees (of which 100 000 are in Europe) Mr. Powell described the development of boiling water reactors including the PRISM reactor, a new reactor for IVth generation with sodium coolant and capability of fuel breeding.

The frequency of core damage in ABWR was reduced to 1.6 E-7/year and in ESBWR to 1.7 E-8/year. The ESBWR reactor does not need steam generators, nor a pressurizer, primary coolant pumps or primary piping. It provides a design for residual heat removal which the designers claim is the best among reactors of the III generation in the case of complete station blackout. The ABWR reactor has been successfully operated for more than a decade and ESBWR is being licensed now in the USA for North Anna 3 NPP and in the UK.

The fourth lecture in this session was entitled “How AP1000 developed for the USA meets UK regulations” and it was presented by Ms. J. Gorgemans from Westinghouse. The de-sign of this reactor was aimed at achieving a simple, passive and standardized construction and this aim has been achieved.

AP1000 is a reactor with passive safety features, being built in the USA (Vogtle and Summer NPPs) and in China (Sanmen and Haiyang NPPs), altogether 8 units, and is being licensed now by the UK nuclear safety authority. Many pictures from the construction sites documented progress made in building this reactor. The completion of licensing in the UK is foreseen for 2017.

An important problem is to demonstrate that the AP1000 meets British safety requirements, which are similar to those in Poland, but very different from the safety regulations in the USA. AP1000 was licensed in the USA according to regulations which allow the dose at the exclusion area boundary to be up to 250 mSv during two hours after accidents, while in the UK the limit is 10 mSv during one year after the accident. However, the assumptions for analysis in the UK are more realistic than those in the USA. Thus Westinghouse expects to be able to prove that the analysis made according to UK rules will yield results within the bounds of British requirements. This is of course a matter of high importance to Poland too.

In general, the atmosphere of the School was very open, many questions were asked and answered so that the School has greatly contributed to better understanding of the actual problems and developments in the world of nuclear power reactors.

The presentations are available on the internet at the page www.szkola-ej.pl.

The next edition of the School is planned for November 2016.

RADIOISOTOPE CENTRE POLATOM

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Overview

The Radioisotope Centre POLATOM is a self-contained unit of the National Centre for Nuclear Research engaged in scientific research and development in the field of the use of radioisotopes in nuclear medicine, industry and science and the production of radiopharmaceuticals and radioactive sources.

The history of POLATOM's operations dates back to the 1950's. Then, in 1957, at the then Institute of Nuclear Research in Świerk, near Warsaw, Ewa, the first research reactor in Poland was commissioned. This was the beginning of the country's activities related to the development of methods for obtaining isotopes and radioactive preparations. Further opportunities for development came in 1974, with the launching of Maria, another research reactor with which POLATOM's activities have been inextricably connected until today.

Currently, POLATOM combines in its activities basic scientific statutory objectives and successfully commercialises 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. The research and development conducted are primarily oriented towards application and often lead to the implementation of innovative products and technologies. The vast majority of the commercial products on offer, including approximately 150 items, are the results of own work.

In recent years POLATOM has launched the manufacture of several innovative products, among them a ^{99m}Tc-Tektrotyd radiopharmaceutical kit for diagnostic imaging of tumours expressing somatostatin receptors useful in oncology, or ItraPol (^{90}Y) and LutaPol (^{177}Lu) as radiopharmaceutical precursors for radiolabelling of peptides and other biomolecules of cancer therapy.

POLATOM is a world famous supplier of high quality radiopharmaceuticals and diagnostic kits for nuclear medicine and an important manufacturer of radiochemical products for customers all over the world. Its products are exported to more than 70 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,
- Ophthalmic applicators for brachytherapy,
- 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 in compliance with PN-EN/ISO 17025:2005.

Dariusz Socha

REPORTS

Development of Radiopharmaceuticals Based on ^{188}Re and ^{90}Y for Radionuclide Therapy in Poland
D. Pawlak, ... , **T. Dziel**, **A. Muklanowicz**, **J.L. Parus**, **P. Garnuszek**, **W. Mikołajczak**, **M. Maurin**, **J. Pijarowska**, **A. Jaroń**, **U. Karczmarczyk**, **E. Laszuk**, **A. Korsak**, **El. Jakubowska**, **E. Byszewska-Szpocińska**, **R. Mikołajczak**, ... et al.
INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA

Estimation of radiological protection on the territory of Nuclear Centre Świerk and its vicinity (2014)
B. Filipiak, ... , **Z. Haratym**, **J. Ośko**, **T. Pliszczyński**, **B. Snopek**, **B. Boimski**, **S. Domański**, **M. Dymecka**, **R. Ejsmont**, **M. Feczko**, **A. Garboliński**, **B. Karpińska**, **J. Lechniak**, **A. Pawełczuk**, **B. Piotrkowicz**, **K. Rzemek**, **R. Sosnowiec**, **M. Szostak**, **W. Śniegoń**, **M. Tulik**, **M. Umaniec**, **K. Wiśniewska**, **K. Wojdowska**, **J. Wojnarowicz**, **Z. Worch**, **D. Zielińska**, ... et al.

PARTICIPATION IN CONFERENCES AND WORKSHOPS

Invited Talk

Znaczniki do obrazowania receptorów somatostatynowych do diagnostyki i terapii
R. Mikołajczak
IV Konferencja Naukowo-Szkoleniowa (Poland, Szklarska Poręba, 2015-05-15 - 2015-05-17)

PSMA- nowości w diagnostyce izotopowej i leczeniu raka prostaty
R. Mikołajczak
IV Konferencja Naukowo-Szkoleniowa (Poland, Szklarska Poręba, 2015-05-15 - 2015-05-17)

Projektowanie radiofarmaceutyków
R. Mikołajczak
XLIII Zjazd Fizyków Polskich (Poland, Kielce, 2015-09-06 - 2015-09-11)

Center for Design and Synthesis of Radiopharmaceuticals for Molecular Targeting CERAD on the Polish Roadmap for Research Infrastructures
R. Mikołajczak
INARIE Integrating Access to PAN-European Research Infrastructures in Central and Eastern Europe (Hungary, Debrecen, 2015-11-30 - 2015-12-02)

Kontrola jakości zestawu Techimmuna do diagnostyki stanów zapalnych
U. Karczmarczyk
IV Konferencja Naukowo-Szkoleniowa (Poland, Szklarska Poręba, 2015-05-15 - 2015-05-17)

Radiopeptides Targeting GCPR Agonists and Antagonists
R. Mikołajczak
Third Theranostic World Congress on Gallium-68 and Radiopeptide Therapy (USA, Baltimore, 2015-03-12 - 2015-03-14)

Radioisotope Centre POLATOM-isotopes for industry and medicine
I. Cieszykowska
HANARO SYMPOSIUM (Korea, Daejeon, 2015-05-11 - 2015-05-13)
KAERI, Daejeon, Korea No. (2015) p. 119

Alternatywne metody produkcji technetu-99m. Produkcja technetu-99m w cyklotronach medycznych.
R. Mikołajczak, **D. Pawlak**
III Międzynarodowa Konferencja Radiofarmaceutyczna (Poland, Łódż, 2015-05-28 - 2015-05-29)

Oral Presentation

Long-term side effects in patients with disseminated neuroendocrine tumors who underwent tandem peptide receptor radionuclide therapy (PRRT) with Y-90/Lu-177-DOTATATE
J. Kunikowska, R. Matyskiel, **D. Pawlak**, L. Krolicki
Third Theranostic World Congress on Gallium-68 and Radiopeptide Therapy (USA, Baltimore, 2015-03-12 - 2015-03-14)

ALTECH-alternatywne metody otrzymywania Tc-99m w cyklotronach medycznych
I. Cieszykowska, **D. Pawlak**, **W. Wojdowska**, **J. Parus**, **R. Mikołajczak**
60th Anniversary of IBJ: Nuclear Physics and Chemistry for Medicine (Poland, Otwock, 2015-06-10 - 2015-06-10)

Biodistribution of ^{64}Cu-HL-1 complex, an aid in the evaluation of potential chemotherapeutic agent.
D. Kłudkiewicz, U. Karczmarczyk, M. Maurin, E. Laszuk, P. Garnuszek, R. Mikołajczak
WG Meeting WG3, COST Action CM1105 (Poland, Warsaw, 2015-09-01 - 2015-09-02)

Recurrent glioblastoma multiforme - local alpha emiters targeted therapy with ^{213}Bi-DOTA-substance P
L. Królicki, A. Morgenstern, J. Kunikowska, H. Koziara, B. Królicki, M. Jakuciński, **D. Pawlak**, C. Apostolidis, F. Bruchertseifer
28th Annual Congress of the European Association of Nuclear Medicine (Germany, Hamburg, 2015-10-10 - 2015-10-14)

Specjalizacja z radiofarmacji
R. Mikołajczak
IV Konferencja Naukowo-Szkoleniowa (Poland, Szklarska Poręba, 2015-05-15 - 2015-05-17)

Overall lecture WG1 Imaging reporters for theranostic agents
R. Mikołajczak
Final meeting of COST Action TD1004 Theranostic Imaging and Therapy: An Action to Develop Novel Nanosized Systems for Imaging Guided Drug Delivery (Serbia and Montenegro, Belgrade, 2015-09-10 - 2015-09-11)

From preclinical development to a Multicentre Clinical Trial: ^{111}In-CP04 targeting CCK2-receptors for personalized diagnosis and therapy of patients with medullary thyroid carcinoma
C. Decristoforo, **D. Pawlak**, Ch. Rangger, **P. Garnuszek**, P. Kolenc-Peitl, K. Zaletel, Th. Maina-Nock, H. Maecke, P. Erba, **R. Mikołajczak**, G. Goebel, A. Hubalewska-Dydejczyk
ICRT 2015, 10th International Conference on Radiopharmaceutical Therapy (Austria, Innsbruck, 2015-05-03 - 2015-05-08)

The role of GLP-1 receptor targeting agents in clinical management of patients with insulinoma and MTC.
B. Janota, **R. Mikołajczak**, **U. Karczmarczyk**, **P. Garnuszek**, A. Hubalewska-Dydejczyk, A. Sowa-Staszczak, HelmutR. Maecke, R. Mansi, M. Fani
Final meeting of COST Action TD1004 Theranostic Imaging and Therapy: An Action to Develop Novel Nanosized Systems for Imaging Guided Drug Delivery (Serbia and Montenegro, Belgrade, 2015-09-10 - 2015-09-11)

Cyclic minigastrin radiolabelled with Lu-177: preclinical evaluation of a kit formulation for clinical use.
Ch. Rangger, **D. Pawlak**, L. Balogh, Z. Postenyi, **R. Mikołajczak**, E. VonGuggenberg
ICRT 2015, 10th International Conference on Radiopharmaceutical Therapy (Austria, Innsbruck, 2015-05-03 - 2015-05-08)

Przygotowanie metalicznej tarczy z Mo-100 do produkcji Tc-99m w cyklotronie
T. Janiak, **I. Cieszykowska**, **T. Barcikowski**, **K. Jerzyk**, **M. Mielcarski**
60th Anniversary of IBJ: Nuclear Physics and Chemistry for Medicine (Poland, Otwock, 2015-06-10 - 2015-06-10)

Physico-chemical and biological comparison of DOTA-minigastrin analogue (CP04) complexes with ^{68}Ga, ^{90}Y and ^{177}Lu.
M. Maurin, **P. Garnuszek**, P. Baran, **D. Pawlak**, N. Metzler-Nolte, R. Stoll, **U. Karczmarczyk**,

R. Mikołajczak
WG Meeting WG3, COST Action CM1105 (Poland, Warsaw, 2015-09-01 - 2015-09-02)

Kit formulation, preclinical evaluation and experimental radionuclide therapy using CCK2 receptor targeting cyclic minigastrin
E. VonGuggenberg, C. Rangger, L. Balogh, Z. Pöstényi, **D. Pawlak**, **R. Mikołajczak**
28th Annual Congress of the European Association of Nuclear Medicine (Germany, Hamburg, 2015-10-10 - 2015-10-14)

Structure characterization of ^{99}Tc-HYNIC peptide complexes
J. Pijarowska-Kruszyna, **A. Jaroń**, **M. Maurin**, **P. Garnuszek**, **R. Mikołajczak**
The 21st International Symposium on Radiopharmaceutical Science (ISRS2015) (USA, Columbia, 2015-05-26 - 2015-05-31)

^{111}In-CP04 - A Novel CCK2/Gastrin Receptor-Localizing Radiolabelled Peptide Probe for management of Patiens with Progressive/Metastatic Medullary Thyroid Carcinoma (MTC): **Rationale, Study Design and Initial Promising Results of Multicentre First Phase Study**
A. Hubalewska-Dydejczyk, C. Decristoforo, P. Erba, **R. Mikołajczak**, H. Maecke, K. Zaletel, P. Kolenc-Peitl, T. Miana, **P. Garnuszek**
28th Annual Congress of the European Association of Nuclear Medicine (Germany, Hamburg, 2015-10-10 - 2015-10-14)

Two kit formulations for radiolabelling a Minigastrin analogue with In-111 for a first in human clinical trial
D. Pawlak, **P. Garnuszek**, Ch. Rangger, E. VonGuggenberg, P. Kolenc-Peitl, Th. Maina-Nock, P. Erba, A. Hubalewska-Dydejczyk, C. Decristoforo, **R. Mikołajczak**
The 21st International Symposium on Radiopharmaceutical Science (ISRS2015) (USA, Columbia, 2015-05-26 - 2015-05-31)

Long term survival analysis after i.a. ^{90}Y-DOTATATE PRRT, in patients with non-resectable, advance progressive liver dominant neuroendocrine neoplasms
M.L. Nowicki, S.J. Konsek, L. Jaskiewicz, M. Mol, A. Sankowski, J.R. Buscombe, L. Bodei, **R. Mikołajczak**, J.B. Ćwikła
28th Annual Congress of the European Association of Nuclear Medicine (Germany, Hamburg, 2015-10-10 - 2015-10-14)

Poster

Wieloletnie doświadczenia OR POLATOM w przygotowywaniu dawek terapeutycznych DOTATATE
M. Radzik, **M. Maurin**, **D. Pawlak**
III Międzynarodowa Konferencja Radiofarmaceutyczna (Poland, Łódź, 2015-05-28 - 2015-05-29)

Comparative evaluation of ^{68}Ga, ^{90}Y and ^{177}Lu complexes of DOTA-minigastrin analogue (CP04).
M. Maurin, **P. Garnuszek**, P. Baran, **D. Pawlak**, **U. Karczmarczyk**, **R. Mikołajczak**
EMIM 2015 European Molecular Imaging Meeting. 10th annual meeting of the ESMI (Germany, Tuebingen, 2015-03-18 - 2015-03-20)

Wpływ chelatora DOTA na aktywność biologiczną Rytuksymabu w badaniach in vivo
U. Karczmarczyk, **W. Wojdowska**, **E. Laszuk**, **M. Maurin**, **P. Garnuszek**, **R. Mikołajczak**
III Międzynarodowa Konferencja Radiofarmaceutyczna (Poland, Łódź, 2015-05-28 - 2015-05-29)

Influence of DOTA-Rituximab conjugates on their biodistribution in mice
U. Karczmarczyk, **W. Wojdowska**, **E. Laszuk**, **M. Maurin**, **P. Garnuszek**, **R. Mikołajczak**
28th Annual Congress of the European Association of Nuclear Medicine (Germany, Hamburg, 2015-10-10 - 2015-10-14)

Juvenile nasopharyngel angiofibromas - in vitro and in vivo examinations of somatostatin receptors expression
J. Kunikowska, W. Kukwa, A. Cyran-Chlebicka, **D. Pawlak**, R. Matyskiel, Ł. Koperski, Z. Gronkiewicz, L. Królicki

28th Annual Congress of the European Association of Nuclear Medicine (Germany, Hamburg, 2015-10-10 - 2015-10-14)

Badania in vivo znakowanych lutetem-177 i itrem-90 koniugatów DOTA-Rituksymab jako potencjalnych terapeutyków chłoniaka nieziarniczego (non-hodkins lymphoma)
U. Karczmarczyk, **W. Wojdowska**, **E. Laszuk**, **M. Maurin**, **P. Garnuszek**, **R. Mikołajczak**
IV Ogólnopolska Konferencja Zwierzeta w badaniach naukowych (Poland, Warszawa, 2015-09-07 - 2015-09-09)

Wytwarzanie peptydu HYNIC-oktreotyd w warunkach GMP
A. Sikora, **B. Janota**, **J. Pijarowska-Kruszyna**, **A. Jaroń**
III Międzynarodowa Konferencja Radiofarmaceutyczna (Poland, Łódż, 2015-05-28 - 2015-05-29)

Structure characterization of ^{99m}Tc-HYNIC peptide complexes
J. Pijarowska-Kruszyna, **A. Jaroń**, **M. Orzełowska**, **W. Wojdowska**, **U. Karczmarczyk**, **M. Maurin**, **P. Garnuszek**, **R. Mikołajczak**
WG Meeting WG3, COST Action CM1105 (Poland, Warsaw, 2015-09-01 - 2015-09-02)

Synteza substancjiczynnej w świetle wymagań GMP na przykładzie peptydu Hynic-Tyr3-Oktreotyd
A. Sikora, **B. Janota**, **J. Pijarowska-Kruszyna**, **A. Jaroń**
III Międzynarodowa Konferencja Radiofarmaceutyczna (Poland, Łódż, 2015-05-28 - 2015-05-29)

Radiometal makes the difference. Synthesis and characterisation of DOTA-minigastrin complexes with ^{68}Ga, ^{177}Lu and ^{90}Y.
P. Garnuszek, **M. Maurin**, P. Baran, **D. Pawlak**, **R. Mikołajczak**
Final meeting of COST Action TD1004 Theranostic Imaging and Therapy: An Action to Develop Novel Nanosized Systems for Imaging Guided Drug Delivery (Serbia and Montenegro, Belgrade, 2015-09-10 - 2015-09-11)

Preparation of metallic target of Mo-100 for production of Tc-99m in cyclotron
T. Janiak, **I. Cieszykowska**, **T. Barcikowski**, **K. Jerzyk**, **M. Mielcarski**
60th Anniversary of IBJ: Nuclear Physics and Chemistry for Medicine (Poland, Otwock, 2015-06-10 - 2015-06-10)

Biological behavior of ^{68}Ga-DOTA-minigastrin (CP04). Preliminary results.
M. Maurin, **P. Garnuszek**, **U. Karczmarczyk**, **R. Mikołajczak**
Third Theranostic World Congress on Gallium-68 and Radiopeptide Therapy (USA, Baltimore, 2015-03-12 - 2015-03-14)

First Polish experiences in the cyclotron production of ^{99m}Tc
W. Wojdowska, **D. Pawlak**, J. Parus, **I. Cieszykowska**, **T. Janiak**, **K. Jerzyk**, **M. Mielcarski**, **T. Barcikowski**, **P. Garnuszek**, **R. Mikołajczak**
4th Balkan Congress of Nuclear Medicine (Macedonia, Ochrid, 2015-09-03 - 2015-09-06)

Localization of an insulinoma with ^{99m}Tc-HYNIC-Exendin-4 in a patient with situs inversus: a case report
L. Lezaic, P. Kolenc-Peitl, K. Zaletel, I. Stotl, A. Tomazic, A. Sowa-Staszczak, **R. Mikołajczak**, A. Hubalewska-Dydejczyk
4th Balkan Congress of Nuclear Medicine (Macedonia, Ochrid, 2015-09-03 - 2015-09-06)

Badania in vivo kompleksu ^{64}Cu-HL-1, potencjalnego radio-chemoterapeutyku do wieloczynnikowej terapii przeciwnowotworowej.
D. Kłudkiewicz, **U. Karczmarczyk**, **M. Maurin**, **E. Laszuk**, **P. Garnuszek**, **R. Mikołajczak**
III Międzynarodowa Konferencja Radiofarmaceutyczna (Poland, Łódż, 2015-05-28 - 2015-05-29)

A new 4π(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**
20th International Conference on Radionuclide Metrology and its Applications (Austria, Wiedeń, 2015-06-08 - 2015-06-11)

Could ^{99m}Tc labelled glucagon-like peptide 1 analogue scintigraphy be an answer for patients with persistent

hypoglycaemia?
A. Hubalewska-Dydejczyk, A. Sowa-Staszczak, A. Stefańska, D. Pach, M. Buziak-Bereza, M. Trofimiuk-Muldner, A. Gilis-Januszewska, A. Jabrocka-Hybel, M. Tomaszuk, R. Tomaszewska, M. Małecki, T. Bednarczuk, G. Kamiński, A. Kowalska, **R. Mikołajczak**, **B. Janota**
17th European Congress of Endocrinology (Ireland, Dublin, 2015-05-16 - 2015-05-20)

Standardization and half-life measurements of ^{111}In
T. Dziel, **A. Listkowska**, **Z. Tymiński**
20th International Conference on Radionuclide Metrology and its Applications (Austria, Wiedeń, 2015-06-08 - 2015-06-11)

Radionuclidic purity tests in ^{18}F radiopharmaceuticals production process
T. Dziel, **Z. Tymiński**, K. Sobczyk, A. Walęcka-Mazur, P. Kozanecki, **E. Kołakowska**, **P. Saganowski**
20th International Conference on Radionuclide Metrology and its Applications (Austria, Wiedeń, 2015-06-08 - 2015-06-11)

What we know about Oslo meteorite from cosmogenic isotope analysis
Z. Tymiński, M. Stolarz, T. Kubalczak, **K. Tymińska**, **E. Kołakowska**, **T. Dziel**, **A. Burakowska**, **E. Miśta**, **P. Saganowski**
European Planetary Science Congress (France, Nantes, 2015-09-27 - 2015-10-02)

Cyclotron production of ^{99m}Tc from highly enriched ^{100}Mo
D. Pawlak, **W. Wojdowska**, **J.L. Parus**, **I. Cieszykowska**, **T. Janiak**, **K. Jerzyk**, **M. Mielcarski**, **T. Barcikowski**, **P. Garnuszek**, **R. Mikołajczak**
28th Annual Congress of the European Association of Nuclear Medicine (Germany, Hamburg, 2015-10-10 - 2015-10-14)

LECTURES, COURSES AND EXTERNAL SEMINARS

Microbiology Requirements in the Production of Radiopharmaceuticals and Locally Prepared Radiopharmaceuticals[a]
A. Korsak
Szklarska Poręba, IV Training and Scientific Conference on Diagnosis and Isotopic Therapy in Oncology , 2015-05-15

Sharing and Developing Protocols to Further Minimize Radiactive Gaseous releases to the Environment in the Manufacture of Medical Radioisotopes as GMP[b]
M. Konior
Vienna, International Atomic Energy Agency , 2015-08-18

a) in Polish
b) in English

INTERNAL SEMINARS

Basic issues of radiological protection and procedures in cases of radiological emergencies[a]
K. Król
Warsaw, National Defence University, 2015-01-10

Nuclear reactor safety[a]
K. Król
Warsaw, National Defence University , 2015-06-13

EURAMET as an element of the Metrology organizational structure in a frame of the Metre Convention[a]
R. Broda
Otwock, National Centre for Nuclear Research, 2015-06-15

Sharing & Developing Protocols to Further Minimize Radioactive Gaseous Releases to the Environment in the Manufacture of Medical Radioisotopes, as Good Manufacturing Practice[a]
M. Konior
Otwock, NCBJ OR POLATOM, 2015-11-19

[a)] in Polish

DIDACTIC ACTIVITY

P. Garnuszek - Lecture entitled "Radiopharmacy" for students of V years of Pharmacy at Warsaw Medical University

P. Garnuszek - Lecture for students of Faculty of Pharmacy WUM "Radiopharmaceuticals - preparation, characteristics, application, quality and safety use." (2 h)

P. Garnuszek - Lectures on the course "Preparation and quality control of radiopharmaceuticals in clinical pharmacy" (course No.SR-1/V/2015) within specialisation in Radiopharmacy

P. Garnuszek - Scientific supervision of the student for the master's degree

D. Kłudkiewicz - Scientific supervision of the student for the enginner's degree-

D. Kłudkiewicz - Scientific supervision of the student during summer practice-

M. Korytkowski - Lecturer:
Specialization in radiopharmacy (postgraduate) Module 3 "Working in aseptic environment"
Faculty of Pharmacy, Medical University of Lodz

R. Mikołajczak - 8 International School of Nuclear Power, 26-30 October 2015

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
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
Radiation Protection Inspectors Association
Polish Society of Medical Physics

P. Garnuszek
European Association of Nuclear Medicine (EANM)
Polish Society of Nuclear Medicine
Expert of Group 14 (radioactive compounds) European Pharmacopoeia,European Directorate for the Quality of Medicines & HealthCare, Council of Europe
Member of Scientific Council of National Centre for Nuclear Research

E. Iller
European Association of Nuclear Medicine (EANM)
member of Scientific Council of National Center for Nuclear Research.
external member of Scientific Council of Institute of Nuclear Chemistry and Technology, Warsaw
National Centre for Nuclear Research
Institute of Nuclear Chemistry and Technology

B. Janota
Polish Society of Nuclear Medicine
European Association of Nuclear Medicine (EANM)

U. Karczmarczyk
Polish Society of Nuclear Medicine
European Association of Nuclear Medicine
Polish Laboratory Animal Science Association
Member of Scientific Council of National Centre for Nuclear Research

M. Konior
Polish Chemical Society

A. Markiewicz
Member of Scientific Council of National Center for Nuclear Research.

M. Maurin
Member, Polish Society of Nuclear Medicine

M. Mielcarski
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ASTROPHYSICS, COSMIC RAYS & ELEMENTARY PARTICLE PHYSICS

Vector Boson scattering

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Interactions between the electroweak gauge bosons W and Z, known collectively as Vector Boson Scattering (VBS) processes, are a window into the mechanism of electroweak symmetry breaking. In the absence of a Higgs boson, the total cross section for these processes would grow indefinitely with energy, up to the point of violating the unitarity condition. The Standard Model (SM) Higgs boson provides cancelation of the divergent terms of the individual amplitudes and renders the total cross section finite and satisfyng unitarity. In the SM, where all the relevant coupling constants, namely the gauge triple and quartic couplings, as well as the Higgs couplings, have fixed values, this cancelation comes out as a free bonus. However, any deviation from the predicted value would result in the amplitude being only partially unitarized, leading again to indefinite growth at some higher energy. Extensions of the SM usually predict not only modified Higgs couplings, but also effective triple and quartic gauge couplings, the latter being an indirect consequence of an extended particle content with respect to the SM. Any such effects are bound to show up in the energy dependence of the VBS processes. Thus, VBS complements Higgs physics and non-VBS electroweak physics in studying the mechanism of electroweak symmetry breaking and provides an important closure test for any underlying theory.However, as already known from direct Higgs studies performed during Run 1 of the LHC, Higgs couplings to vector bosons are indeed close to their SM values, these effects are bound to be small. It therefore becomes of special importance to determine and fully explore the most sensitive kinematic variables and optimize data analysis techniques in order to obtain the best possible results from the upcoming runs of the LHC, including the High Luminosity LHC programme. In addition, VBS is well known to be the best process to study the quartic gauge couplings, practically unmeasured so far.

Polish physicists from the NCBJ and the University of Warsaw have been active in the field since 2010. The phenomenology of physics scenarios with modified couplings is found akin to the phenomenology of the earlier Higgsless studies. These studies indicate that the same-sign $W^{+-}W^{+-}$ scattering process, followed by purely leptonic W^{+-} decays offers the best experimental sensitivity to physics beyond the SM at the LHC. Given the multitude of physics scenarios under possible consideration, the polarization states of the interacting W pairs are an important handle in the data analysis. This follows directly from the observation that each scenario affects the energy behaviour of different polarization in a different way. The W^{+-} polarizations were shown to be able to the determined in an experiment on a statistical basis from the transverse momentum distributions$p_T^{j1}$and p_T^{j2} of the two hadronic “tagging" jets in the event. For any physics scenario which modifies the high energy behaviour of longitudinally polarized pairs, $W_L^{\pm}W_L^{+}$ as is indeed the case of, e.g., a Higgs coupling scaled by a constant, the kinematic variable that offers improved sensitivity to physics beyond the SM was determined to be $R_{p_t} = p_T^{l1} \cdot p_T^{l2} / p_T^{j1} \cdot p_T^{j2}$ where p_T^{l1} and p_T^{l2} are the transverse momenta of the two charged leptons from a W^{+-} decay. The same criteria are equally useful in the study of gauge quartic couplings.

First partial phenomenological studies also exist for future colliders with a higher beam energy and in particular for the Future Circular Collider (FCC-hh), with a proton-proton C.M. energy of 100 TeV. They indicate both the usefulness of all the analysis methods worked out for the LHC, as well as a qualitative leap in the VBS physics reach compared to 14 TeV physics.

Photons and neutral pions in the ALICE experiment

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The quark-gluon plasma (QGP) is the state of matter at high temperature characterized by deconfinement of quarks and gluons. Present-day heavy-ion experiments try to produce extremely hot matter with vanishing baryon density by colliding heavy ions, which would lead to a temperature above the quark-gluon plasma transition point $T \sim 155$MeV. The hot matter fireball formed in the collision undergoes subsequent expansion going through the quark-gluon plasma and hadron gas stages and ending by freeze-out when the final-state particles stream freely out of the reaction zone.

The measurement of photons is one of the most interesting challenges in exploring the quark-gluon plasma. Direct photons, formed in the reaction zone due to interactions of the colliding particles or by the secondary particles in the hot matter fireball, experience a very weak interaction with matter and escape almost unperturbed from the reaction zone carrying information about the thermal and dynamical properties of the medium at the point of their emission. Decay photons, which constitute the major part of the photon spectrum, help to reconstruct short-lived particles, such as neutral pions that have a dominant two-photon decay channel.

The production of neutral pions is highly affected by the medium.

The ALICE experiment detected photons by their conversions to electron-positron pairs in the tracking detector (TPC, ITS) and by means of calorimeters (PHOS, EMCAL).

The results for neutral pion and direct photon production for Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$TeV/c obtained during Run 1 of the LHC are presented in Figures 1 and 2.

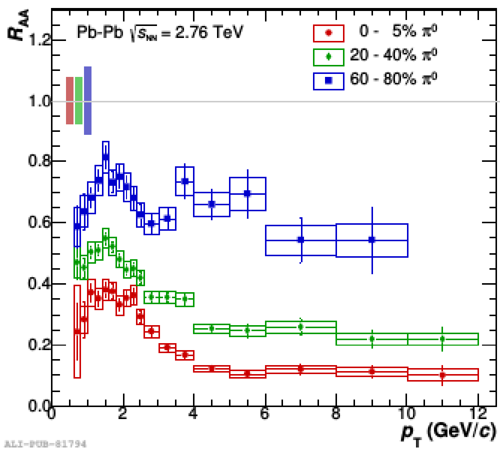

Fig. 1. Neutral pion modification factor for three different centralities (0-20%, 20-40%,60-80%) in Pb-Pb collisions at √sNN=2.76 TeV per nucleon pair.

Figure 1 shows the nuclear modification factor for neutral pions, which is expressed by the formula:

$$R_{AA} = \frac{\left(\frac{d^2N}{dp_T dy}\right)_{AA}}{\langle T_{AA}\rangle \times \left(\frac{d^2\sigma}{dp_T dy}\right)_{pp}},$$

R_{AA} measures the ratio of neutral pion yield in Pb-Pb collisions compared to the yield in pp collisions at the same energy scaled by the number of binary nucleon-nucleon collisions in a specified centrality range, $N_{coll} = \langle T_{AA}\rangle \sigma_{inel}^{pp}$. A deviation of R_{AA}below unity represents a suppression of π^0 production in Pb-Pb collisions.

As one can see from Figure 1, the modification factor is smaller at most central collision which indicates the greater stopping power of the hot strongly interacting medium formed in the collision. The suppression observed in the ALICE experiment is two times greater than the result obtained by RHIC at $\sqrt{s_{NN}} = 200$GeV/c.

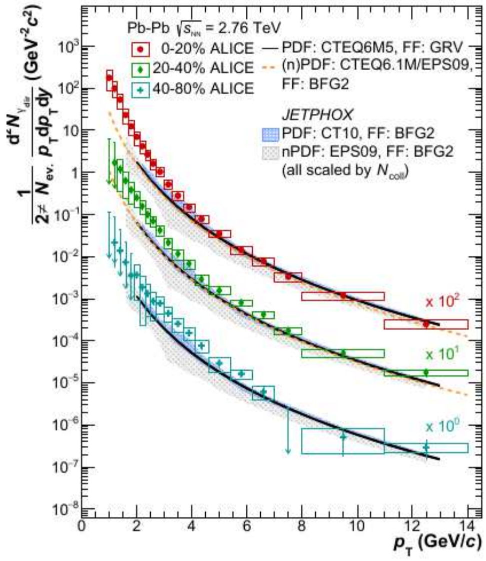

Fig. 2. Direct photon spectra in Pb-Pb collisions at √sNN=2.76 TeV for the 0-20% (scaled by a factor 100), the 20-40% (scaled by a factor 10) and 40-80 % centrality classes compared to NLO pQCD predictions for the direct photons in pp collisions at the same energy, scaled by the number of binary collisions for each centrality class.

The results for direct photon measurements are presented in Figure 2. The results for invariant yield at different centralities are compared to the perturbative QCD (pQCD) prediction for the production of prompt photons in pp collisions at the same energy, scaled by the number of binary nucleon-nucleon collisions.

The obtained direct photon spectrum demonstrates a significant excess of over the pQCD prediction in the interval $p_T \leqslant 4$GeV/c, signaling the dominance of thermal photons at low p_T.

The spectrum of thermal photons has been fitted by the exponential function exp($-p_T/T_{eff}$) and the effective temperature was found to be $T_{eff} = 304 \pm 11^{stat} \pm 40^{sys}$ for centrality 0-20% and $T_{eff} = 407 \pm 61^{stat} \pm 96^{sys}$ for centrality 20-40% which is higher then the effective temperatures observed at the PHENIX experiment at = $\sqrt{s_{NN}} = 200$GeV.

Optical properties of the symbiotic X-ray binary V2116 Oph

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The X-ray source GX 1+4 was discovered by Lewin, Ricker and McClintock in 1971 during a balloon mission observing the Galactic Centre. The authors also reported periodic variation of the X-ray flux, with an approximate frequency of 1 cycle per 2.3 minutes. Later observations confirmed that GX 1+4 is a pulsar with spin period P_{spin}~123.5-125.5s (Galloway et al. 2001), which is powered by accretion (Glass et al. 1973, Davidsen et al. 1977, Chakrabarty et al. 1997). Davidsen et al. (1977) classified this source as a symbiotic X-ray binary (SyXB), containing an M6 giant and a neutron star instead of a white dwarf - it was the first identification of a SyXB, but see also Shahbaz et al. (1996). The orbital period P=303.8±1.1 d was obtained by Pereira et al. (1999). Based on infrared spectroscopy, Hinkle et al. (2006) obtained an orbital period of P_{orb}=1161±12d, but see also Corbet et al. (2008).

We analyze unprecedented long term and very accurate optical observations of the symbiotic X-ray binary GX 1+4 (V2116 Oph), obtained by the OGLE IV project during monitoring of the Galactic Bulge. A comprehensive description of the instrumentation of OGLE IV can be found in Udalski et al. (2015).

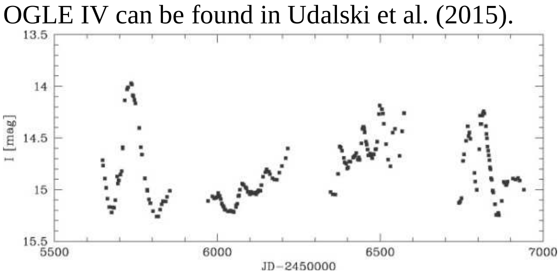

Fig.1. Light curve of V2116 Oph from OGLE IV data, obtained in I filter. Typical error of I brightness equals 0.005 mag and is smaller than the size of a single point in the light curve.

Observations of this object cover 1558 days (about 4.27 years), from 8th July, 2010 to 12th October, 2014. V2116 Oph is a very well known X-ray source, but optical data are very scarce so far, so our observations give a rare occasion to study the long term optical behaviour of a Symbiotic X-ray Binary. What is characteristic in the light curve of this binary are the numerous brightenings of this source taking place every several dozen of days. These events are not strictly periodic and have different amplitudes. Three of them exhibit an amplitude of at least 1mag (see Fig. 1), the remaining ones usually have less than 0.5mag. In our opinion the high amplitude brightenings could be caused by a different mechanism than those of low amplitude.

We analysed the central part of the light curve, between 5971 and 6573 days. The central part of the light curve shows a specific pattern of light oscillations, which can be analysed in the frequency range of 0.002-0.1d^{-1} (periods from 500 to 10 days). In our opinion the leftmost brightenings have an unexplained origin, and may not be related to the orbital or oscillation period.

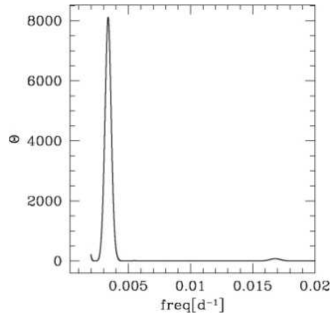

Fig. 2. Power spectrum of V2116 Oph obtained from the central part of the OGLE IV data. The peak is at a frequency of ν =0.003384±0.000771d^{-1} (period P=295±70 days), the secondary peak in the power spectrum at ν =0.016812±0.000843 d^{-1} (P=59± 3 days).

Figure 2 shows the relevant part of the power spectrum of GX 1+4. The most prominent peak occurs at frequency ν =0.003384±0.000771d^{-1} (period P = 295 ± 70d). This value is in agreement with the values of the orbital period obtained by Cutler et al. (1986) and Pereira et al. (1999). However, we should stress here that there is a gap in the central part of the optical light curve, which divides the analysed time period into two parts, lasting approximately 300 days. In the power spectrum we also found another, much smaller peak at frequency ν =0.016812±0.000843d^{-1} (P=59±3 days). Note that the peak is weakly visible in the periodogram, presented in Fig. 2, but the corresponding light variations in I filter are clearly seen in Fig. 1. Probably it is some kind of an average period between the brightenings mentioned above.

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Lateral distributions of EAS muons measured with the KASCADE-Grande muon tracking detector in the primary energy range 10^{16} –10^{17} eV

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When a primary cosmic ray (CR) particle interacts with the Earth's atmosphere a cascade of secondary particles, an extensive air shower (EAS), is created. Investigations of the muonic component in EAS are of primary importance for understanding air shower physics. Muons carry nearly undistorted information about their parent particles which are the most numerous products of hadronic interactions responsible for the development of the shower cascade in the atmosphere. This longitudinal development contains information on the mass of the primary CR particle, which is related to astrophysical questions. It also carries information relevant to particle physics on the underlying properties of hadronic interactions in the energy range and the kinematical region only recently being accessed by the forward detector of the LHC.

The most common way used by all EAS experiments with a sufficient number of muon detectors is the investigation of lateral distributions of muons, being a projection of the development of the muonic component onto the shower plane [1]. This is usually measured with arrays of scintillation detectors, where the number of muons in each detector is derived from the energy deposited in the scintillators, using non-trivial procedures based on simulations [2,3]. One such experiment is the KASCADE-Grande EAS experiment [4] located on the site of the Karlsruhe Institute of Technology – Campus North, Germany. It was designed to detect the three EAS particle components: hadrons, electrons and muons (at 4 energy thresholds) in a distance range up to 700 m from the shower core, and for primary CR particle energies from 5×10^{14} eV to 10^{18} eV. For the reconstruction of muon tracks a large area Muon Tracking Detector (MTD)[5] was included in the experimental setup.

The MTD gives the possibility to study the longitudinal development of EAS muons with energy above 800 MeV. For the first time it was possible to investigate the lateral distribution of muons by counting muon tracks for the radial distances 100–610 m, in four primary energy ranges above 10^{16} eV and with high statistical accuracy [6]. The main results of this investigation are presented in Fig 1.

The MTD distributions can be described with the lateral distribution function (LDF) developed by Greisen [7], however in a limited distance range, different for each energy interval. This is due to the limited efficiency of track reconstruction of the MTD, caused by the saturation of the detector, as well as by trigger inefficiency (for details see Ref. [6]). The LDFs become steeper with the energy of the showers, see Tab. 3 in Ref. [6]. The same behavior was observed for the muon and electron LDFs obtained with the KASCADE Array, as shown in Ref [3].

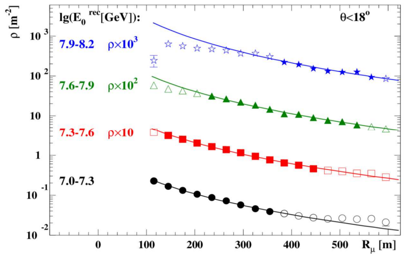

Fig. 1. Lateral density distributions of muons from the MTD in four primary energy ranges. The distributions can be described by the Greisen function in the distance ranges marked with full symbols [6].

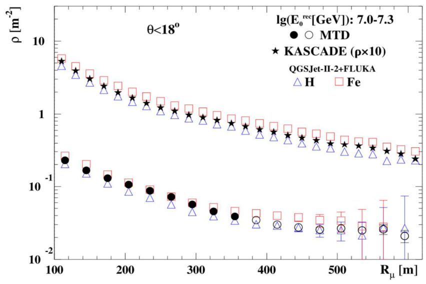

Fig. 2. Example of the lateral muon density distributions obtained with the MTD (circles) and KASCADE Array measurements (stars) together with simulations (triangles; squares) in the primary energy range lg(E^{rec} [GeV]): 7:0 – 7:3.

In Fig. 2 the lateral distributions obtained with the MTD (E_{thr} =800 MeV) are compared with the density distributions based on energy deposits obtained with the KASCADE Array of scintillator detectors (E_{thr} =230 MeV) for the same sample of EAS. The measured distributions are compared with distributions of simulated showers initiated by Hydrogen and Iron primaries. The comparisons of the lateral muon density distributions show that the MTD and KASCADE results are bracketed by the simulated distributions, i.e. no unexpected physical processes are visible. This also indicates that the hadronic interaction models have been significantly improved because the simulations performed with earlier models could not describe the KASCADE air shower data.

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Clustering of 24 μm selected galaxies in the AKARI north ecliptic pole deep field

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The observed distribution of colours measured for galaxies is reported to be bi-modal. On one hand we have red galaxies, which contain almost exclusively old stellar populations and very little gas or dust. On the other hand we observe galaxies, which are rich in dust and show clear evidence of ongoing star formation processes, and, due to the strong emission at short wavelengths coming from new-born hot stars, appear blue in colour. However, the origin of the differences between these two main populations of galaxies is unknown; what processes contribute to the truncation of star formation (SF)? Different models of galaxy formation and evolution can reproduce these two main observed populations by implementing different mechanisms which influence SF processes, such as (but not limited to) virial shock heating, supernova feedback or gravitational interactions with other objects. In particular, it is expected that the evolution of a galaxy depends on the properties of the dark matter halo in which it resides. To explain this variety of different types of galaxies in the Universe, it is crucial to understand how each population of galaxies is formed, how it evolves throughout cosmic time and what are the key factors controlling its evolution. With the aid of measurements of galaxy clustering it is possible to investigate what is the typical environment in which SF galaxies reside. By tracing the evolution of clustering of different populations of SF galaxies appearing at different cosmic epochs, we can fit them into an evolutionary sequence to find out their future fate, and we can explain the origin of different types of galaxy populations observed today.

Emission in the mid-infrared (MIR) originates mainly from dust particles, which are heated by young hot stars. That is why in order to obtain catalogues of sources actively forming stars, observations in the MIR are necessary. We investigate the evolution of clustering of the MIR galaxies observed by the AKARI satellite which carried out, among others, a deep survey of the north ecliptic pole (NEP) region [1]. To estimate the clustering properties of different populations of SF galaxies we have split the infrared galaxy catalogue into four redshift (z) ranges and for each we estimated the galaxy correlation function.

To relate the clustering of the galaxies to that of the underlying dark matter we then calculated the linear bias parameter b for each subsample. In Fig. 1 we show b measured for our different samples as a function of redshift and compare it with theoretically predicted evolution of dark matter halo (DMH) bias for different thresholds of minimal halo masses derived by [2].

We found that in the lowest z, least luminous subsample we are dealing with normal SF galaxies typically observed in optical and ultraviolet surveys, which exhibit clustering properties typical for this population. For medium z subsamples (z~0.7 and z~1.1) the clustering signal is high – these galaxies are more active in star formation and also more massive. However, the sample at z~1.1, composed of even brighter galaxies, seems to be residing in lower minimal mass DMH than the fainter galaxies at z~0.9. This could indicate that brighter infrared galaxies do not necessarily reside in more massive halos and that their luminosity is not necessarily a good indicator of their mass. This also means that despite similar clustering properties, we are dealing with at least two different populations of star-forming galaxies. This can be attributed to the fact that SF galaxy infrared spectra are characterized by the presence of strong polycyclic aromatic hydrocarbon (PAH) features, and different aspects of these features pass through the 24 μm passband at different redshifts.

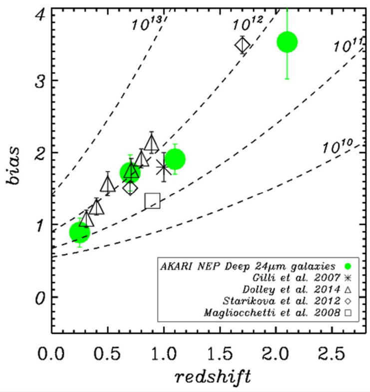

Fig. 1. Linear bias as a function of redshift for the AKARI photometric redshift samples (filled circles). Dashed curves represent the theoretical linear halo bias evolution of dark matter haloes of different minimal masses.

Additionally, we found that 24 μm galaxies at redshifts 0.5 < z < 1.3 might have evolved into present-day very strongly clustered galaxies, most likely massive elliptical galaxies residing in galaxy clusters [3].

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Properties and evolution of galaxy clustering at high redshift z > 2 based on the VIMOS Ultra Deep Survey

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By definition cosmology is the study of the origin, evolution and eventual fate of the Universe. However, there are numerous unknowns about the beginning of the Universe, only some uncertain theories about its future, and huge questions about what happened in the middle. One of the most important among these questions is how the complex structure of galaxies observed in the local universe formed and evolved through cosmic time.

Through our research we are trying to bring closer the answers to these fundamental questions of modern cosmology. Specifically, how did the complex large scale structure evolve? How did the relation between luminous and dark matter change through cosmic time and how does this relation depends on the galaxy properties? What processes drive and regulate star formation and mass growth in galaxies along cosmic time? With this purpose in mind, we studied the properties and evolution of the large scale structure of the Universe at high redshift z > 2 which corresponds to a cosmic epoch when the age of the Universe was less than 3 Gyr. This unprecedented study was made possible thanks to the depth and reliability of the spectroscopic galaxy sample from the VIMOS Ultra Deep Survey (VUDS).

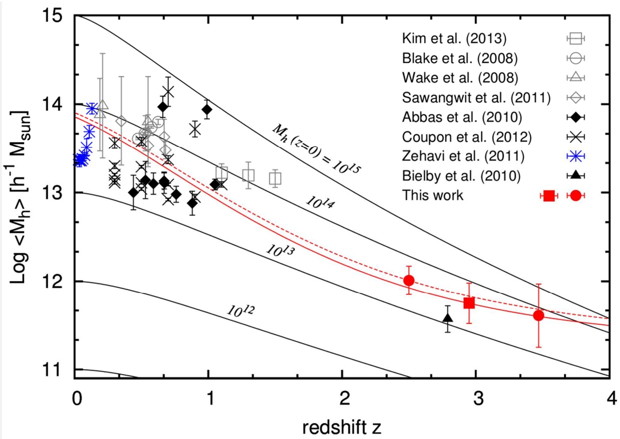

Fig. 1. Evolution of the number-weighted average host halo mass in three redshift ranges analysed in my study. Picture adapted from [2].

In my work I used galaxy clustering to quantify the physical properties of large scale structures at 2 < z < 5. I measured the two-point correlation function - a commonly used statistical tool to describe how galaxies are clustered as a function of scale. I interpreted these measurements using two types of approximation. The first one was based on a classical description of the correlation function using a power-law function. The second more detailed approximation was based on a halo occupation distribution model (HOD).

These studies resulted in two refereed publications in the Astronomy&Astrophysics journal. In the first one [2] I took a closer look at the shape, properties and evolution of the Large Scale Structure at early stages of galaxy formation, by measuring galaxy clustering of the general galaxy population at 2 < z < 5 and comparing the results with similar measurements obtained for the local and mid-redshift Universe. Next, in the framework of the halo occupation distribution (HOD) formalism I estimated an average host dark matter halo mass at redshift z ~3. I checked if it is possible to trace the history of these host dark matter haloes, and through that to find which present galaxy population the VUDS sample would evolve into. As presented in Figure 1, by comparing our results with the local measurements made in the Sloan Digital Sky Survey (SDSS), we found that the general galaxy population observed at redshift z ~ 3 should have evolved into the brightest and most massive galaxies (solid red line), which occupy the most massive haloes observed in the local Universe, as expected from the hierarchical mass growth paradigm.

In the second article [1] I studied the efficiency of star formation and stellar mass assembly in galaxies at redshift z ~3. I computed the stellar-to-halo mass ratio (SHMR) and the integrated star formation efficiency (ISFE), by taking advantage of HOD modelling of clustering measurements and SED fitting over the large set of multi-wavelength VUDS data. We found that the star formation efficiency of our z ~ 3 VUDS galaxies was close to the maximal efficiency allowed by the models, and their growth and build-up of stellar mass was not yet significantly quenched by feedback effects at this epoch.

Additionally, in the last year the VUDS observations have been finalized and the number of measured galaxies in it increased to ~10,000. This allows studies of the luminosity and stellar mass dependency of galaxy clustering at z>2, through correlation function measurements in the HOD framework, over the volume limited luminosity and stellar mass subsamples. Preliminary results suggest a strong dependence of the galaxy clustering on these properties. Similarly, as reported for the lower redshift ranges, more luminous and massive galaxies tend to be more clustered than their less luminous and less massive counterparts. This implies that the processes differentiating the clustering for different luminosities and masses have already been effective by z~3. The results of this research will be published in the near future.

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Smooth quantum dynamics of the mixmaster universe

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The Friedmann-Robertson-Walker model is successfully used to describe the data of observational cosmology. Nevertheless, the isotropy of space is dynamically unstable towards the big-bang singularity. On the other hand, if the present Universe originated from an inflationary phase, then the pre-inflationary universe is supposed to have been both inhomogeneous and anisotropic. Both analytical and numerical evidence suggests that the dynamics of such a universe backwards in time becomes ultralocal and effectively identical with the homogeneous but anisotropic one at each spatial point. In both cases quantization of the isotropic models alone appears to be insufficient. Hence the quantum version of an anisotropic model, comprising the Friedmann model as a particular case, is expected to be better suited for describing the earliest Universe.

We advocate[1,2] a new quantization method of the dynamics of a vacuum Bianchi type IX geometry, the Mixmaster universe. We identify a soluble sector of this model, which lies deeply in the quantum domain and, as we show, contains relevant physics.

The Mixmaster universe exhibits complex behaviour. As it collapses, the universe enters chaotic oscillations producing an infinite sequence of distortions from its spherical shape. Those distortions essentially correspond to the level of anisotropy and may be viewed as an effect of a gravitational wave evolving in an isotropic background. The dynamics of this wave is nonlinear, and its interaction with the isotropic background fuels the gravitational contraction. Not surprisingly, the quantization of the Bianchi IX model is a difficult task. Some formulations can be found in the literature, including the Wheeler-DeWitt equation or, more recently, a formulation based on loop quantum cosmology. However, the search for solutions within these formulations is quite challenging, leaving the near big-bang dynamics largely unexplored.

To fill this gap we propose a quantum Mixmaster dynamics[1,2], which originates from the affine coherent state (ACS) quantization that was recently used to obtain the quantum Friedmann model. It was shown that ACS quantization causes some new terms to appear in the quantum Hamiltonian, producing a strong repulsive force counteracting the contraction of the universe. The capacity to resolve the singularity constitutes the basic advantage of our quantization method. In order to solve the dynamics in the present, more complex setting, we employ the adiabatic approximation widely utilized in quantum molecular physics. This approach is reasonable when the vibrations of the shape of the universe are significantly faster than the contraction of its volume.

The main result[1,2] is a semiclassical Friedmann-like equation obtained from expectation values in ACS, a description peculiar to our approach. In that equation, the expansion of the universe is governed by two terms of quantum origin. The first is proper to the quantum Mixmaster model and corresponds to the energy of the wave in an eigenstate. It is proportional to the energy level number. The second, which is more universal, corresponds to the repulsive potential preventing the singularity. The lowest energy eigenstates of this system are interpreted as the quantum Friedmann universe supplemented with vacuum fluctuations of the anisotropy.

Beyond issues of singularity resolution, the Friedmann-like equation describes two novel and rather surprising properties of the quantum dynamics. Firstly, the anisotropic degrees of freedom remain in their lowest energy states during the quantum phase consistent with our approximation. This implies that the quantum Friedmann model, unlike its classical counterpart, is in fact stable with respect to the anisotropy. Therefore, the classical chaos is suppressed within the considered domain. Secondly, during the contraction the quantum energy of anisotropy grows much slower than it does on the classical level. Namely, it effectively gravitates as radiation leading to a significant reduction in the overall gravitational pull from anisotropy due to quantum effects.

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Hydrodynamics beyond the gradient expansion: resurgence and resummation

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The past 15 years have witnessed the rise of the practical importance of relativistic viscous hydrodynamics. One reason for this is the success of hydrodynamic modelling of the quark-gluon plasma (QGP) in heavy ion collision experiments at RHIC and LHC and the realization that the QGP viscosity provides a crucial probe of QCD physics. The perfect fluid approximation is widely used in astrophysics and this theoretical description of relativistic inviscid fluids is rather well-established. On the other hand, relativistic viscous hydrodynamics is much less well understood. One of the issues is that of causality, which is violated in the relativistic version of Navier-Stokes theory, making it necessary to include higher order gradient corrections.

One of the recent insights is to regard hydrodynamics as a systematic gradient expansion, much in the spirit of low-energy effective field theory. However, the requirement of causality leads to a framework which necessarily incorporates very large momenta (and frequencies). In all known examples this is accompanied by the appearance of short-lived excitations: non-hydrodynamic modes. It has recently been shown, in the context of the AdS/CFT correspondence, that their presence leads to the divergence of the hydrodynamic gradient series for strongly coupled N=4 super Yang-Mills (SYM) plasma. In view of this it is not clear whether or how a naive gradient expansion defines the theory. This is in fact a fundamental conceptual question concerning relativistic hydrodynamic as such.

In our work [1] we proposed a definite answer: since the non-hydrodynamic modes decay exponentially, the system relaxes to an attractor regardless of when an initial condition is set. We consider a simple situation in which this can be made completely explicit: the Israel-Stewart theory specialized to a longitudinally expanding conformal fluid. We show that the attractor (see Fig. 1) can be determined by relaxation from solutions which take the form of a trans-series. The higher orders of this trans-series are encoded in the divergent hydrodynamic gradient expansion, in line with expectations based on resurgence ideas.

In our setting, we have calculated the gradient expansion of the boost invariant Israel-Stewart hydrodynamic theory up to very high order (200) and showed that the series is divergent. The precise manner in which this occurs encodes the relaxation time of the non-hydrodynamic mode present in Israel-Stewart theory.

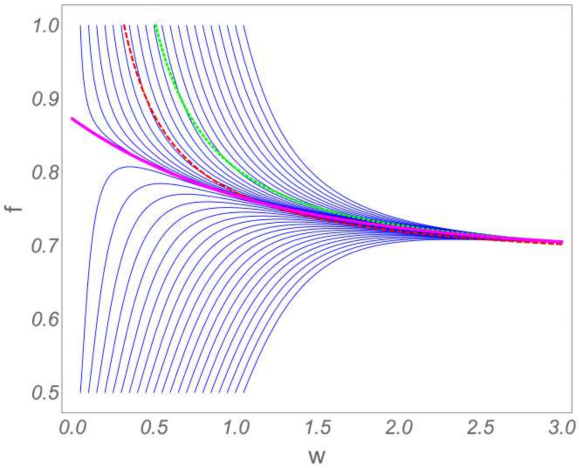

Fig. 1. The attractor of Israel-Stewart theory for boost invariant flow.

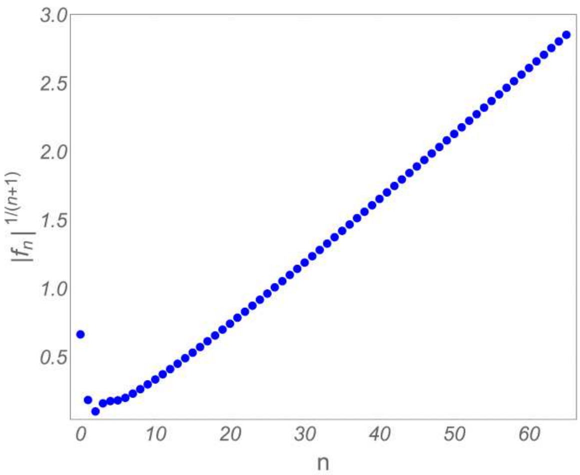

Fig. 2. The expansion coefficients of the pressure anisotropy diverge factorially at high order.

Borel summation fails due to the presence of a singularity on the real axis in the Borel plane; the answer is complex, which is clearly unphysical. However, one has to recognize that the hydrodynamic series is in fact an element of a trans-series, which captures an infinite set of exponential and non-analytic corrections. Taking these into account cancels the imaginary part and yields an answer consistent with the presence of the attractor.

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Neutrino production of a charmed meson and the transverse spin structure of the nucleon

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The transverse spin structure of the nucleon - that is the way the quark and antiquark spins share the polarization of a nucleon, when it is polarized transversely to its direction of motion - is almost completely unknown. The transversity distributions which encode this information have proven to be among the most difficult hadronic quantities to access. This is due to the chiral odd character of the quark operators which enter their definition; this feature enforces the decoupling of these distributions from most measurable hard amplitudes.

It is now well established that generalized parton distributions (GPDs) give access to the internal structure of hadrons in a much more detailed way than parton distributions (PDFs) measured in inclusive processes, since they allow a 3-dimensional analysis. The study of ex- clusive reactions mediated by a highly virtual photon in the generalized Bjorken regime benefits from the factoriza- tion properties of the leading twist QCD amplitudes for reactions such as deeply virtual Compton scattering. A welcome feature of this formalism is that spin related quantities such as helicity or transversity GPDs may be accessed in reactions on an unpolarized nucleon.

Neutrino production is another way to access (generalized) parton distributions. Neutrino induced cross sections are orders of magnitudes smaller than those for electroproduction and neutrino beams are much more dif- ficult to handle than charged lepton beams; nevertheless, they have been very important in scrutinising the flavour content of PDFs, and the advent of new generations of neutrino experiments will open up new possibilities. We want to stress that they can help to access the elusive chiral-odd generalized parton distributions.

In Ref. [1] we consider the exclusive reactions

nul(k)N(p1) → l−(k′)D+(pD)N′(p2)

a-nul(k)N(p1) → l+(k′)D−(pD)N′(p2),

in the kinematical domain where collinear factorization leads to a description of the scattering amplitude in terms of nucleon GPDs and the D−meson distribution amplitude, with the hard subprocess (q = k′ − k; Q2 = −q2):

W+(q)d → D+d′   and   W−(q)u → D−u′ ,

described by the handbag Feynman diagrams, as shown below. We have demonstrated that the transverse amplitude WT q → Dq′ gets its leading term in the collinear QCD framework as a convolution of chiral odd leading twist GPDs with a coefficient function of order mc/Q2 (to be compared to the O(1/Q) longitudinal amplitude) and that it should be measurable in near future experiments at neutrino factories.

The main results of our study are

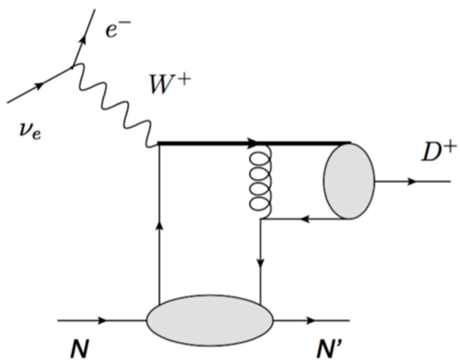
• Collinear QCD factorization allows the calculation of neutrino production of D−mesons in terms of GPDs.

• Chiral-odd and chiral-even GPDs contribute to the amplitude for different polarization states of the W boson .

• The azimuthal dependence of the cross section allows access to chiral-odd GPDs.

• There is no small factor preventing the measurement from being feasible, provided the skewness ξ and the ratio of the charm quark mass to the W's virtuality are not too small.

Planned high energy neutrino facilities which have their scientific programme oriented towards understanding of neutrino oscillations or the elusive inert neutrinos may thus allow - without much additional equipment - some important progress in the realm of hadronic physics.



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The combined analysis of ν_μ and ν_e data samples in the T2K experiment

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The existence of neutrino periodic flavour change (oscillations) was confirmed over 10 years ago [1,2] and honoured with the Nobel prize in 2015. The most important task for currently running and planned experiments is to investigate closely the three-flavour oscillation paradigm by precise measurement of the θ_{23} mixing angle, resolution of the mass hierarchy and a search for CP violation in the lepton sector.

While the mass hierarchy can also be determined in reactor experiments, CP violation can be found only in the appearance oscillation mode, which was discovered at T2K [3]. T2K [4] is a 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 neutrino mixing parameters through measurement of oscillations of muon neutrinos. A very pure beam is produced using the accelerator complex at Tokai in Japan and sent towards the SK detector 295km away, with an off-axis angle of 2.5 degrees. T2K can study 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.

A set of Near Detectors is located 280m from the neutrino production point to measure the unoscillated beam. The off-axis detector, 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 reaction types (quasi-elastic, resonant and deep inelastic) and samples different neutrino energy ranges. The samples are then used in the fit of neutrino energy flux and cross section parameters used to model neutrino interactions in Monte Carlo simulation. The multi-dimensional fit is performed based on distributions of reconstructed muon candidate angle and momentum. As a consequence of the ND280 measurement the expected 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 2.7% for ν_μ induced events and 3.2% for events originated by interactions of ν_e, while without the ND280 constraints these uncertainties would be as large as 21.7% and 26.0%, respectively.

The NCBJ group participates 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.

T2K started to take data in 2010 and collected 6.6×10^{20} protons on target till the end of 2013. The results obtained on the ν_e appearance and ν_μ disappearance have already been published [4,5]. In 2015, T2K published the results of the combined ν_μ–ν_e analysis, in which both $\nu_\mu \rightarrow \nu_e$ and $\nu_\mu \rightarrow \nu_\mu$ oscillation channels were used simultaneously [6].

Fig. 1. Members of the Warsaw Neutrino Group with the 2015 Nobel Prize winner Takaaki Kajita, who is also working in T2K.

In the oscillation analysis the event rates and distributions of the reconstructed neutrino energies for the observed ν_μ and ν_e candidate events are compared with the model predictions. To calculate the ν_μ disappearance and ν_e appearance probabilities, the complete formulas were used, including matter effects. Four oscillation parameters were fit simultaneously: $|\Delta m^2_{32}|$, θ_{23}, θ_{13} and δ_{CP}. The rest of the oscillation parameters were based on external measurements and allowed to change within their errors. The fits were performed separately for both mass hierarchy assumptions.

The analysis was done using the frequentist and Bayesian approaches and the best set of oscillation parameters is such that it minimizes the negative log-likelihood function or maximizes the posterior probability density, respectively.

The best fit points and 90% confidence regions are presented on the two-dimensional plots showing Δm^2_{32} versus $\sin^2\theta_{23}$ on Fig.2 and δ_{CP} versus $\sin^2\theta_{13}$ on Fig. 3. The results, in which only T2K data were used, are shown in red.

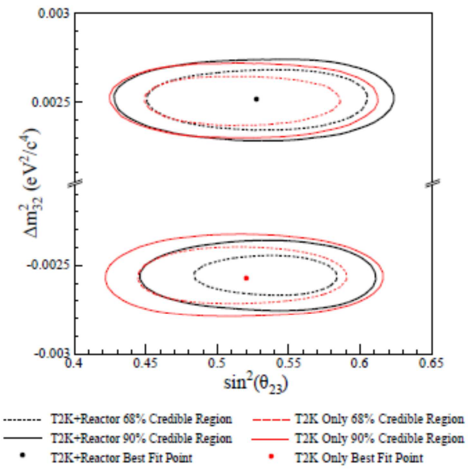

Fig. 2. The T2K 2015 results for the combined ν_μ–ν_e analysis. The loops show the allowed regions of $\sin^2\theta_{23}$ and Δm^2_{23} at 68% (dashed line) and 90% (solid line) confidence level.

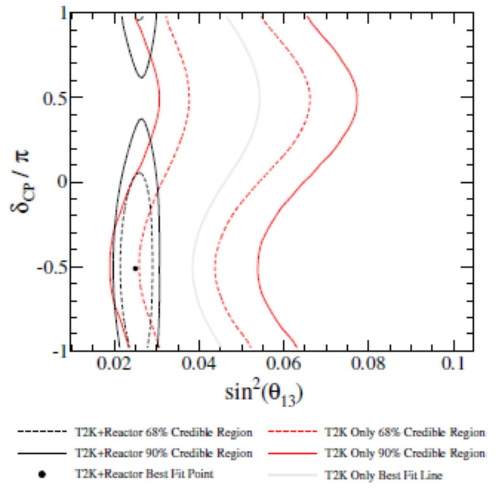

Fig. 3. The T2K 2015 results for combined ν_μ–ν_e analysis. The loops show the allowed regions of $\sin^2\theta_{13}$ and δ_{CP} at 68% (dashed line) and 90% (solid line) confidence level.

The fit using only T2K data has little power to constrain δ_{CP}. Therefore, the reactor measurement of θ_{13} was included, as additional constraint term in the likelihood or posterior probability. The black contours on Figs. 2 and 3 are obtained with the additional information from reactor experiments. The fits show weak preference for $\delta_{CP} = -\pi/2$ and the normal mass hierarchy. For the first time, some regions of possible values of δ_{CP} were excluded at 90% confidence level: [0.15, 0.83] π for normal mass hierarchy and [-0.08, 1.09]π for inverted hierarchy.

In order to find or better constraint the value of δ_{CP} T2K plans to collect more data, in particular using antineutrino beam, to measure $\bar{\nu}_e$ appearance probability and compare it to ν_e probability. The first antineutrino events were recorded in 2014 and the data taking continued in 2015.

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NUCLEAR PHYSICS

Strong multistep interference effects in ^{12}C(d,p) to the 9.50 MeV 9/2$^+$ state in ^{13}C

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The strong population of the narrow (≤ 5 keV) 9.50 MeV 9/2$^+$ resonance in ^{13}C via the ^{12}C(d,p) reaction provides an excellent case study for testing two-step reaction models. The observed population and narrow width are incompatible with a simple $0^+ \otimes g_{9/2}$ single particle structure for this level, and structure calculations, e.g. Refs. [1,2], predict a dominant contribution from the $2^+ \otimes d_{5/2}$ configuration built on the 4.44 MeV 2$^+$ excited state of the ^{12}C core. Contributions from configurations built on the 14.08 MeV 4$^+$ state of ^{12}C were shown to have a negligible effect on the results of CCBA calculations [1] although they did make significant contributions to the wave function. To date, possible contributions from configurations built on the 9.63 MeV 3$^-$ state of ^{12}C had not been considered. The original motivation of this work was therefore to search for the influence of hypothetical components of this type on the measured ^{12}C(d,p) angular distribution for stripping to the 9.50 MeV 9/2$^+$ resonance at an incident deuteron energy of 30 MeV [1].

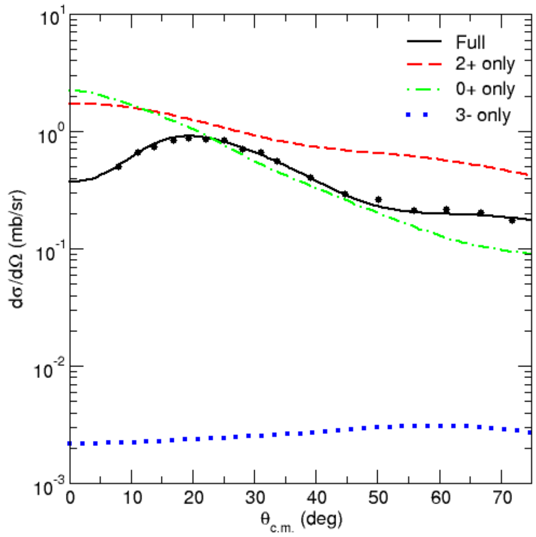

Fig. 1. CRC calculations for ^{12}C(d,p) to the 9.50 MeV 9/2$^+$ resonance of ^{13}C at E_d = 30 MeV. The data (filled circles) are from Ref. [1]. The solid curve denotes the full calculation, the dashed curve 2-step transfer via the ^{12}C 2$^+$ only, the dot-dashed curve direct 1-step transfer via the ^{12}C 0$^+$ and the dotted curve 2-step transfer via the ^{12}C 3$^-$ only..

In a recent publication [3] we presented CRC calculations including two-step paths via the 2$^+$ and 3$^-$ states of ^{12}C as well as the direct path. We limited the configurations built on the excited states of the core to the $2^+ \otimes d_{5/2}$ and $3^- \otimes f_{7/2}$ which we considered to be the most important. Spectroscopic amplitudes for all transfer paths were varied to obtain the best description of the experimental data of Ref. [1]. Full details of the calculations are given in Ref. [3].

In Fig. 1 we show the results of our calculations. It will be seen that the good fit of the full calculation is the result of strong interference between direct and two-step transfer via the ^{12}C 2$^+$ state (the contribution from the two-step transfer via the ^{12}C 3$^-$ state is much smaller but is necessary to give the good description of the data at the larger angles). The best fit values for the spectroscopic amplitudes, together with the mixing ratios, are given in the Table.

Component	Spectroscopic amplitude	Mixing ratio (%)
$0^+ \otimes g_{9/2}$	−0.17	1.57
$2^+ \otimes d_{5/2}$	1.33	93.0
$3^- \otimes f_{7/2}$	0.32	5.40

Note that in spite of its small mixing ratio the contribution of the $0^+ \otimes g_{9/2}$ component is comparable to the dominant $2^+ \otimes d_{5/2}$ while that of the $3^- \otimes f_{7/2}$ component is almost two orders of magnitude smaller. This “kinematic” effect, due to the need to find the extra energy to excite the ^{12}C core for these two-step paths, sets important limitations on the extraction of “empirical” mixing ratios from direct reaction data. It may well occur that reaction data are more sensitive to the smallest components of the wave function because of this.

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Determination of impact parameters in aligned breakup of projectile-like fragments in ^{197}Au + ^{197}Au collisions at 23A 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 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	AF1	AF2	TKE* MeV)	L (h)
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 ≈ 1000-1100 ħ (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 $L_{graz} \approx 1570$ ħ.

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†Deceased

Candidates for long-lived high-*k* ground states in superheavy nuclei

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On the basis of systematic calculations for 1364 heavy and superheavy (SH) nuclei, including odd systems, we have found a few candidates for high-K ground states in superheavy nuclei. The macroscopic-microscopic model based on the deformed Woods-Saxon single-particle potential that we use offers a reasonable description of SH systems, including known nuclear masses, Qα values, fission barriers, ground state (g.s.) deformations, and super- and hyperdeformed minima in the heaviest nuclei. Exceptionally untypical high-K intruder components of the g.s. found for some nuclei, accompanied by a sizable excitation of the parent configuration in the daughter, suggest a dramatic hindrance of the α decay, shown in Fig1.

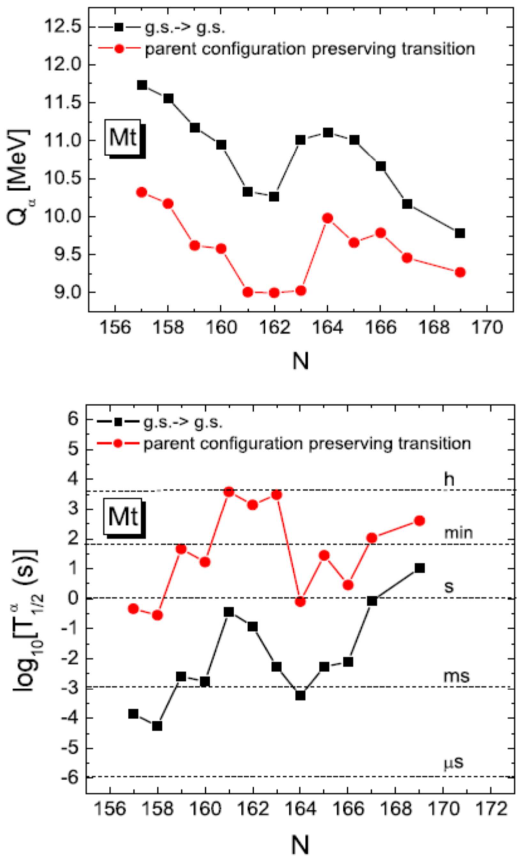

Fig. 1. Qα values calculated with blocking following from the WS model and the increase in α half-life.

Multidimensional hypercube configuration-constrained calculations of the potential energy surfaces (PESs) for one especially promising candidate, 272Mt, show a 6MeV increase in the fission barrier above the configuration-unconstrained barrier.

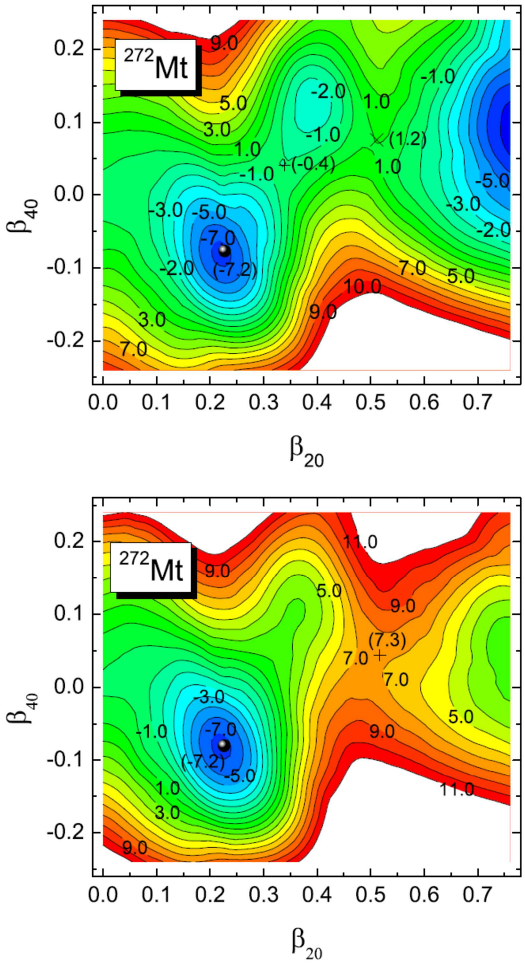

Fig. 2. Calculated vs experimental Q alpha values and α half-lives for the decay chain of Z = 117, A = 294.

It is possible that one such high-K ground or low-lying state may be the longest-lived superheavy isotopes.

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PLASMA PHYSICS & TECHNOLOGY

Investigation of visible radiation emitted from HOT plasma streams and interactions of such streams with solid targets*

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In the first quarter of 2015 the authors made the final revisions of a paper presented at the 15th LAWPP in 2014 and published in J. Phys. [1], describing experimental studies of the physics and applications of plasma streams produced by plasma-focus discharges, performed within the framework of an international collaboration.

Final revisions were also made to a paper, presented at the same conference and published in J. Phys. [2], on the interaction of high-power plasma streams with samples of different grades of tungsten. Particular attention was focused on surface profile development in the course of irradiation, as shown in Fig. 1.

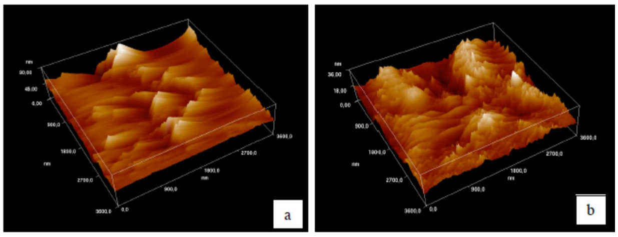

Fig. 1. AFM images of single forged tungsten sample: a – the initial surface, b – the surface exposed to 10 pulses of a 0.75 MJ/m^2 plasma stream.

Much experimental effort was devoted to an analysis of data obtained during optical emission measurements of plasma streams which were generated within a modified PF-1000U facility operated without and with additional gas puffing. An example of the optical spectrum is shown in Fig. 2.

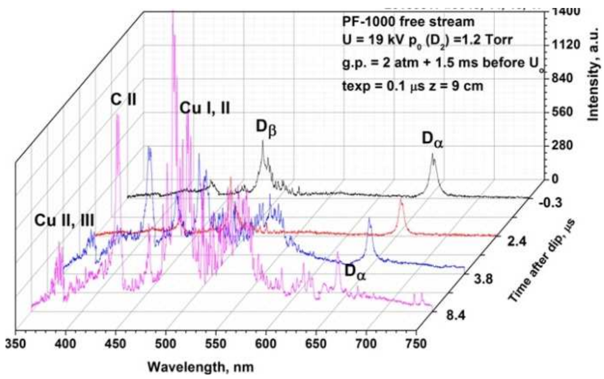

Fig. 2. Changes of optical spectra from plasma produced within the PF-1000U facility with gas-puffing about 1.5 ms before the discharge initiation.

A detailed analysis of the recorded spectra enabled changes in the D_α line profile to be determined, as shown in Fig. 3.

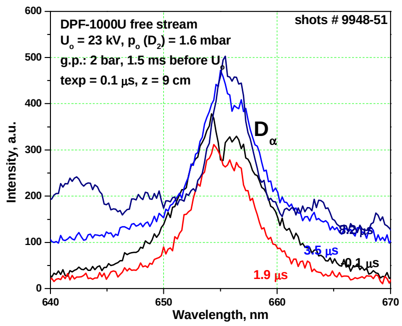

Fig. 3. Changes of the D_α line profile observed at different instants after the current peculiarity (dip) for a discharge performed with gas-puffing about 1.5 ms before discharge initiation.

This was the basis for estimates of temporal changes in the electron concentration of the investigated plasma streams. The analysis and the data obtained were presented in a paper that was published in Nukleonika [3].

Results of other experimental research on intense plasma stream interactions with targets made of tungsten, obtained within the PF-1000U facility, were analyzed by a joint Polish-Ukrainian team. Particular attention was focused on identification of tungsten spectral lines and determination of mass-losses caused by the irradiation of the investigated W-samples, as shown in Table 1.

Table 1. Weights of the investigated W-samples.

	W-sample after 1 shot	W-sample after 3 shots	W-sample after 5 shots
Initial mass [g]	8.2804	8.6732	8.4694
Loss of mass [mg]	0.4	2.5	2.0

The results of spectroscopic measurements and sample analyses were presented in a separate paper published in Nukleonika [4].

The Polish-Ukrainian team also elaborated results of optical emission measurements, performed during free propagation of pulsed plasma streams within the PF-1000U facility and during their interaction with carbon-fibre composite (CFC) samples. During experiments with CFC targets different CII and CIII spectral lines were recorded and identified, as shown in Fig. 4.

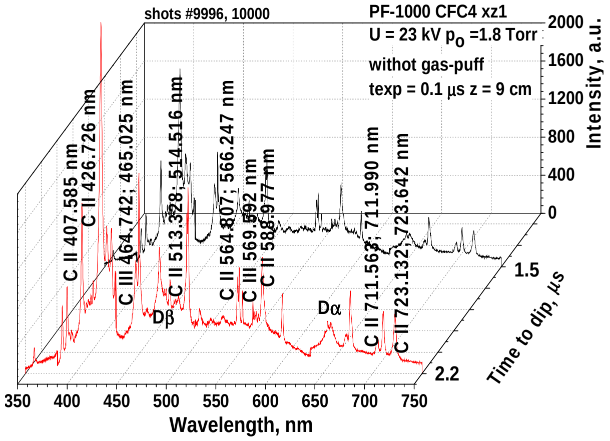

Fig. 4. Temporal changes in the optical spectrum measured near the CFC-target surface in the PF-1000U facility.

The observation of these spectral lines at different instants after the current dip enabled the erosion dynamics of the CFC target to be estimated. Detailed results were published in Probl. Atom. Sci. Technol. [5].

Optical emission spectra from plasma streams and plasma produced from different targets in PF-1000U experiments were also analyzed in a paper presented at a Joint ICTP-IAEA Advanced School in Trieste [6].

Another task was research on interactions of plasma streams with CFC targets within an RPI-IBIS (rod plasma injector) facility. In addition to optical spectra surface changes of the irradiated targets, were investigated as shown in Fig. 5.

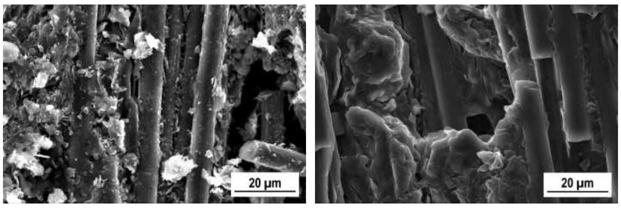

Fig. 5. Comparison of SEM images of a virgin CFC sample (left) and that irradiated by 10 discharges (right). Both images were obtained at a magnification of 3000x.

In order to study the morphology of irradiated CFC samples, their surfaces were also analyzed by means of an EDS (energy dispersive spectroscopy) technique. The obtained EDS images showed that some impurity ions,are also deposited an the irradiated forget surfece e.g., ions from the applied metal electrodes. The results of the measurements were reported at the PLASMA-2015 international conference and submitted for publication in Nukleonika [7].

Results of earlier studies of plasma interactions with pure (99.95%) tungsten targets, obtained in the PF-1000U facility, were summarized and analyzed. Particular attention was focused on comparison of different parts of the optical spectra and identification of W-lines, as shown in Fig. 6.

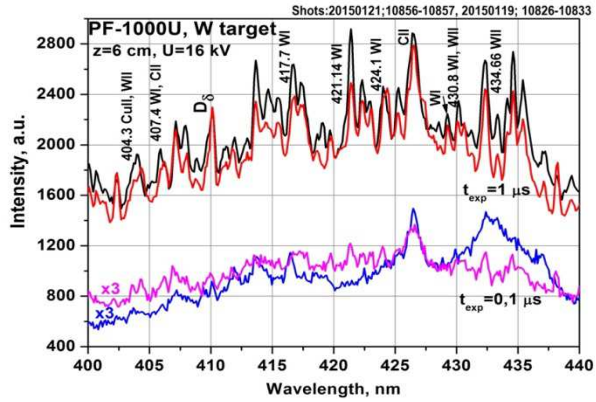

Fig. 6. Optical spectra in the range of λ = 440-480 nm, recorded near the irradiated W-target surface at different exposition times (0.1 μs and 1 μs), obtained during4 plasma discharges (marked by different colours).

To investigate changes in the target surface morphology induced by plasma streams, an additional analysis was performed by means of an optical microscope. The results were reported at the PLASMA-2015 conference and submitted for publication in Nukleonika [8].

The main experimental results of the studies described above can be summarized as follows: 1. Optical emission spectra were recorded for pulsed plasma streams during their free propagation and during their interactions with different targets (CFC, W, W alloys); 2. Analysis of the D_β line enabled temporal changes of the plasma electron density to be determined; 3. Temporal changes of spectral lines originating from exited atoms and ions, which were produced from the irradiated targets, enabled the target erosion dynamics to be studied; 4. Microscope-, EMS- and EDS-images of the irradiated targets were helpful in estimation of changes in morphology of the samples.

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[10] * Collaboration with IFPiLM and IPP KIPT.

Studies of X-rays, ions and neutrons emitted from plasma facilities of the RPI- and PF-type

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In the first quarter of 2015 the joint experimental team completed corrections of a revised paper on studies of the anisotropy of fusion-produced protons and neutrons emitted from high-current plasma discharges. These studies were performed using so-called "sandwich-detectors", which were composed of an Al-filter absorption and two PM-355 nuclear track detectors separated by a neutron-proton converter made of polyethylene. Detailed measurements performed within a modified PF-1000U facility enabled the anisotropy to be determined, as shown in Fig. 1.

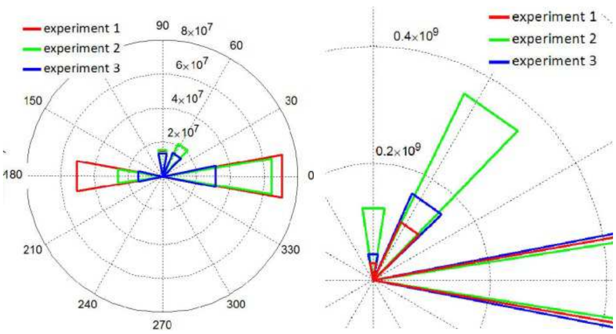

Fig. 1. Anisotropy of the fusion-produced neutrons (left) and protons (right) measured in 3 experiments. The numbers of tracks are given after normalization to a steradian.

The applied detectors as well as detailed results of these measurements were described in a paper published in Rev. Sci. Instr. [1].

The results of earlier measurements of fast ion beams emitted from plasma discharges in the PF-1000U facility were analysed. The ion beams were recorded by means of a pinhole camera equipped with a PM-355 track detector, and their microstructure was investigated, as shown in Fig. 2.

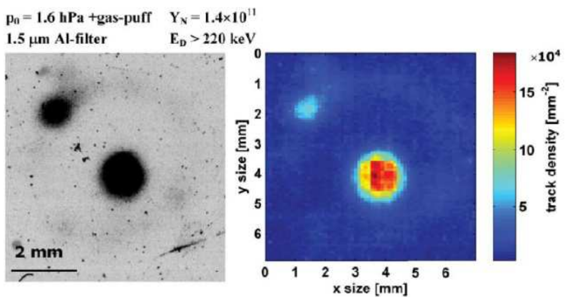

Fig. 2. Image and density map of deuteron beams of energy > 220 keV emitted from a single PF-1000U discharge.

Energy distributions of the emitted ions were determined by means of a Thomson-type analyser. The analysed experimental data were presented in a revised paper published in Nukleonika [2].

The earlier energy- and time-resolved measurements of fast ions from the PF-1000U facility, which were performed with the Thomson analyser, placed at a distance 135 cm from the electrodes outlet and equipped with miniature scintillation detectors, were also analysed. Signals of deuterons, which were obtained from different energy channels, were compared to determine the periods of fast deuteron emission, as shown in Fig. 3.

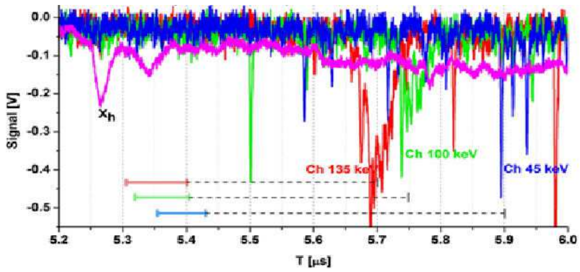

Fig. 3. Deuteron signals from 3 energy channels of the Thomson analyser and a signal from a scintillation probe (recording hard X-rays and neutrons). Straight lines mark periods when the deuterons could be emitted.

The detailed analysis of the deuteron emission was reported at an international symposium and published in Proc. SPIE [3].

The ion studies described above were also reported at the 1st European Conference on Plasma Diagnostics, held in Frascati, Italy, and published in Proc. of Sci. [4].

Different methods of electron- and ion-diagnostics, applied in various PF studies and applicable also to measurements in tokamaks, were compared. Particular attention was focused on various versions of Cherenkov-type probes used in different tokamak experiments and new ion probes, which were developed for measurements of fast ions (including those produced by nuclear fusion reactions) in tokamaks. An ion pinhole camera, which enables irradiation of several nuclear track detectors during a single tokamak discharge, was described as well as a miniature Thomson-type spectrometer, which can be used for ion measurements at plasma borders. These diagnostic methods were summarized in a paper published in Nukleonika [5].

The most important problems which have to be solved before construction of future thermonuclear reactors were also analysed. Attention was paid to the fact that fossil fuels pollute the environment, energy from renewable sources is very dilute and costly, and energy from conventional nuclear fission reactors is also not a good option, because such facilities produce many radioactive wastes. Therefore, it will be necessary to exploit fusion energy in the near future. In order to construct an efficient fusion reactor, however, it is necessary to solve many difficult technical problems, as discussed at the PME conference and described in a paper published in Nukleonika [6].

During the whole of 2015 the joint NCBJ-IFPiLM team also continued experimental studies of the X-ray emission from PF discharges. Results of the earlier measurements of soft X-rays from the PF-1000U facility were analysed and summarized. Particular attention was paid to X-ray pinhole images which demonstrated the appearance of plasma filaments or "hot-spots", as shown in Fig. 4.

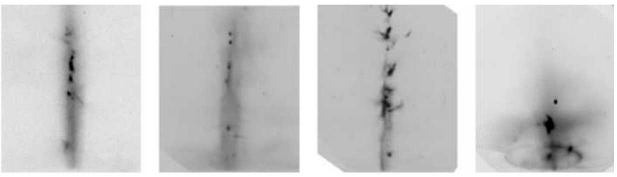

Fig. 4. Time-integrated X-ray pinhole images, as obtained from 4 discharges (from left to right - shots #9987, #10143, #10144 and #10338, performed at p_0 = 2.0-2.4 hPa D_2 and D_2 puffing), which show distinct "hot-spots".

The analysed X-ray images and results of preliminary time-resolved measurements of X-ray pulses were presented in a revised paper published in Nukleonika [7].

The NCBJ-IFPiLM team also performed a very detailed analysis of the recorded time-integrated X-ray images, as shown in Fig. 5.

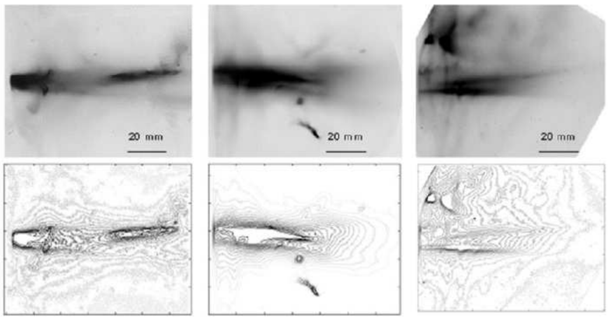

Fig. 5. Analysis of X-ray pinhole images and corresponding density contours, which show the appearance of distinct plasma filaments in 3 different discharges (from left to right): shot #10080, #10230 and #10333, performed at p_0 = 2.0 hPa D_2 and D_2 puffing.

The team also analysed the results of time-resolved measurements performed with 4 PIN diodes located behind filtered pinholes, which observed different regions of a dense plasma column, as shown in Fig. 6.

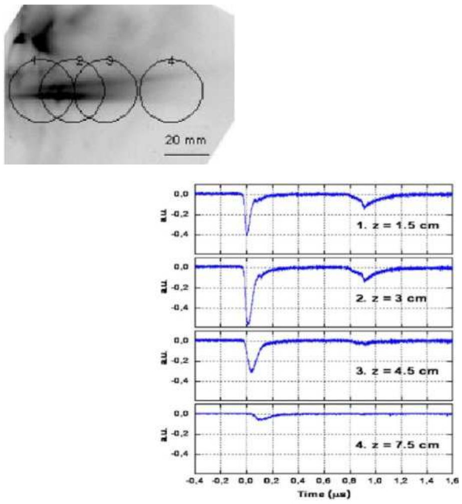

Fig. 6. Time-integrated X-ray image (with marked observation fields) and time-resolved X-ray signals from PIN diodes, as recorded for shot #10333 (shown earlier in Fig. 5).

The most important results of the studies performed by the NCBJ-IFPiLM team were reported at the ICOPS conference and presented in a paper published in PSST [8].

Much experimental effort was also devoted to measurements of fast electron beams emitted from a modified PF-360U facility, mostly in the upward direction through a central channel in the anode. For this purpose use was made of magnetic analysers equipped with miniature Cherenkov or scintillation detectors. A general view of a small magnetic analyser is shown in Fig. 7.

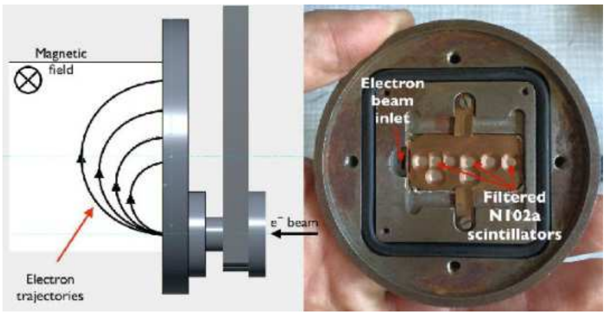

Fig. 7. Side-on view of the small magnetic analyser with a 180^0 deflection of the analysed electrons (left) and a view of the plate with miniature scintillation detectors (right).

The results of the studies described above were reported at the PLASMA-2015 international conference and presented in a paper submitted for publication in Nukleonika [9].

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Studies of fast electron streams in tokamaks with Cherenkov-type diagnostics

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High-temperature plasmas in tokamaks usually contain large populations of high-energy electrons and ions. Investigations of fast electrons produced in the plasma and escaping from tokamak-type facilities are of particular interest for diagnostics, because such electrons deliver information about processes occurring inside the bulk plasma. From the practical point of view the control of intense high-energy electron beams, which can damage the first wall, also plays a significant role because it enable us to avoid or to mitigate disruptions during tokamak operation.

Experimental and theoretical studies, performed in order to determine the conditions of runaway electron generation and to investigate mitigation techniques, were started at the IPP ASCR in Prague in 2014, as part of the MST-2 project realised in the framework of the EUROfusion Consortium. Such studies were also continued in 2015. A team from the National Centre for Nuclear Research (NCBJ) proposed to apply Cherenkov-type probes to fast electron measurements, because of the high spatial- and temporal-resolution of such detectors.

New single- and multi-channel Cherenkov detectors were installed within the COMPASS tokamak during the spring and autumn campaigns in 2015. During the spring campaign some very short time-resolved Cherenkov signals were recorded, with the help of the single-channel detector, in addition to the often observed long-lasting signals. For the autumn campaign a new multichannel Cherenkov detector was constructed and manufactured. It was equipped with three channels with radiators made of CVD diamond crystals, which were covered by different filters in order to establish various lower-energy detection thresholds: 58 keV, 145 keV and 221 keV. The first channel of the probe was roughly calibrated with a 100-keV electron beam taken from an accelerator.

Preliminary measurements of runaway electrons during the autumn campaign were also performed. Signals from the Cherenkov probe channels were correlated with the fusion-produced neutrons and hard X-rays, but during numerous shots some electron-induced spikes were recorded in the Cherenkov channels only (see Fig. 1).

The results of the earlier experimental campaigns, which were carried out within the FTU tokamak with the single-channel detector, were summarized in two papers [1-2]. During recent studies within the FTU tokamak in Frascati a new kind of modulated signal was found

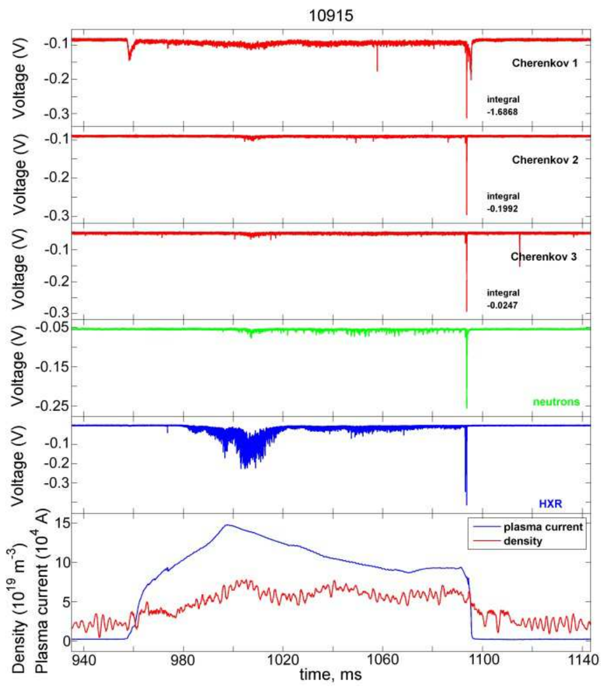

Fig. 1. Comparison of neutron and hard X-ray signals (HXR) with electron-induced signals from a three-channel Cherenkov detector (signal intensity [V] versus time [ms]). Fast runaway electrons were recorded mainly during a discharge disruption.

and interpreted [1]. In the course of more detailed studies the Cherenkov-signals were correlated with a whole variety of data collected from other diagnostics, including X-ray and gamma-ray signals, neutron detectors, electron cyclotron emission, and the Mirnov coils used for investigation of MHD instabilities [2]. In addition to the first observation of the correlation between runaway electrons and the evolution of magnetic islands, some disruptions caused by the injection of deuterium pellets were recorded. Other correspondences of the observed phenomena will be the subject of further studies, both theoretical and experimental ones.

A summary of the results obtained in the design and construction of Cherenkov-type measuring heads, as well as in experimental studies of fast electron beams within the CASTOR, ISSTOK, TORE-SUPRA, and FTU facilities, was presented in [3]. Another paper presented a development of the measuring head construction designed for different tokamak devices, and in particular the specific issues of signal acquisition to a data storage system [4].

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Metastable alloy layers obtained by the impulse plasma deposition method

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The pulsed plasma in impulse plasma deposition (IPD) synthesis is generated in a coaxial accelerator by strong periodic electrical pulses, and is distributed in the form of energetic plasma packets [1]. A nearly complete ionization of gas, in these conditions of plasma generation, favours the nucleation of a new phase of ions and the synthesis of metastable materials in the form of coatings which are characterized by amorphous and/or nanocrystalline structure. In this work, an Fe–Cu alloy, which is immiscible in the state of the equilibrium, was selected as a model system to study the possibility of formation of a non-equilibrium phase during IPD synthesis.

In our work, we studied the structure of the Fe–Cu alloy layers formed during impulse plasma deposition (IPD) synthesis [2]. The obtained phase structure was characterized by the presence of single-phase supersaturated solid solutions: bcc-Fe(Cu) in the case of the Fe-rich layer and fcc-Cu(Fe) in the case of the Cu-rich layer, which were formed in these immiscible systems. Single phases, bcc and fcc, occurred in the Fe–Cu layers with a copper content less than about 25 at.% and with a copper content larger than about 50 at.%, respectively. Structural characterization of the layers was done by means of X-ray diffraction (Fig 1).

The lattice parameters of both structures were larger than those of pure Fe and pure Cu. The results of our investigation showed that the phase composition of the layer material synthesized by IPD was dependent on the atomic mixing effect between the layer components delivered to the substrate independently and separately in time. The solubility in the Fe–Cu system was extended relative to the equilibrium state. This demonstrates that the IPD method is successful in producing metastable structures of alloy layers in a large composition range.

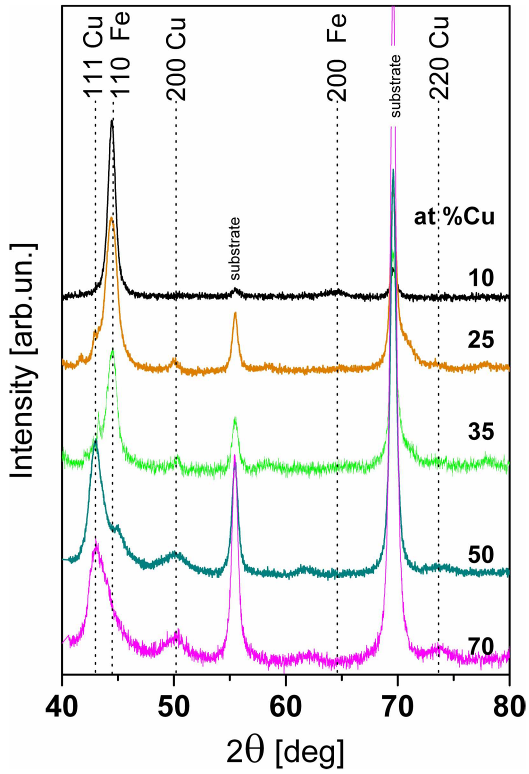

Fig. 1. X-ray diffraction patterns of Fe–Cu alloy layers obtained by the impulse plasma deposition method.

A schematic diagram of the solid solutions of the Fe–Cu system (the phase boundary) produced by various methods, compared to the equilibrium phase boundary at room temperature is illustrated in Fig. 2. As one can see, good results, i.e. the extension of the single-phase zones, especially the fcc single-phase zone, are achievable in the case of the mechanical alloying method, but also in the case of plasma surface engineering methods.

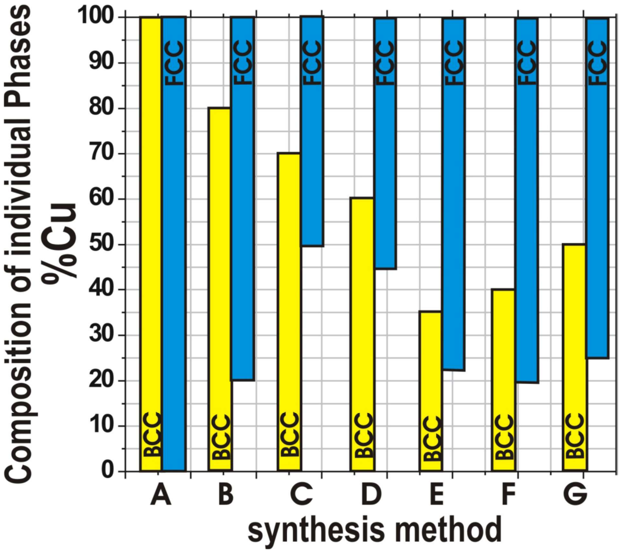

Fig. 2. Metastability regions of the structure of Fe–Cu alloy obtained by different methods supplemented by the results of our study. Phase boundaries obtained by: (A) equilibrium phase boundary at room temperature, (B)liquid quenching, (C) vapour deposition, (D) electrodeposition, (E)sputtering on cryogenic substrates, (F) mechanical alloying, and (G) the IPD method (this work).

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High intensity plasma pulses for the modification of alumina ceramic

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Alumina ceramic with its good (also high-temperature) mechanical (wear), physical (electrical resistivity, thermal conductivity) and chemical (corrosion) properties is still a very popular material in modern engineering (electronics, high vacuum techniques, nuclear techniques, aerospace, automobiles, cutting tools, medical, biomaterials etc.)[1-5]. It is used e.g. as a substrate for functional structures or as a component of joints between different materials, including vacuum tight ones, where helium leak should be no higher than 1.3e-9 Pa/s)[6].

To improve the workability and reliability of ceramics, these materials must be combined with metals[7]. Usually, for technical applications, the metallic layers are deposited on the alumina ceramic. There are e.g.: (a) layers of high-melting point materials (like Mo and W) for high-temperature applications or as interlayers in ceramic-metal joints, (b) layers of noble materials (Pd, Ag, Au) and other materials (like Ti, Fe, Ni, Cu) for good electrical and thermal conductivity and/or as interlayers in ceramic-metal joints[8-9].

There are several methods (e.g. galvanic methods, arc methods or vacuum methods) which can be applied for the deposition of metallic layers on ceramic substrates. However, no universal technique for preparation of the surface has been developed thus far. We propose the use of the high-intensity pulse plasma beam, HIPPB, technique for the modification of alumina ceramic as a method characterized by its high universality. The HIPPB technique allows for melting of the superficial region of the modified surface and simultaneous introduction of a modifying element. The melting depth is about a few micrometres and the content of the introduced element is at a level of a few 10^{16} ions per cm^2 per pulse. The deposited layers are alloyed into the surface (not only adhesive joints), new phases can be created in the interface area and additionally there is the possibility of designing the depth profile of the introduced element (e.g. graded profile) to relax the generated stresses[10-11].

In our work, we used a Rod Plasma Injector (RPI) referred to as IBIS. The main parameters of the modification process were:

- modified materials: Al_2O_3 type ceramic, 0.5 mm thick,
- introduced material (layer material): Ti, Cr, Fe, Ni, Cu, Pd, W,
- working gas: Ar,
- number of pulses up: to 50, mono- and multienergetic pulses,
- energy density: from 1 J/cm^2 to 7 J/cm^2,
- regime of generator work: DPE (Deposition by Pulse Erosion).

Fig. 1 shows the selected EDS maps of the scratch-test track on Al_2O_3 ceramic with an Fe layer (for the start point, at 1/4, 1/2 and 3/4 of the scratch length, and for the finish point, magnification 500×). This sample was modified with 5, 10, 15 and 20 pulses with sequentially decreasing energy, i.e.: 7, 5, 3 and 1 J/cm^2 respectively.

The scratch length was 10 mm. The load force was 0-100 N per 10 mm.

We can see that the metallic layer has good adhesion to the ceramic substrate. Due to the alloyed deposited material, a classical crack does not occur. The scratch indenter compresses the deposited layer into the substrate. The bright areas, visible on the 2 last maps, are chipping of the substrate.

This kind of layer may be advantageous for some applications in comparison with conventional ones, for example as interlayers in ceramic-metal joints.

Acknowledgments
Many thanks to Mr. S. Karpisz, B. Staszkiewicz, J. Zagórski and D. Grygiel for technical assistance.

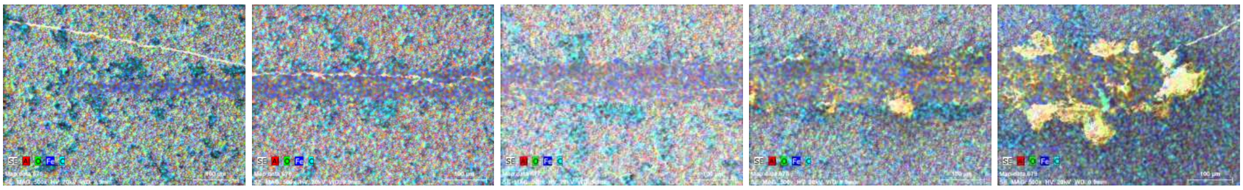

Fig. 1. EDS maps of a scratch-test track on an Al_2O_3 ceramic with an Fe layer (from the left: for the start point (load force 0 N), at 1/4, 1/2 and 3/4 of the scratch length (25 N, 50 N and 75 N respectively), for the finish point (100 N)); EDS colours: red - Al, green - O, blue - Fe, cyan - C.

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DETECTORS, ACCELERATORS, PHYSICS OF MATERIALS & APPLICATIONS

Applications of PM-355 nuclear track detectors to investigation of $^{11}B(p,2\alpha)\alpha$ reactions induced by pals-laser beams. Change in the sensitivity of track detectors for protons after long – term storage

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Laser-induced nuclear fusion reactions are nowadays investigated as an alternative approach for the production of fusion energy. In 2013 – 2015 NCBJ scientists were engaged in an experiment performed at the PALS laser in which the $^{11}B + p \rightarrow 3\alpha + 8.7$ MeV nuclear reaction was investigated in order to achieve the aforementioned goal.

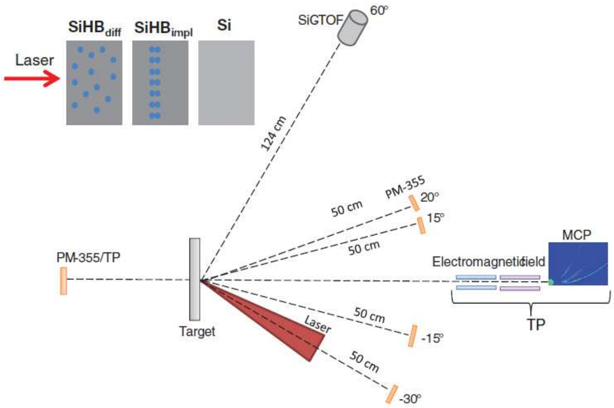

Fig. 1. The experimental setup; the inset shows a simple sketch of the three different target geometries used in the experiment.

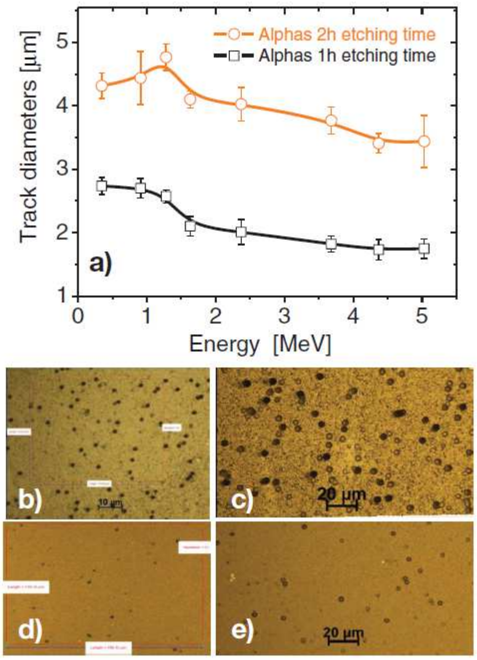

Fig. 2.(a) The alpha particles calibration curves; (b,c) Snapshot showing the craters produced by protons (small spots) and alpha particles (larger spots) for the thick Si-H-B_{impl} target, 1 and 2 h etching time; (d,e) snapshots showing the craters produced by protons for the thick Si target (without B) after a 1 and 2 h etching time.

The experiment is carried out by an international team and our scientists using suitably calibrated solid-state nuclear track detectors of the PM-355/CR-39 type, undertook to measure angular distributions and energy spectra of fast primary protons and alpha particles which are produced in the $^{11}B(p,2\alpha)\alpha$ reaction induced by laser beams. Some results obtained in this experiment were already presented in the NCBJ Annual Report – 2014.

Since the PALS – laser experiment was continued in 2015 and new data were obtained, we present the most important results in this issue of the NCBJ Annual Report. Figure 1 presents the experimental setup used in the experiment with both thick and thin targers. Figure 2 shows the alpha particle calibration curves of the detector after 1 and 2 h etching times and typical PM-355 snapshots (1 and 2 h etching times, respectively) obtained when the massive boron implanted hydrogenated silicon samples were irradiated [1-2].

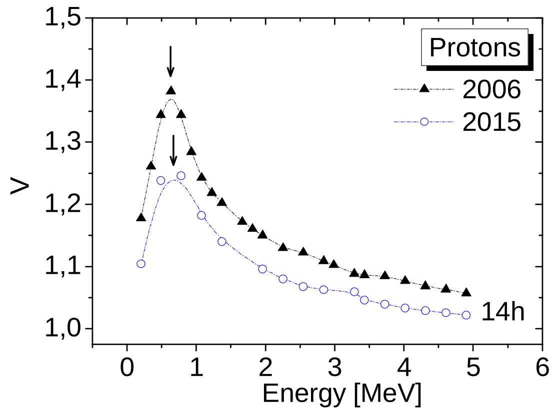

Fig. 3. Variation of the sensitivity function $V=V_T/V_B$ measured in 2006 and 2015. The arrows on the figures indicate the positions of the maxima of the sensitivity function.

Solid State Nuclear Track Detectors (SSNTDs) are widely used for dosimeter applications, as air radon concentration dosimeters, for neutron monitoring and in space research for investigations of the depth distribution of radiation in different organs of astronauts during long duration missions. These measurements are characterized by long-term exposure of up to a few months. It is known that exposure during space missions leads to the fading of CR-39 sensitivity. For practical applications the detectors require a calibration procedure which must be represented in the sensitivity measurements of the dose [3].

Changes in the sensitivity function $V = V_T/V_B$ (V_T - track etch rate; V_B - bulk etch rate) due to the ageing of CR-39/PM-355 type track detectors stored over a 9-year period have been studied using protons in the energy range 0.2 – 5 MeV. The track diameters were found to decrease as time passed from the detector exposure to etching, whereas the bulk etch rate V_B is not affected by ageing effects and remains almost constant over a nine year period of storage.The values of the sensitivity function V obtained in 2006 and 2015 are presented in Fig 3 versus proton energy and etching time 14 h. An examination of the sensitivity function V(E, t) from these figures clearly shows the following behaviour:

• It is evident that the sensitivity function obtained in 2015 is smaller than that in 2006. The reduction for 14 h etching time is about 15 % at the maximum and about 10 % in the region of proton energies 2 – 4 MeV;

• The positions of the maxima in 2006 and 2015 are about the same and the maxima indicate a small shift with etching time towards higher proton energies.

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The EUROfusion_NCBJ_JET4 project for gamma-ray detectors in plasma experiments

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The EUROfusion_NCBJ_JET4 Project for Gamma-Ray Detectors in Plasma Experiments is a four-year project realized within the European Joint Programme, co-financed by EURATOM, the Research and Training Programme of the European Atomic Community (2014 - 2018) Complementing Horizon 2020 - The Framework Programme for Research and Innovation, and partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of 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 Tokamak facility (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.

Members of the Nuclear Techniques & Equipment Department are participating in the development of detectors for gamma-ray diagnostics at JET.

At JET the α particle diagnostics are based on the $^{9}Be(\alpha,n\gamma)^{12}C$ nuclear reaction occurring between confined α particles and beryllium impurity ions typically present in the plasma. A 4.4 MeV gamma ray is emitted in the reaction:

$$^{9}Be+\alpha \rightarrow {}^{13}C \xrightarrow{n} {}^{12}C^{*} \xrightarrow{\gamma(4.44MeV)} {}^{12}C_{g.s.}$$

Gamma ray diagnostics of magnetically confined plasmas provide information on runaway electrons (fast electrons that often appear during plasma disruptions), fusion products and other fast ions due to nuclear reactions on fuel ions or main plasma impurities such as carbon and beryllium.

The following projects are currently being carried out by NCBJ within the JET4 Enhancement Projects: modernization of two detector systems at JET, the Gamma Camera (GCU) and Gamma Spectrometer (GSU) and building new diagnostics, the Lost Alpha Gamma Rays Monitor. Due to technical reasons the third project, the Lost Alpha Gamma Rays Monitor, was closed in 2015.

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 high resolution spectroscopy measurements with the Gamma Spectrometer. Upgrade of the gamma-ray diagnostics is necessary because in planned deuterium-tritium campaigns measurements at high count rates are expected.

At NCBJ we tested the use of $CeBr_3$ scintillators, characterized by good energy resolution (4.2% for 662 keV), short decay time (~20 ns) and a relatively high detection efficiency for a few MeV gamma rays. $CeBr_3$ crystals are considered as one of the best scintillators, besides $LaBr_3$:Ce, for the upgraded gamma-ray diagnostics at JET to be used in experiments at high count rates.

Two prototype detectors, based on a $CeBr_3$ crystal coupled to a Multi-Pixel-Photon-Counter (MPPC), were prepared at NCBJ and in May 2015 mounted in the horizontal part of the Gamma-ray Camera at JET. First tests with high energy AmBe source, emitting gamma rays with an energy of 4.4 MeV, were performed in October 2015. Due to the fact that the properties of the MPPC are strongly affected by temperature, it was necessary to stabilize the MPPC operation caused by temperature variations. An MPPC temperature compensation device MTCD@NCBJ was designed and produced for real-time temperature monitoring and MPPC gain stabilization.

In 2015 we prepared a new detector for the Gamma Spectrometer based on a 3”×3” $CeBr_3$ scintillator coupled to a photomultiplier tube. $CeBr_3$ is characterized by a short decay time and low noise conditions. A dedicated active voltage divider was designed for this detector. The $CeBr_3$-based detector is now ready for further tests and installation at JET.

The current status of our activities are presented in more detail in subsequent articles of the NCBJ Annual Report 2015.

This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of international co-financed projects.

This work was carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Gamma camera upgrade at JET

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The DT-experiment at the JET tokamak performed in 1997 has shown that direct measurements of confined alpha particles are very difficult. Alpha-particle studies require a significant development of dedicated diagnostics. JET now has an excellent set of confined and lost α-particle diagnostics. However, in order to take full benefit from the extensive DT campaign in the future, a number of diagnostic upgrades are necessary.

Among these necessary upgrades, the gamma camera plays an important role as a very useful diagnostic tool for the study of confined α particles as well as fast ions. The information provided by the upgraded gamma-camera will complement high resolution spectroscopy measurements.

The upgraded camera will measure nineteen line integrated γ-ray emission spectra associated with specific reactions among fast ions or fusion alphas with impurities, e.g., $^{9}Be(\alpha, n\gamma)^{12}C$ with a 4.4 MeV gamma emitted.

The upgraded detectors should have an energy resolution of about 5% FWHM at 1.1 MeV and the ability to register counting rates higher than 500 kHz. This is a challenging upgrade given the existing constraints (available space for detectors and shielding, use of existing cabling).

Tests were performed with a $CeBr_3$ crystal coupled to a Multi-Pixel-Photon-Counter (MPPC).

The $CeBr_3$ scintillator is characterized by good energy resolution (4.2% for 662 keV), a short decay time (~20 ns) and a relatively high detection efficiency for a few MeV γ -rays.

MPPC is a silicon–based monolithic array of micro-pixel avalanche diodes operating in Geiger mode. The main advantages of MPPC are: large internal gain, high photon detection efficiency, high – speed response, excellent time resolution, wide spectral response, immunity to magnetic fields and compactness.

Due to the fact that the properties of MPPC are strongly affected by temperature, it was necessary to stabilize the MPPC operation caused by temperature variations. A MPPC temperature compensation device MTCD@NCBJ was designed and produced for real - time temperature monitoring and MPPC gain stabilization. MTCD@NCBJ is based on the ATmega microcontroller family and temperature readout from a high precision, longterm stable temperature sensor (model TSic™ 506F). The block scheme of the prototype photodetector with the temperature compensation device is presented in Fig. 1.

For stabilization the feed forward gain control method was used (see Fig. 2.).

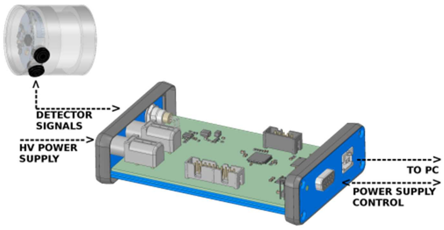

Fig. 1. Scheme of prototype detector based on MPPC with a temperature sensor placed in an aluminium capsule and the MTCD@NCBJ device.

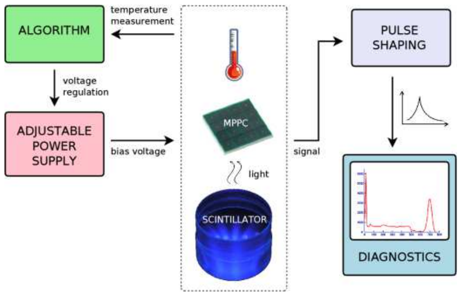

Fig. 2. Block scheme of the MTCD@NCBJ device for real - time temperature monitoring and MPPC gain stabilization.

In May 2015 two prototype γ-ray detectors were mounted in the horizontal part of the gamma camera at JET. First tests with a high energy gamma source of AmBe (4.4 MeV) were performed in October 2015. Due to the short measuring time, only the double escape peak from the 4.4 MeV line is clearly visible. A calibration source of ^{22}Na with two lines: 0.511 MeV and 1.274 MeV was used to get reference points. Fig. 3 presents the spectra obtained.

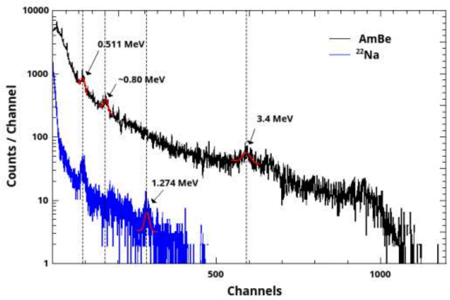

Fig. 3. Gamma energy spectrum of AmBe and ^{22}Na registered with the KN3G digitizer. Red lines correspond to fitted Gaussian functions.

This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of international co-financed projects.

Gamma spectrometer upgrade at JET

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The α-particle diagnostics at JET are based on the gamma-radiation emitted as one of the products of the nuclear reaction between beryllium impurity ions and confined α particles, i.e. ^{9}Be(α,nγ)^{12}C. During the DT campaign the gamma-ray detector must fulfil requirements for high count rate measurements. The existent BGO scintillator with long decay time should be replaced by a new detector module DM2 based on a $CeBr_3$ or $LaBr_3$:Ce scintillator. The module consists of a 3”×3” scintillator coupled with a photomultiplier tube and a voltage divider.

$CeBr_3$ is characterized by a short decay time and low noise conditions. $CeBr_3$ is an alternative to a $LaBr_3$:Ce scintillator, already tested at JET. During 2015 the properties of a detector based on a $CeBr_3$ scintillator were determined [1].

Table 1. Parameters of a 3”×3” $CeBr_3$ scintillator equipped with a Scionix voltage divider.

γ-ray energy (keV)	γ-ray source	energy resolution (FWHM, %)	detection efficiency (%)
511	^{22}Na	4.8±0.1	56±2
662	^{137}Cs	4.2±0.1	51±2
1115	^{65}Zn	3.5±0.1	38±2
1173	^{60}Co	3.4±0.1	34±1
1275	^{22}Na	3.3±0.1	32±1
1332	^{60}Co	3.3±0.1	32±1

In order to study the performance of the detector at high count rates, use was made of a highly active ^{137}Cs source.

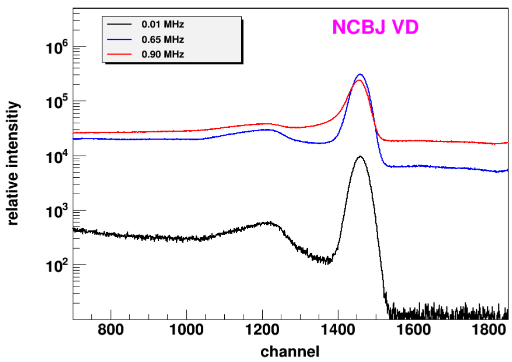

Fig. 1. ^{137}Cs gamma-ray spectra measured with a 3”×3” $CeBr_3$ scintillator and the NCBJ dedicated active voltage divider.

Such measurements were performed using an active voltage divider specially designed for high count rates, produced at NCBJ. The spectra were recorded at count rates of 0.06, 0.58 and 0.89 MHz. The relative difference in the ^{137}Cs peak position is less than 0.5%.

Measurements of gamma rays emitted from standard sources performed using $LaBr_3$:Ce and $CeBr_3$ showed that the detection efficiency of both scintillators is comparable, while $LaBr_3$:Ce is characterized by better energy resolution.

Table 2. FWHM of 3”×3” $CeBr_3$ (with Scionix VD) and 3”×3” $LaBr_3$:Ce scintillators.

γ-ray energy (keV)	γ-ray source	FWHM, %	
		$CeBr_3$	$LaBr_3$:Ce
511	^{22}Na	4.8±0.1	3.4±0.1
662	^{137}Cs	4.2±0.1	3.0±0.1
1115	^{65}Zn	3.5±0.1	2.4±0.1
1173	^{60}Co	3.4±0.1	2.4±0.1
1274	^{22}Na	3.3±0.1	2.4±0.1
1332	^{60}Co	3.3±0.1	2.2±0.1

We also compared the intrinsic activity of $CeBr_3$ (produced as a ‘low background’ crystal) and $LaBr_3$:Ce (standard crystal). Peaks originating from gamma transitions observed in natural background (1.461 MeV from ^{40}K and 2.615 MeV from ^{208}Tl) are clearly seen. Both scintillators show peaks between 1.5 MeV and 2.5 MeV related to contamination by α-radioactive actinides. $LaBr_3$:Ce is also contaminated with ^{138}La decaying by electron capture (EC) or β^-.

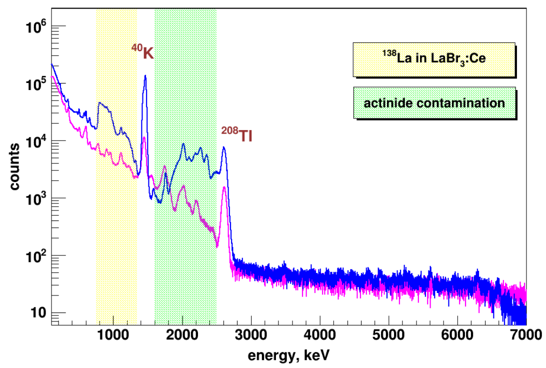

Fig. 2. Response of 3”×3” $CeBr_3$ and $LaBr_3$:Ce crystals to natural background radiation.

References

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This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2017 allocated for the realization of international co-financed projects.

Preparation of PLC modules for the first six experiments at X-FEL

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The X-FEL accelerator is planned to begin operation in 2017, and in the first period six experimental stations will be available for users. All six experiments, except the main experimental data acquisition, will require control and monitoring systems for handling devices like pumps, collimators, step motors, temperature monitors, pressure/vacuum monitors, moving stages, etc. All devices of these kinds do not require high speed data transfer, and often they are called "slow control". This kind of control equipment may be built of commercially available devices, without the necessity of designing custom systems, as is usually the case for real time acquisition for experimental data.

Within the Polish In-kind contribution to the X-FEL project, NCBJ will prepare about 200 modules with PLC (programmable logic controller) terminals, for handling slow control in the first six experiments at X-FEL. Prepared modules will be mounted on double chassis (two modules in one box), making 100 PLC Crates.

Design of the modules has been approved by the physicist, responsible for each experimental station at X-FEL. Each module is different and has unique wiring. To prepare each module, the following steps have to be performed:

- Ordering of component
- Module specification cross-check
- Component (PLC terminals, connectors, fuses, etc.) selection
- Labelling of each terminal and wire
- Wiring of the module
- Module electrical verification (each wire connection)
- Power-up test
- Protocol preparation
- Packing and shipment to Hamburg

For the preparation of 200 PLC Modules a dedicated laboratory has been established. The laboratory has 4 workplaces (up to 4 people working in parallel at the same time), a storage space and necessary tools and devices.

By the end of 2015 about 25% of all required PLC terminals had been ordered, all procedures like part ordering, module assembly, testing and shipment had been performed, and the first devices had been delivered and successfully accepted by X-FEL GMBH.

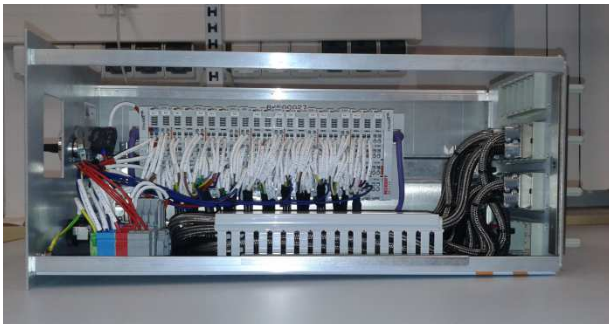

Fig. 1. Assembled PLC Module.

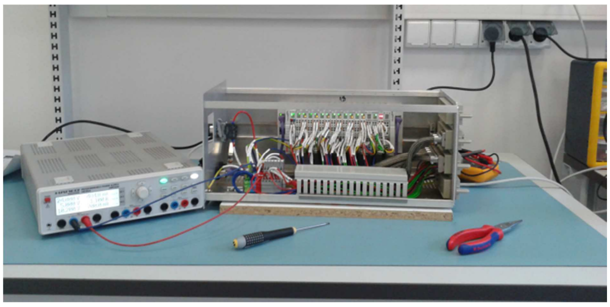

Fig. 2. PLC module under the test.

Fig. 3. PLC Module Laboratory – assembly work place.

DNG@NCBJ - high counting rate digital spectrometry system

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A data acquisition system for high resolution spectrometry measurements at Mcps count rates, DNG@NCBJ (Digital Neutron Gamma @NCBJ), is under development at the National Centre for Nuclear Research (NCBJ).

The DNG@NCBJ measurement system is based on direct sampling of the input signal, see Fig. 1.

Data acquisition and signal processing operations are performed digitally by FPGA with an ARM9 processor on a Xilinx ZC706 evaluation board. Since direct sampling of the input signal requires a high speed ADC, a Texas Instruments ADS5400 (12 bit/1 GSPS) ADC is used.

Data acquired from the ADC is processed on line by FPGA. A dedicated IP core has been developed to fulfill the system requirements.

The following major operations have been implemented:

1. pulse detection (triggering),
2. baseline estimation (offset compensation),
3. pulse energy estimation,
4. list mode creation,
5. communication.

The DNG@NCBJ system is optimized for high count rate detection applications. The DNG@NCBJ system is controlled by embedded Linux. The user has access to internal registers in diagnostic modules and can initiate and stop data transfer.

The DNG@NCBJ system is characterized by:

1.12-bit @ 1 GSPS ADC,

2.wideband DC-coupled to ADC input,

3.2 V input full scale,

4.signal processing algorithms implemented in FPGA,

5.communication based on Ethernet,

6.the system is controlled and managed by the Linux operating system.

Table I. Characteristic Parameters of DNG@NCBJ.

	DNG@NCBJ
measured max count rate, Mcps	2.2
dead time, ns/pulse	10
bandwidth, MHz	~2100
sampling rate, MSPS	1000
input voltage	2 V_{PP}
available channel number	1

To perform measurements at higher counting rates under laboratory conditions a PuBe source was used simultaneously with a strong ^{137}Cs source, with an activity of ~400 MBq, in order to increase the event rate. In our experiments a $LaCl_3$:Ce scintillator was coupled to a Photonis XP5200 PMT characterized by high quantum efficiency. Performance of a PMT-based detection system depends on the voltage divider, therefore a dedicated active voltage divider was built to accommodate gain shifts in the presence of high rates and a few MeV energy gamma radiation.

Results from DNG@NCBJ are compared with those obtained using a commercially available device, a CAEN Desktop Digitizer DT5720 with DPP-CI firmware [11].

As an example, in Fig. 1 spectra of PuBe and ^{137}Cs registered with a 1”×1” $LaCl_3$:Ce scintillator with the DNG@NCBJ device and the CAEN Desktop Digitizer are shown. Measurements were performed at a count rate of 0.2 Mcps. Such a count rate allows one to observe peaks from both sources because of the much lower PuBe source activity.

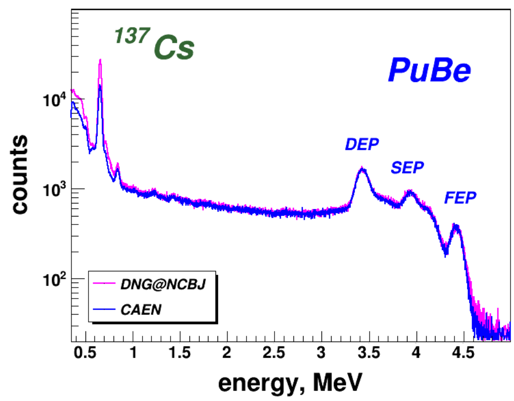

Fig. 1. Spectrum of ^{238}PuBe and ^{137}Cs measured with a 1”×1” $LaCl_3$:Ce scintillator. Measurements were performed with DNG@NCBJ and CAEN Desktop Digitizer DT5720.

The DNG@NCBJ is integrated into a single compact unit and was checked for count rates up to 2.2 Mcps with dead time not exceeding 10 ns/pulse.

This DAQ is well suited for use in plasma experiments in which high count rates are expected.

Almost identical spectra were obtained with DNG@NCBJ and a commercially available CAEN Desktop Digitizer DT5720, especially concerning one of the most important parameters in plasma experiments, the full width at half maximum.

With DNG@NCBJ it is easy to create a data acquisition system for a multi-detector setup. Off-line processing could be used for setting optimization.

An algorithm to correct pile-up events without rejecting them is under development.

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.

Silicon photomultipliers in scintillation detectors used for Gamma-Ray energies up to 6.1 MeV

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The aim of this work was to the study usefulness of SiPM light readout in the detection of gamma rays up to 6.1MeV in combination with various scintillators. The reported measurements were made with 3 samples of one type of Hamamatsu TSV (Through Silicon Via technology) MPPC arrays. These 4x4 channel arrays have a 50x50 μm^2 cell size and 12x12 mm^2 effective active area. All the tests were done in a climatic chamber. The following scintillators were used: CsI(Tl), $CeBr_3$, NaI(Tl). The studies were focused on optimization of the MPPC performance for practical use in the detection of high energy gamma rays. The optimization included selection of the optimum operating voltage in respect to the energy resolution, verification of the dynamic range, linearity and pulse amplitude. The energy spectra for energies between 320keV and 6.1MeV are presented and compared with data acquired with a classic photomultiplier. Such a comparison allowed the of nonlinearity of the tested MPPCs to be studied, correction of the energy spectra and proper analysis of the energy resolution. The temperature tests showed strong breakdown voltage dependence on the temperature change and defined requirements for the stabilization method in real life applications.

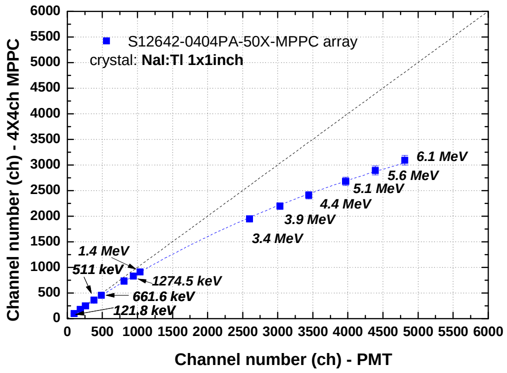

Fig. 1. Linearity characteristics for NaI(Tl) coupled to a 12x12 mm^2 TSV MPPC Array. The plots show the relation of gamma peaks measured using the MPPC Array (Y-axis) and a classic photomultiplier (X-axis).

In the case of gamma spectrometry the optimal operating voltage in MPPCs (and all SiPMs) is a trade-off between an increase in the photoelectron (PHE) number at higher bias voltage due to higher photon detection efficiency (PDE) and worsening of energy resolution due to an increase in the excess noise factor (ENF). The optimal value of 66.4V for the tested MPPC was determined in measurements with a 12x12x12mm BGO and a low gamma energy of 320keV from ^{51}Cr.

Nonlinear response of the MPPC (and all SiPMs) is the main problem that appears in the detection of high energy gamma rays. Measurement of the linearity range allows correction of the recorded data and proper identification of gamma lines. Fig. 1 presents an example of the linearity characteristics recorded for the NaI(Tl) scintillator. The nonlinear behaviour is strong, especially for few MeV events, however far from saturation. Even stronger nonlinearity was recorded for a $CeBr_3$ scintillator, nevertheless the spectra can still be corrected and gamma lines up to 6.1 MeV can be clearly resolved. In Fig. 2 the corrected energy spectrum for the NaI(Tl) scintillator and a PuBe neutron source is presented. The weakest influence of the MPPC nonlinear response to the observed energy spectra was observed for the slowest CsI(Tl) scintillator.

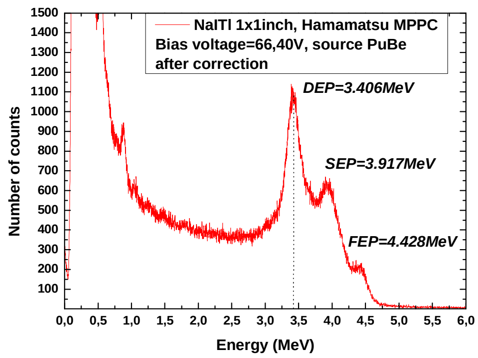

Fig. 2. Energy spectrum recorded for PuBe neutron sources with a NaI(Tl) scintillator coupled to the MPPC array. In the case of the MPPC data the raw spectrum has to be corrected for the nonlinearity.

The large capacitance of MPPC matrices is another problem during readout of these detectors as a single, large area device (like classic photomultipliers). In the case of the tested 12x12 mm^2 detector, read by a 50ohms input resistance of the electronics, the decay time of the output pulse is much longer than the scintillator decay. It may have a negative influence on data acquisition, especially in applications with high counting rates (Mcps). The long decay time of the MPPC pulse can be shortened by means of a 10ohms loading resistance added at the output. Such a circuit can change the decay time from 1ms to about 100ns without destroying the detector performance, in particular the energy resolution [1].

The study proved that a scintillation detector with light readout by means of an MPPC array can be successfully used in the detection of gamma rays up to 6.1 MeV with a wide range of scintillators (fast, moderate and slow).

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Gamma spectrometer based on a $CeBr_3$ scintillator with compton suppression for identification of trace activities in water

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The TAp WAter RAdioactivity Real Time Monitor (TAWARA_RTM) project [1] is aimed at providing online inspection of radiological contamination of water processed at water distribution plants. The TAWARA_RTM platform consists of a few-step monitoring system that allows for detection and identification of radioactive isotopes that may potentially appear in the public water supply network. The SPEC system, being a part of the TAWARA_RTM platform, is intended for identification of the isotopes detected in water by means of gamma-ray spectroscopy.

The SPEC system comprises a cylindrical $CeBr_3$ scintillator coupled to a photomultiplier (PMT). To reduce the influence of both external background and Compton continua on the sensitivity of the SPEC system, an active anti-Compton shield (ACS) made of BGO is used. For further reduction of the external γ-ray background, a lead shield was made in the form of a 50 mm thick cylinder of 400 mm length with two 50 mm thick end-caps. The detector bias and signal read-out are performed using a CAEN DT5780 dual digital multichannel analyzer (MCA), embedding two high voltage power supply channels.

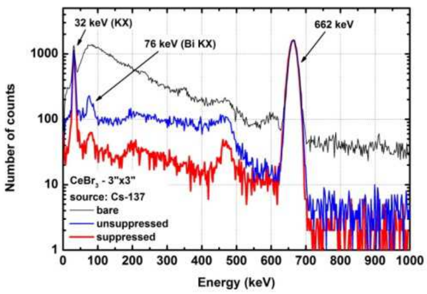

Fig. 1. Spectra recorded with the bare $CeBr_3$ detector (black line), shielded passively by BGO and lead (blue line) and in Compton-suppressed mode of the SPEC system (red line).

The effect of the ACS on the recorded γ-ray spectra is presented in Fig. 1. A weak intensity (1.2 kBq) ^{137}Cs source was placed at a distance of 25 mm from the front face of the $CeBr_3$ detector. When the detector was kept outside the shields, a relatively large number of counts originating from background appeared over the entire spectrum. Placing the detector inside the shields, but not using the ACS signal for rejecting the events, showed a typical spectrum of a ^{137}Cs source with a build-up of 76 keV KX-rays from bismuth present in the BGO ACS. Operating the SPEC system in Compton suppressed mode results in further reduction of the background and Compton continuum between the detection threshold and the Compton edge.

Several small activity sources (between 0.93 kBq and 36 kBq) were used to evaluate the minimum detectable activity for the SPEC system. Based on the counting statistics, the MDA values were calculated using the Currie equation [2], assuming that the detection time was limited to 1000 s. The MDA values presented in Table 1 are compared with the guidance levels for radioisotope presence in drinking water. The guidance levels are provided by the European Commission in Council Directive 2013/51/EURATOM.

Table 1. Guidance levels for water contamination and the MDA values calculated for the SPEC system.

Source	Eγ (keV)	Activity (kBq)	Guidance level (Bq/L)	MDA (Bq)
Cs-137	662	1.2	10	1.48
Mn-54	835	0.93	100	1.53
Zn-65	1116	1.8	100	3.83
I-131	364	10.8	10	3.08
Cd-109	22.1	36	100	3.61
Am-241	60	11.5	1	3.66
Co-57	122	2.3	1000	1.25

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[1] www.tawara-rtm.eu

[2] L.A. Currie, "Limits for qualitative detection and quantitative determination", Anal. Chem., vol. 40, pp. 586-593, Mar. 1968.

This work was supported in part by the project ”TAp WAter RAdioactivity Real Time Monitor” funded by the EU FP7

Security Programme under grant agreement no. 312713 and by the Polish funds for science for 2014-2016 allocated to co-funded international projects – contract 3036/7.PR/2014/2.

Energy resolution of scintillation detectors

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According to present knowledge, the non-proportionality of the light yield of scintillators appears to be the fundamental limitation of their energy resolution. A good energy resolution is of the great importance for most applications of scintillation detectors. Thus, the limitations arising from the non-proportional response of scintillators to gamma rays and electrons are discussed below, as they are of crucial importance to the intrinsic energy resolution of the crystals. The important influence of Landau fluctuations and the scattering of secondary electrons (δ-rays) on the intrinsic resolution are pointed out. The study of undoped NaI and CsI at liquid nitrogen temperature with light readout by avalanche photodiodes suggests strongly that the non-proportionality of many crystals is not an intrinsic property and may be improved by selective co-doping. Finally, several observations collected in the last 15 years on the influence of slow components of the light pulses on energy resolution suggest more complex processes in the scintillators. This was observed with CsI(Tl), CsI(Na), ZnSe(Te), undoped NaI at liquid nitrogen temperature and finally for NaI(Tl) at temperatures reduced below 0°C. A common conclusion of these observations is the fact that the highest energy resolution, and particularly the intrinsic resolution measured with scintillators, characterized by two components or more of the light pulse decay, is obtainable when the spectrometry equipment integrates the whole light of the components. In contrast, slow components observed in many other crystals deteriorate the intrinsic resolution. In the limiting case, the afterglow could also be considered as a very slow component that spoils the energy resolution. The aim of this work is to summarize all the above observations in a search for their origin.

Invited paper published in a special issue of Nuclear Instruments and Methods A in memory of Glenn F. Knoll.

Photomultipliers with the screening grid at the anode for TOF PET block detectors

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Although most efforts of the scientific community are addressed to the development and application of SiPMs in TOF PET detectors [1], classical block detectors, with light readout by photomultipliers (PMTs), are still in general use. This is associated with the simplicity of the TOF PET design based on block detectors and their low price. Thus, further development of superior PMTs is of importance.

According to general knowledge, the time resolution measured with scintillation detectors is limited by two main parameters of photodetectors, the time jitter (transit time spread) and the quantum efficiency of the photocathode. The present offer of the leading manufacturers has reached, in both cases, superior performance difficult to improve further. The time jitter of 200 – 300 ps and the blue sensitivity, above 15 μA/lm blue, reported for the R10560-100, being an enhanced version of the R9800 PMT, are difficult to improve further.

A study carried out earlier [1] showed clearly that there is another source of time resolution degradation in fast PMTs, associated with the commonly used construction of the anode. The anode built as a grid is placed inside the last dynode, see Fig. 1. This configuration ensures a short time-of-flight of electrons from the last dynode to the anode and good charge collection at the anode.

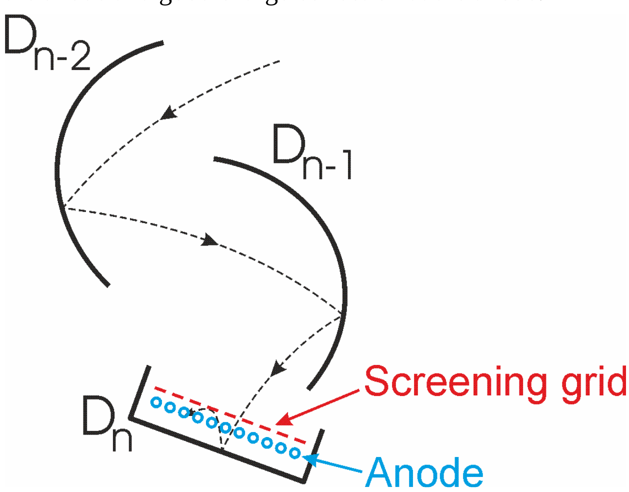

Fig. 1. Geometry of the last dynodes and the anode in a

typical linear-focused photomultiplier. Note that the anode is built as a grid inside the last dynode. The position of the screening grid is also shown.

However, one can easily note that the anode signal consists of two components: the main one due to the collection of electrons from the last dynode and a parasitic one induced at the anode by electrons travelling towards the anode from the penultimate dynode. This parasitic component is shifted in time relative to the main component and, in fact, its charge triggers mainly the fast discriminator. Thus, the triggering point is far too high compared to that resulting from the statistical properties of scintillation detectors requiring a low fraction of the anode pulse height for the best time resolution.

Recently, the ADIT Co. has started development of a 1" diameter fast PMT with the screening grid at the anode. Below we report on the first comparative study of a L25, classical PMT, with that equipped view with the screening grid. Table 1 summarizes the main parameters of the tested PMTs.

Since all the timing studies were carried out with a leading-edge discriminator, optimization of the triggering fraction was of importance. It is presented in Fig. 2, where a normalized time resolution to the PHE number and ENF, is plotted versus triggering fraction.

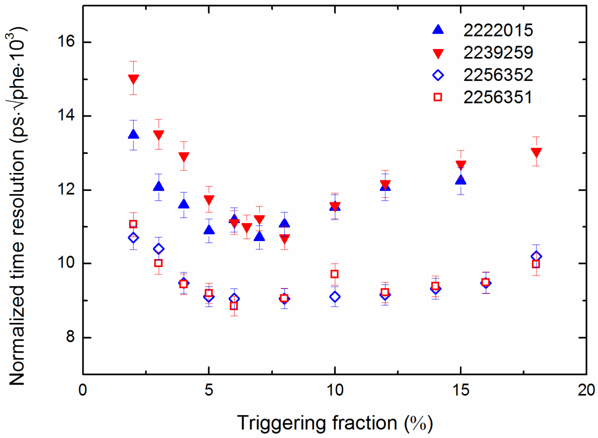

Fig. 2. Time resolution normalized to the number of photoelectrons and the excess noise factor of the tested L25 SA3 PMTs with the grid in comparison to the classical L25 PMTs.

The performed comparison of 1" diameter PMTs in fast timing showed a superior performance of the L25 SA3 equipped with the screening grid at the anode. As reported previously, improvement by a factor of 1.2 is obtained when the normalized time resolution to the PHE number and excess noise factor is discussed.

Presented at the IEEE NSS-MIC Conference, San Diego, USA, 31.10-7.11.2015, submitted to the Conference Records. A full paper is submitted to the IEEE Trans. Nucl. Sci.

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Study of fluorine-based plastic scintillators for fast neutron detection by means of ^{19}F activation

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In this study we present the response of a novel pentafluorostyrene-based plastic scintillator (F-plastic) to fast neutrons by means of fluorine activation (Threshold Activation Detection - TAD [1]). The method relies on the activation of specific types of nuclei (such as ^{19}F), with appropriate reaction threshold (greater than 2.5 MeV), useful cross section and half-life in the range of seconds. The ^{19}F nuclei, after activation, can decay into successors, which emit high-energy β particles with an energy endpoint up to 10.4 MeV**.** In the case of the ^{19}F nuclei, the following reaction channels can occur:

$$n + {}^{19}F \rightarrow {}^{16}N + \alpha$$

$$n + {}^{19}F \rightarrow {}^{19}O + p$$

The first prepared sample based on pentafluorostyrene with size of Ø 32 × 4 mm^3 was introduced in [2]. The motivation of this research is to find an alternative solution to hexafluorobenzene-based liquid scintillators, which are toxic and flammable. In the present study the Ø59 × 41 mm^3 F-plastic was exposed to 14 MeV neutrons emitted from the NSD Gradel D+T generator. The neutrons picked-up in the ^{19}F(n,α)^{16}N reaction result in the emission of β particles with an endpoint at approximately 10.4 MeV. The spectra shape was compared with that recorded with a Ø51 × 51 mm^3 EJ-200 polyvinyltoluene (PVT) based scintillator, which does not contain fluorine. The new F-plastic and EJ-200 used in the present investigation are shown in Fig. 1 (centre-right and right).

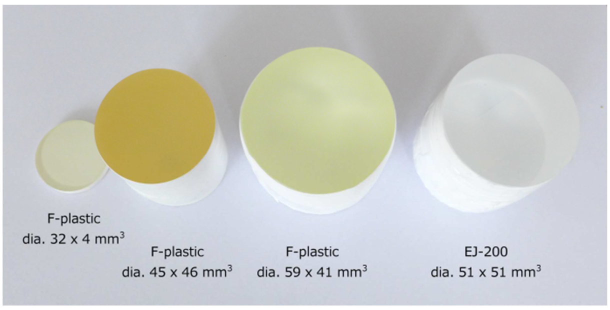

Fig. 1. Picture of developed F-plastic and EJ-200 organic scintillators.

The scintillators were exposed to 14 MeV neutrons emitted from an NSD Gradel fusion-chamber type DT neutron generator at NCBJ. The fast neutrons are registered by activation of ^{19}F in the scintillator medium, resulting in emission of β particles. The exposition lasted until the neutron flux was stabilized, then after 1 s of cooling time the acquisition ran for 60 s. The net spectrum for the F-plastic clearly shows an increased number of counts in the energy region between 6.0 and 10.5 MeV compond to that for EJ-200, see Fig. 2

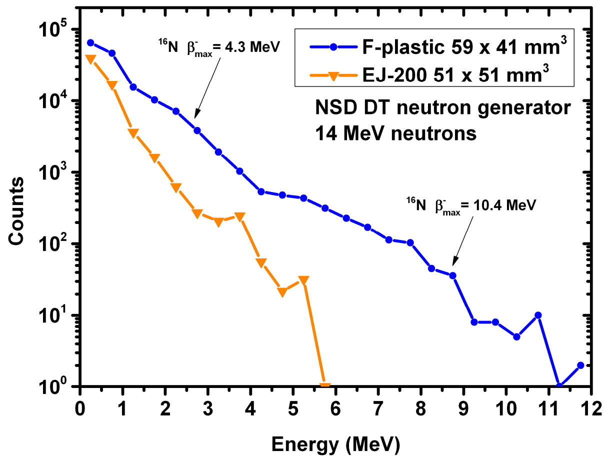

Fig. 2. Energy spectra obtained after exposure of the scintillators to neutrons from the DT neutron generator.

Summarizing, the F-plastic scintillator can be used for the detection of fast neutrons by means of fluorine activation,. even though the F/H ratio for F-plastic is only equal to 1.66 (EJ-313 F/H ratio is equal to 307.8). Further tests will cover direct comparison of the F-plastic and EJ-313 response to 14 MeV neutrons.

This work was performed within the framework of the C-BORD EU project no. 653323 of the Horizon 2020 Programme.

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Energy resolution and slow components in undoped CsI crystals

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Recent intense studies showed evidence that the energy resolution of scintillation detectors is mainly limited by their non-proportional response. However, several observations collected in the last 20 years on the influence of slow components of the light pulses on energy resolution suggest more complex processes in the scintillators [1]. This was done with CsI(Tl) and CsI(Na), ZnSe(Te), undoped NaI at liquid nitrogen temperature and finally for NaI(Tl) at temperatures reduced below 0 C. A common conclusion of these observations is the fact that, in the case of scintillators showing two components of the light pulse decay, the best energy resolution, and particularly the lowest contribution of the intrinsic resolution, is obtainable when the spectrometry equipment integrates the whole scintillation light.

In contrast, some other crystals like LuAG:Pr, CsI(In) and different samples of undoped NaI at liquid nitrogen temperature showed a deterioration of the energy resolution correlated with the intensity of the slow components.

In the present work, a number of undoped CsI crystals, with varying intensity of the slow component, were tested with the aim of learning the performance of CsI in gamma spectrometry and studying the influence of slow components on the energy resolution. It is expected that the conclusions of the study can be applied to other crystals exhibiting intense slow components.

Fig. 1 presents the energy resolution of the tested CsI crystal and its components measured versus peaking time.

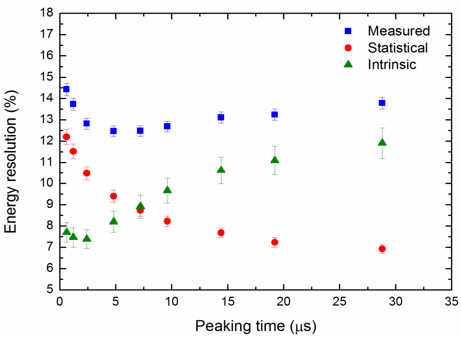

Fig. 1. Energy resolution for the 662 keV peak measured with ISM 6 sample and its components versus peaking time.

Fig. 1 presents two unexpected effects. The major one is a large deterioration of the intrinsic resolution with the peaking time and the intensity of the integrated slow component, suggesting a deterioration of the energy resolution by slow components of the light pulses. Another minor effect is an improvement of the intrinsic resolution at the peaking times up to about 3 μs. This seems to follow a contribution of the third 4.55 μs component, which acts in a similar way to the earlier observed improvement of the intrinsic resolution in CsI(Tl) due to the integration of the slow components [1].

Fig. 2 presents the nonproportionality characteristics measured for the fast component for all the tested samples with varying intensity of the slow component.

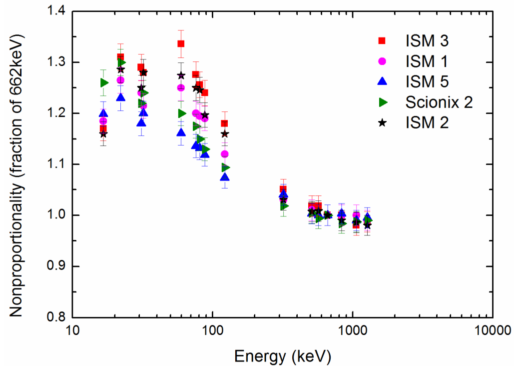

Fig. 2. Nonproportionality characteristics of different samples of CsI crystal measured with fast shaping. The largest nonproportionality is measured for the ISM 3 sample showing the lowest contribution of the slow components.

A larger intensity of the slow component improves the non-proportionality and intrinsic resolution of the fast component, but the intrinsic resolution measured with the total light is much poorer in each case. In other words, having a significant slow component is beneficial; but collecting increasing amounts of light from this component is detrimental. This finding is not particularly intuitive and may even seem paradoxical.

Further tests have covered the analysis of the intrinsic resolution of the tested crystals and, for a better understanding of the problem, the nonproportionality response to Compton electrons was measured by the Wide Angle Compton Coincidence Technique.

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Presented at the Conference on Inorganic Scintillators and Their Application, SCINT, Berkeley, USA, June 7-12, 2015, IEEE Trans. Nucl. Sci., in press.

Nanodosimetry with the Jet Counter – modification towards radial measurements – first results

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To date, only a few nanodosimeters have been developed that are capable of measuring the track structure of ionizing particles in a gas target equivalent to a nanometric site. They are known (chronologically) as the Track Ion Counter[1], the Jet Counter[2], the Ion Counter[3] and the Startrack Counter[4]. All these constructions are able to measure the ionization cluster-size distribution, ICSD. The Ion Counter and the StarTrack Counter are able to perform a radial measurements by shifting the beam of particles in a controlled manner away from the central position allowing only delta electrons to interact in the sensitive volume. The Jet Counter, which was described in detail elsewhere[5] has a gas cavity surrounded by a wall (like in an ionization chamber). In this construction radial ICSD measurements are not possible, because the wall is impenetrable to delta electrons. To overcome this disadvantage the Jet Counter has been modified. The interaction chamber has been extended in addition to the gas flow and divided into two volumes (V1 and V2) by a high transparency grid G1. The grid separates ions from both volumes. The idea of this modification is explained in Figure 1.

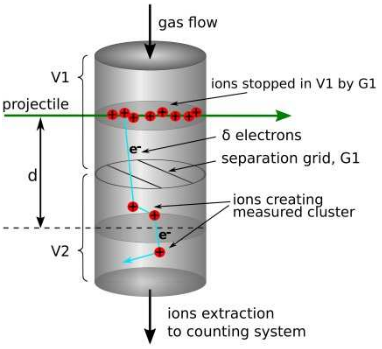

Fig. 1. Schematic view of the modified interaction chamber of the Jet Counter. The distance d is determined by the beam axis and the centre of volume V2.

A series of experiments with 3.8 MeV alpha partides has been carried out to verify the properties of the modified chamber. The mean cluster size (first moment M1 of ICSD) has been estimated as a function of the repelling voltage on grid G1. The results are shown in Figure 2. The mean cluster size reaches a plateau starting from about +10 V. This means that the value of M1 at the plateau corresponds only to the contribution of secondary (delta) electrons produced by a projectile crossing volume V1. The time of flight spectra shown in figure 3 confirm the above results. The time of flight spectrum has two peaks in the case of 6.5 V applied on grid G1. This voltage is insufficient completely to separate ions from V1. The first (faster) peak corresponds to ions from volume V2 and the second (slower) peak corresponds to ions from volume V1. Thus, the sensitive volume is not well defined in this case. Applying +10 V on grid G1 (plateau region on fig. 2) prevents all ions produced in V1 from passing through the separation grid. In this case the sensitive volume is well defined and restricted to V2.

The separation voltage depends on the gas jet density, as the ions from V1 drift with the gas flow. Thus, the separation voltage must be optimized for different sizes of the simulated nano site.

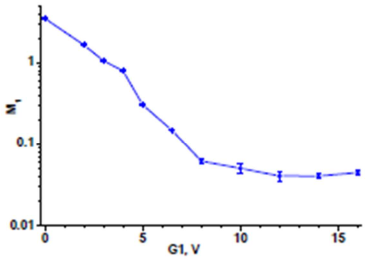

Fig.. 2. Mean cluster size (M1) vs repelling voltage on the separation grid G1.

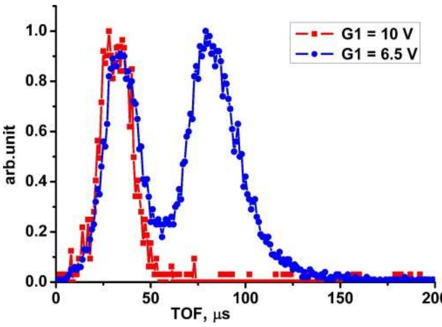

Fig. 3. Time of flight spectra. Double peak curve corresponds to ions created in V1 (by projectile) and V2 (by delta electrons) for ań incompletely repelling voltage (6.5 V) on G1. Single peak curve corresponds to a 10 V repelling voltage i.e. for complete separation between V2 and V1.

Acknowledgements

The technical assistance of Mrs E. Jaworska and Mr A. Dudziński is appreciated.

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SOLID STATE PHYSICS

Spontaneous wetting of quasi-2D systems with strong evaporation

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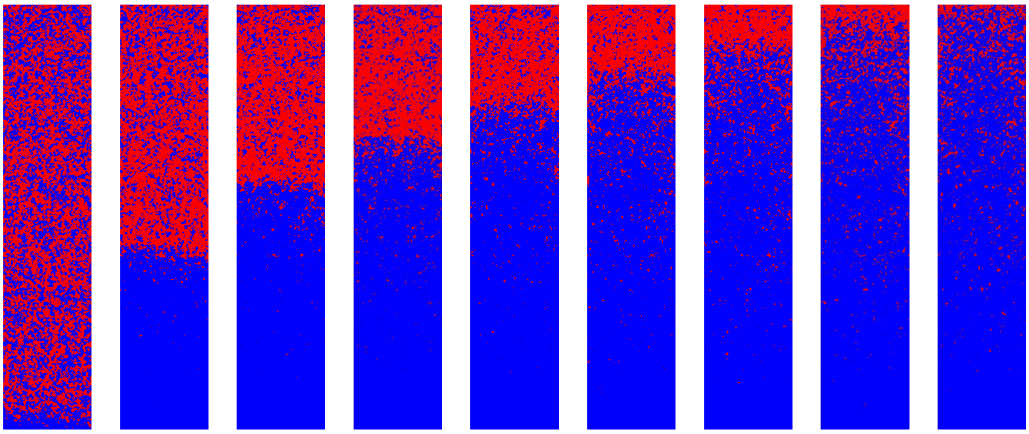
Studies of wetting of porous materials reveal such properties of the medium as the effective size of the pores and its wettability by the liquid used. These studies are commonly performed on massive samples with their lateral surfaces impregnated to get rid of the evaporation of the liquid. However, there are systems of interest like tissues, textiles and paper sheets, which cannot be protected against evaporation by coating without substantial change in their properties. Due to their small thicknesses these systems can be considered as quasi – two-dimensional and the evaporation of the wetting liquid cannot be ignored.

Dynamic neutron radiography has been used for decades as a technique suitable for quantitative investigation of migration of hydrogenous liquids in porous media. Both imbibition and drying processes have been investigated in rigid and loose porous media with neutron radiography revealing non-classical or anomalous kinetics of wetting and drying fronts [1-4]. In the present research we prove that the method is sensitive enough to study systems of 0.1 mm thickness such as sheets of various textiles.

The systems under study consisted of a 20 mm wide and 130 mm long strip of fabric spanned on a vertical aluminum frame (Fig.1) with its flat side parallel to the detector screen. 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 system was kept at a stabilized temperature of 30°C. The experiments were performed with the thermal neutron dynamic radiography facility at the MARIA reactor of NCBJ. The neutron images of the sample during the wetting process were recorded on-line every 1.7 s by a dedicated computer system.

Fig. 1. The sample spanned on the frame.



2s 32s 62s 92s 122s 152s 182s 212s 240s

Fig. 2. False colored neutron images of water wetted cotton fabric. The blue and red color indicates the water saturated and dry regions, respectively. The values at the bottom indicate the time elapsed since the moment of filling the lower container with water.

Due to strong scattering of thermal neutrons on hydrogen nuclei the wetted part of the sample was visible as a dark region in its neutron images. The darker the region the more water it contains. According to the Beer-Lambert law [5,6] the amount of water contained at some point of the sample is proportional to the optical density (the negative logarithm of the relative brightness) of the corresponding pixel. (Fig.3). The average distribution of water along the sample was delineated by averaging the brightness on the segments perpendicular to the sample long axis (Fig.3). The wetting front position was estimated from the optical density vs. distance plot as the abscissa of the average optical density equal to 0.01.

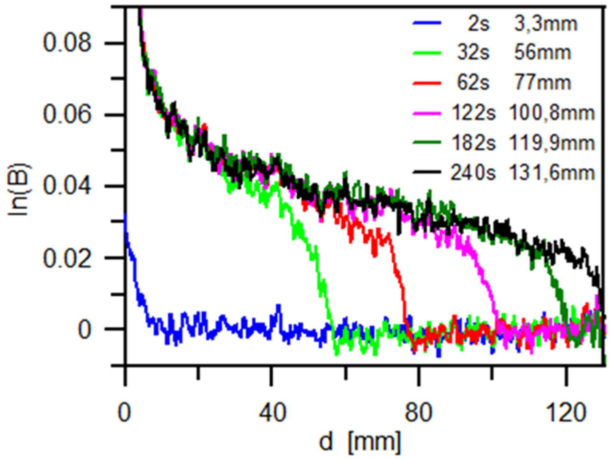


Fig. 3. The dependence of the negative logarithm of the average relative brightness on the distance from the water immersed end of the sample.

The distribution of the optical density along sample indicates that the amount of water (mass of water per pixel) drops very fast in the lowest part of the sample then decreases almost linearly with distance from the water immersed end to reach the wetting front region with marked sudden drop. The initial sharp drop and linear decrease parts of this dependence remain even after complete saturation of the sample with water. The former is due to a kind of meniscus formed at the water immersed part of the sample whereas the latter should be attributed to the dynamical equilibrium between the evaporation and capillary transport processes.

In search for the kinetic law describing the wetting rate we analyzed the time dependence of the wetting front position (Fig. 4). In most cases studied we have found that it can be approximated with the power law $d(t)\propto t^{\alpha}$ with the exponent α between 0.36 and 0.43 (±0.005) (Fig.4). This value is distinctly different from the classical one of 0.5 predicted by the capillary suction theories and observed for bulk porous systems [1-3]. Moreover it indicates significant reduction in the wetting front velocity for imbibition proceeding with accompanying evaporation in comparison to that of the process evolving without evaporation.

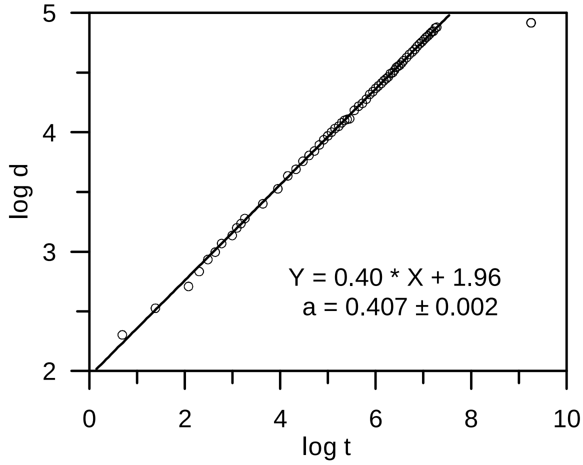


Fig. 4. Logarithmic plot of the wetting front distance from the water immersed end of the cotton fabric as a function of time.

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Low energy phonons in an homogenized sample of the $Mn_{0.3}Ni_{0.3}Cu_{0.4}$ alloy investigated by inelastic neutron scattering

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Pseudo quasi-binary $Cu_{1-2x}Mn_xNi_x$ alloys are known to harden due to the effect of the phase decomposition which affects both atomic and magnetic ordering in the sample and induces tetragonal distortion in one of the phases. The influence of the decomposition induced strain on lattice vibrations is of some interest due to their importance for the phase transitions observed in Mn-Cu and Mn-Ni alloys [1-2]. We began with a determination of the phonon dispersion relation for an homogenized sample of the $Cu_{0.4}Mn_{0.3}Ni_{0.3}$ alloy investigated previously for magnetic and atomic ordering in the precipitated phase at the initial stage of decomposition [3].

Longitudinal and transverse acoustic phonons were investigated with the triple axis neutron spectrometer at the MARIA reactor of NCBJ. The low energy part of the dispersion relation was determined for the [100] and [110] wave-vector directions at room temperature (Figs.1 and 2).

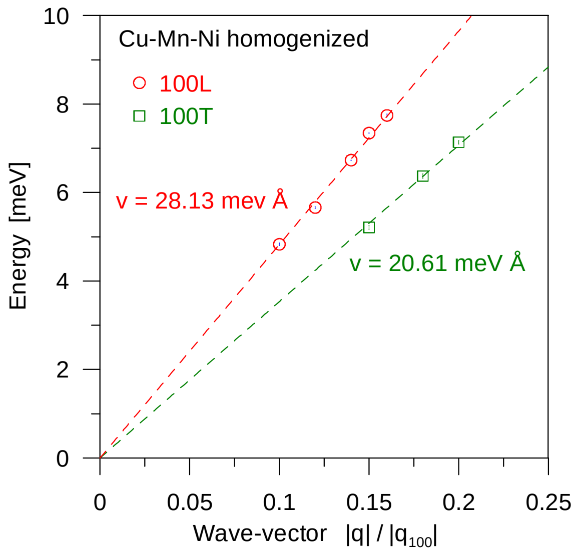

Fig. 1. The low energy part of the longitudinal and transverse phonon dispersion relation in the [100] direction.

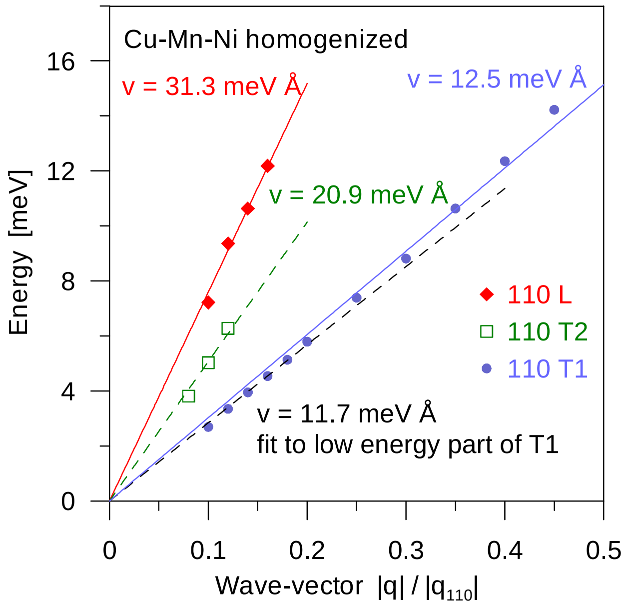

Fig. 2. The low energy part of the longitudinal and two transverse phonon dispersion relation in the [110] direction.

The elastic stiffness constants relevant to the FCC structure were obtained from the velocities of the longitudinal and transverse phonons for both directions studied. Our results are compared to the stiffness constants for pure copper (Table 1).

Table 1. The elastic stiffness constants at room temperature for the homogenized sample of the $Cu_{0.4}Mn_{0.3}Ni_{0.3}$ alloy compared with the known values for pure Cu.

Stiffness constants $[10^{11}\ N\ m^{-2}]$	$Mn_{0.3}Ni_{0.3}Cu_{0.4}$	Cu
C_{11}	1.46(5)	1.684
C_{12}	1.04(9)	1.214
C_{44}	0.785(14)	0.754
$(C_{11} - C_{12})/2$	0.212(20)	0.235

The C_{11} and C_{12} constants of the investigated alloy are evidently smaller than those of the pure copper. Only the C_{44} constant is a bit higher than that of Cu. One should note that the C_{11} constant is significantly higher than that measured for Mn alloys exhibiting martensitic transition to the tetragonal phase i.e. the $Cu_{0.4}Mn_{0.6}$ alloy (~1.2 10^{11} N m^{-2}) [1] and $Mn_{0.94-x}Ni_xC_{0.06}$ for $0.088<x<0.11$ (0.76-1.08 10^{11} N m^{-2}) [2].

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Al_2O_3 – TiO_2 composite coatings structure

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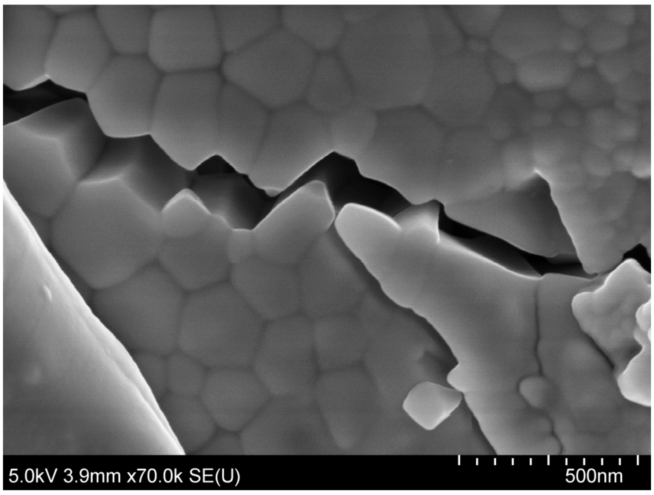
Protective coatings based a Al_2O_3 have excellent anticorrosive properties as well as high temperature resistance. Due to strong resistance to corrosion and erosion Al_2O_3 coatings protect the surface of a material from aggressive chemical and physical environments [1,2]. Therefore, they are used as an alloying agent in materials that are exposed to corrosive agents. They are especially used as thermal barrier coatings of increasing resistance to thermal shocks and conditions of corrosion and as erosion coatings in hot gases and liquids.

The results presented here concern coatings resistant to destructive factors at elevated temperatures. Two different compositions of Al_2O_3 based protective coatings were studied. In particular the temperature induced emergence of new nanostructure in alumina based coatings stabilized with some other oxides was observed. The coatings were made by means of the sol-gel method and the plasma spray technique.The detailed microstructural evolution and morphology was observed with a scanning electron microscope (SEM), Atomic Force Microscopy (AFM) and Energy-dispersive X-ray spectroscopy (EDXS).

The coatings studied contained 15 or 40 % by weight of TiO_2 [3]. XRD results reveal that their main constituent is the fine crystalline γ-phase with embedded larger crystallites of the α-phase. The Al_2TiO_5 phase is just present at 15% of the TiO_2 and becomes the main phase at coatings containing 40% of TiO_2. The Al_2TiO_5 phase yields higher thermal resistance especially to thermal shocks [4,5]. The SEM images indicate the columnar structure as well as the presence of microcracks (Fig. 1). The TEM pictures obtained after milling with FIB revealed the microstructure of the coatings interior and in regions near coatings – the substrate interface. important for coating adherence and stability. Several layers of amorphous, nanocrystalline and polycrystalline phases of equi-axial and columnar shape with various crystallite sizes were found [4,5]. The coating microstructure in the nanometric range is studied by the SPM method. Some examples for Al_2O_3 + 15% of TiO_2 are given below. Crystallites of different size were observed. The larger blocs were separated by cracks and some fine crystallites (20-30 nm in diameter) for both groups of materials. Distinct nanocrystallites were observed in AFM images of the Al_2O_3 + 15% TiO_2 coatings (Fig. 2) [3].

a)



b)

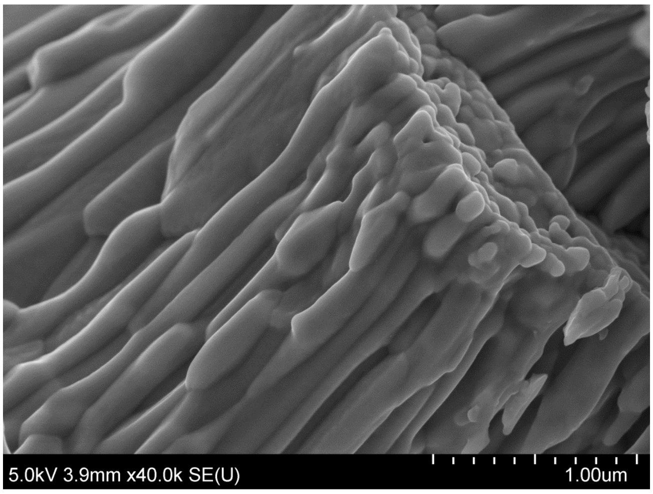
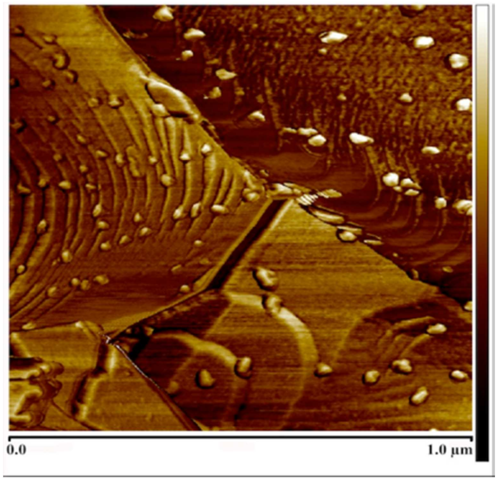


Fig. 1. Scaning Electron Microscopy microphotograph of an Al_2O_3:TiO_2 coatings with column structure a) top view b) side view.

a) b)



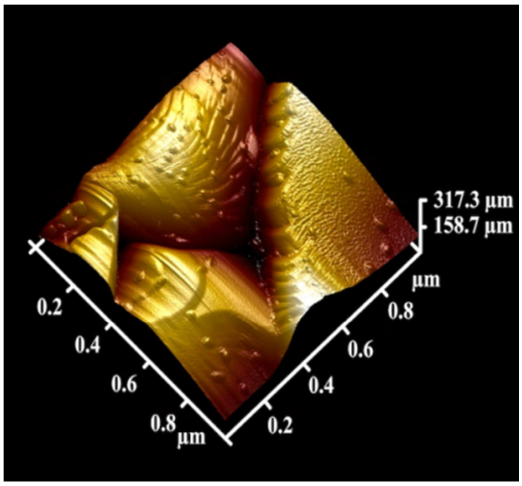


Fig. 2. Atomic Force Microscopy image of an Al2O3 + 15% TiO2 sample. Tapping mode, a) phase image, b) 3D height image [3].

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Novel (+)-3-carene derivatives and their application in asymmetric synthesis

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Chemical synthesis of chiral compounds of predictable chirality is an important task. Several ways lead to this goal and crystallographic structures serve as the final proof of the success of the reaction strategy. Naturally occurring terpenes like (+)-3-carene, (-)-α- and ( ) β-pinene and (R)-(+)-limonene are readily available chiral reagents that are widely used in organic synthesis. We present here the synthesis of new chiral (+)-3-carene-based monotosylated diamines and their application in the asymmetric hydrogenation of acetophenones and enantioselective addition of diethylzinc to benzaldehydes [1]. The synthetic route to obtain mono-N-tosylated trans-1,2-diamine is described in Fig. 1.

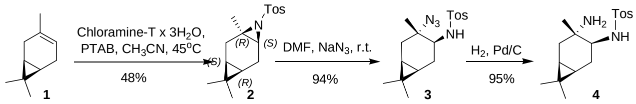

Fig. 1. Synthetic pathway of monotosylated diamine 4.

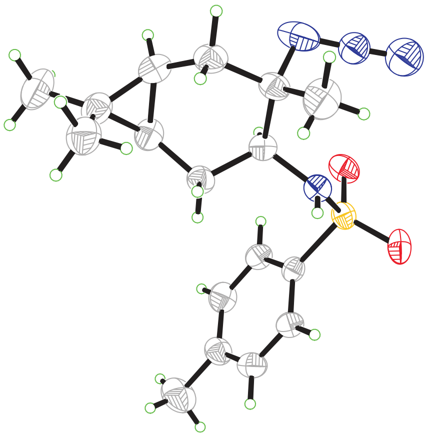

Fig. 2. The ORTEP diagram for X-ray analysis of compound 3.

The reaction path was proved after isolation and recrystallization of intermediate **3**. Monocrystals were used in X-ray diffraction experiments and the data obtained enabled their crystal and molecular structure to be solved [2]. The crystallographic representation of the molecule is shown in Fig. 2.

When the reaction was carried out at 0°C the bromine compound 5 was isolated as the main product with 23% yield and the aziridine was formed with only 20% yield (Fig. 3).

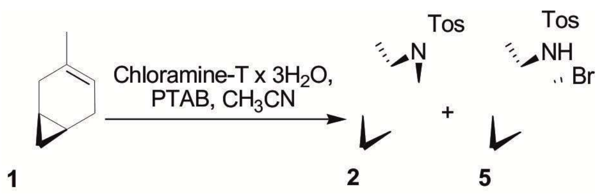

Fig. 3. Optimization of the reaction.

After isolation the crystal structure of **5** was studied [3]. The molecular structure is shown in Fig. 4.

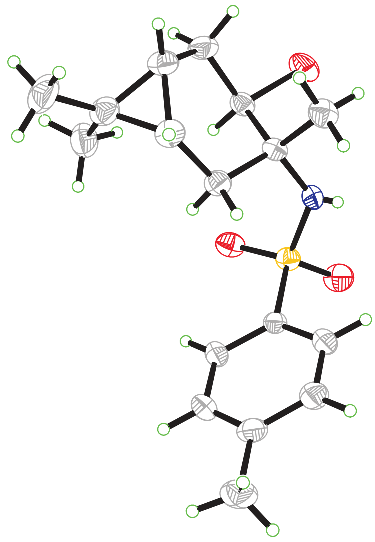

Fig. 4. The molecular structure of 5.

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The enantioselective synthesis of (*S*)-(+)-mianserin and (*S*)-(+)-epinastine

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Mianserin and epinastine – four-ring alkaloids – are important active pharmaceutical compounds. Mianserin is widely used as a drug in the treatment of depression. Despite the fact that the (*S*)-(+)-enantiomer of mianserin was more potent than the (*R*)-antipode in pharmacological tests for antidepresant activity [1][2][3] it is still administered as a racemate due to the fact that so far no effective enantioselective method has been developed. The synthesis of racemic mianserin was originally described by Organon.[4][5]. Mianserin has demonstrated its efficacy as a monotherapy for the treatment of Parkinson's disease psychosis in an open-label clinical trial. Here the (*S*)-(+)-enantiomer is also 200-400 times more active than the other enantiomer. Epinastine is an anti-histamine drug used e.g. in eye drops. Because of the very different activity of the two enantiomers of both compounds the goal of this study was the enantioselective synthesis of both compounds. The synthesis path for (S)-(+)-mianserin is shown in Fig. 1.

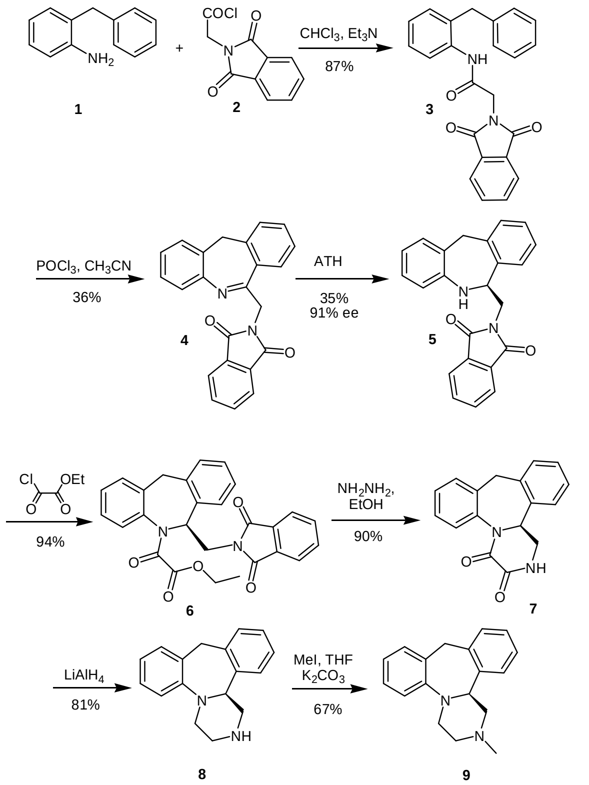

Fig. 1. Synthesis of mianserin.

Similarly, the scheme for obtaining (S)-(+)-epinastine is shown in Fig. 2.

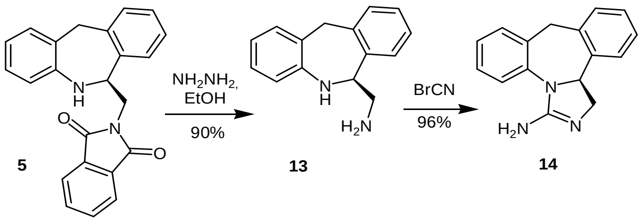

Fig. 2. Synthesis of (S)-(+)-epinastine

Crystallographic studies of intermediates **5** and **7** proved the stereoselectivity of the reactions. The molecular structures are shown in Figs. 3 and 4, respectively.

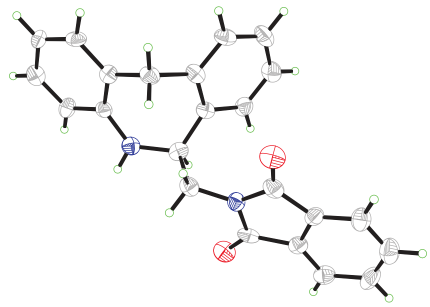

Fig. 3. Molecular structure of 5.

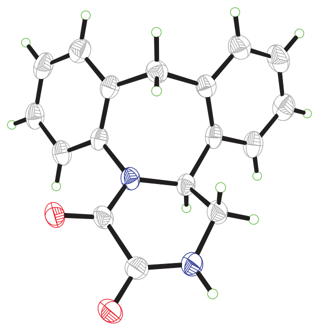

Fig. 4. Molecular structure of 7.

The results were published [6] and detailed crystallographic data were deposited with the Cambridge Crystallographic Data Centre [7]

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Analysis of the elemental composition of artifacts from the Kosewo archaeological site

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Archaeology is a scientific discipline that uses a methodological workshop in various fields of science. The analysis of antique objects made from metal alloys is an area of interest of archaeometallurgy, dedicated to research related to the origin of the raw material alloy, the technological processes that have influenced the antique objects and the problem of corrosion degradation of the object, which is directly used in restoration work.

The aim of this work was to determine the elemental composition of artifacts from the archaeological site in Kosewo (Mrągowo). In order to determine the elemental composition the ED-XRF (energy-dispersive X-ray fluorescence) method was applied [1, 2]. An X-ray tybe developed at NCBJ was used as the X-ray source. Since the X ray penetrates ~100 µm the composition of the matrix alloy was determined and the surface traces of corrosion and maintenance changes were eliminated. Because the incident X-ray beam irradiated 2.1 cm of the studied surface an average composition of the analyzed artefact was obtained. Quantitative analysis (elemental content) was performed by FP (fundamental parameters). For this purpose, the software CrossRoads Fundamental Parameters XRF Scientific Application, which converts the peak intensity to the percentage of a given element, was used.

The composition of bronze artifacts found in a cremation cemetery in the Mazurian Lakes District, dated to the Migration Period (480-550 A.D.), were investigated. Among them are fibulae and fragments of bracelets (Fig. 1). Due to the nature of the archeological site all the objects demonstrate morphological changes causing by secondary heat treatment associated with burning.

Moreover, the pieces of bracelets were found among the analyzed archaeological material, therefore one can suppose that they may originally have constituted one object. The elemental composition analysis lets us divide the alloys of copper into lead-tin bronzes and lead bronzes. An example of the experimental XRF spectrum is shown Fig. 2.

Fig. 1. Studied bronze artifacts divided into groups.

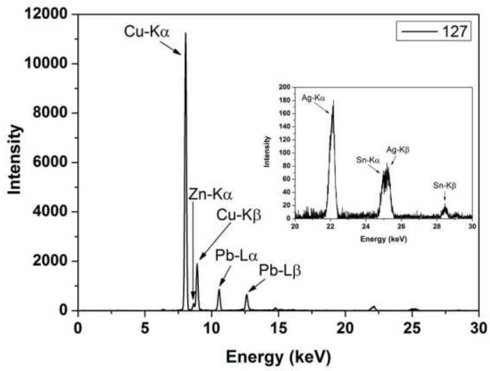

Fig. 2. Measured XRF spectra of artifact #127.

The analyzed artifacts have been interpreted as tin-lead bronzes and lead bronzes and were divided into four groups depending on the similarity of the constituent alloys of copper. Elements such as silver and traces of gold, indium, palladium are included in the ore deposits so that their presence in the analyzed objects may confirm the use of silvering or melting of the raw material containing these components.

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Technical study of tiles (XIII to XV AC) from Aveh, Qom and Masshad in Iran

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In this study SEM/EDX, Raman spectroscopy and complementary techniques are used to identify chemical components of ancient Iranian tiles (Photo 1) [1,2].

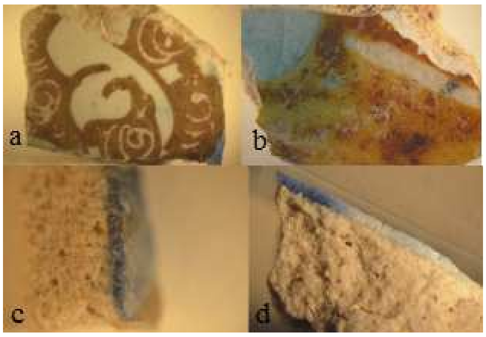
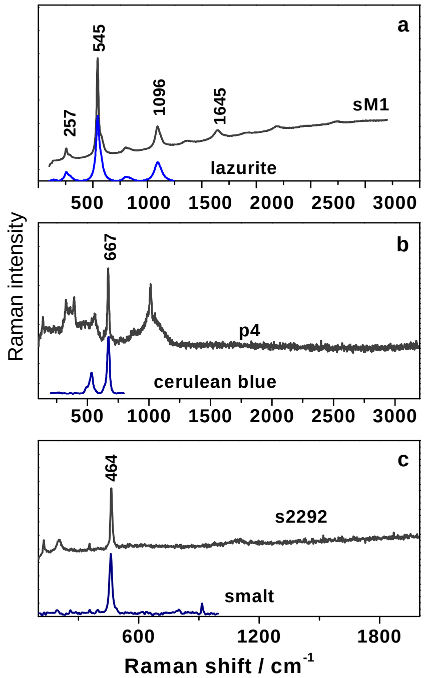


Photo 1. Optical microscope images of tile samples from Aveh (a) and Mashhad (b), and cross sections of the samples (c,d).

The pigment compositions of the tile samples from Aveh (Photo 2) were analyzed and compared to sample compositions from archaeological sites in Mashhad and Qom in order to clarify questions regarding the pigment components and production technology. **The results are an important component of the study of the provenance and origin of the tiles.** All the excavation sites are localized from 100 to 1000 km apart and are dated from XIII to XV AC. It is worth mentioning that Aveh was once a vital place on the active trade route from Soltaniyeh (the former capital of the Mongol Ilkhanate) to Saveh, Qom, Kashan, Ispahan and Shiraz up to the coast of the Persian Gulf.

Photo 2. Aveh archaeological site, Iran.

The results indicate the use of different blue pigments for the production of tiles (fig.1), the usage of Fe oxide based ochre and red pigments [3,4] in mixtures and confirm advanced lustre technique with Pb-rich oxides and traces of corroded Ag (fig.3) [5] .



Raman spectra of the blue pigment used at Masshad (a), Aveh (b,c) and the reference spectra of lazurite, cerulean blue, smalt (http:/rruff.info/) [3].

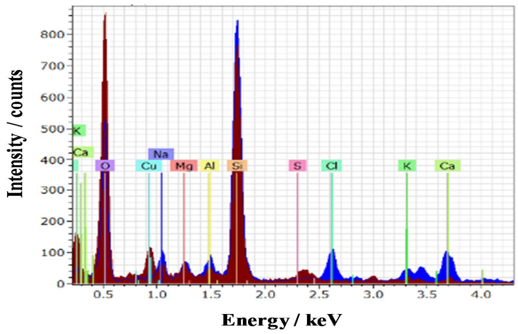


Fig. 3. Sample of EDX spectrum obtained for the Aveh tile (1) for blue and brown surface areas. Traces of Cu, which are part of lustre wire techniques, are present in the brown areas.

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X-ray computed tomography study of ancient objects

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Modern archaeology and conservation science use imagining techniques like X-ray and neutron radiography, also tomography to obtain information about the structure the objects. All these methods are used in the NCNR for this type of research [1].

Non-invasive imagining shows the original shape of objects, especially when artifacts are destroyed by corrosion. Moreover, it can reveal the techniques which were used to produce and ornament the object. Overexposure of closed shapes, such as filled dishes, shows what is inside the structure, based on this information the researcher separate all potential forms trapped inside without damage to the object. In the case of X-ray radiography, differences in density associated with different interaction with atoms of different mass, enables the imaging of diferent material. X-ray computed tomography (X-ray CT) was used to study ancient artifacts, i.e. swoards, fibulae, clay burial pottery, in collaboration with the National Archaeology of Museum in Warsaw and Institute of Archaeology Warsaw University.

The Nikon XT H 225 ST Computed Tomography system located at NCBJ with a 225 kV reflection target source was used. Below are examples of the results.

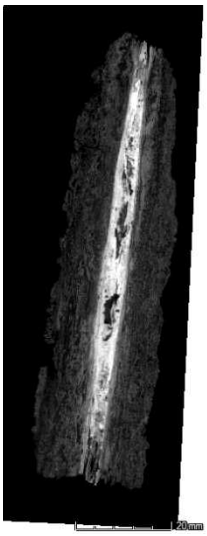
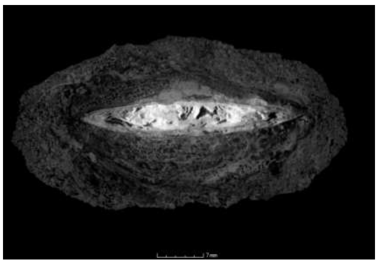

Fig. 1. Iron sword with preserved wooden scabbard (find from Czersk castle). Left hand side: longitudinal section X-ray CT image and cross-section X-ray CT image.

Visible metal-wood border and a considerable degree of sword corrosion.

In most cases high X-ray attenuation of the objects required the use of the maximum possible X-ray energy (225 kV). To achieve proper exposure conditions additional filtering of around 1 mm of copper was mainly needed. The attenuated radiation was detected by aPerkin Elmer 1620 Flat Panel. Reconstruction of the volume was made with Nikon CT-Pro software.

Fig. 2. From the left hand side: real photo and cross-section microscopic photo of silver medieval coins with zinc-copper core covered by silvering, X-ray CT grey-scale image with differing colour areas. The X-ray CT method can be use to detect coins with a core, mint forgeries.

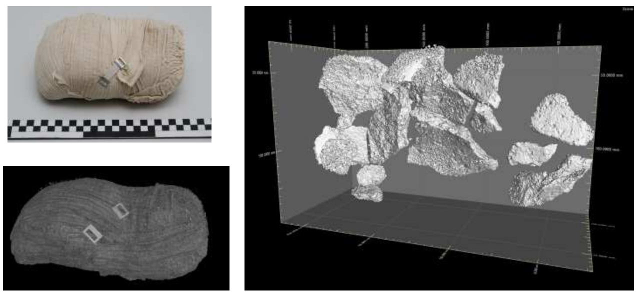

Fig. 3. Burial form from the Czerwony Dwór archaeological site. 3d visualization of burial pottery with cavity backfill protected by bandage, separated fragments of clay in the xyz plane. This type of visualization is useful in conservation work.

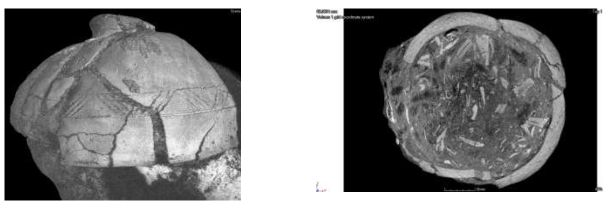

Fig. 4.X-ray CT images of burial pottery protected by a bandage from the Czerwony Dwór site, Masurian Lake District. From the left hand side: 3d surface reconstruction with visible ornamentation, cross-section with bone, pottery, charcoal elements (cremation stack components).

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[2]

Origins and production of silver objects in early medieval Poland

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Based on materials research modern *archeometallurgy* gives answers about the technological and deposit provenance of objects. This project is focused on the study of silver jewelry and coins from the Xth and XIth century in Poland. *Figure 1* show example of studied deposits. Until now there was no certain knowledge about sources of silver for making these objects. Data from a very large material, one of the largest in Europe, consisting of female earrings, pendants and other pieces of various types, formally with their origin in late antique art and further development in the first Slav state of Great Moravia in the ninth century AD [1] are required. So far 120 objects have been studied.

Fig. 1. Example of study coins type and deposits from Słuszków (ca. 1105 year AC).

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 [2]. LA-ICP-MS (Laser Inductively Coupled Plasma Mass Spectrometry) was used with a specially constructed statistical method [3]. Furthermore, a technological study is being performed. By using SEM/EDX (Scanning Electron Microscopy with X-ray Energy Dispersive Microanalysis) morphological changes can be traced and quantitative elemental composition obtained [4] ED-XRD (Energy Dispersive-X-ray Fluorescence Analysis) was used as a complementary technique. There are ongoing attempts to apply the INAA (Instrumental Neutron Activation Analysis) volumetric method to noninvasive detection of a copper matrix in coins and WD-XRF (Wave Dispersive-XRF) as a reference technique to EDX and ED-XRF. Moreover, the jewelry ornamentation, especially types of soldering were studied. *Figure 2* show an example of an SEM image of an area with granulate ornamentation attached to the surface by copper-tin solder.

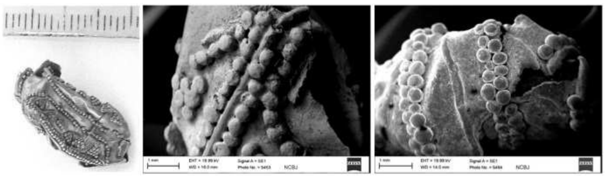

Fig. 2. From the left hand side: photo of jewelry: granulated silver bed, SEM images of surface with granulate mounting to surface by copper-tin solder.

Results of the coin elemental composition analysis indicate two types of production technology: 1.coins (so-called cross-deniers) with copper alloy matrix covered by surface silvering *(fig.3)*. The cover can be made in two ways, by fire-silvering or soldering with the addition of zinc. 2. typical silver alloy coins with Ag concentration ca. 70-90% wt. and ca. 2-10% wt. of Cu. All the studied coins we hot stamped *(fig.4)* [4].

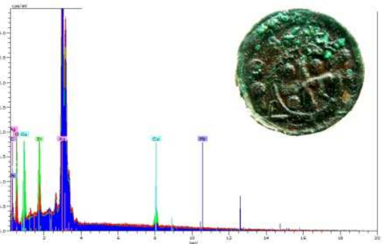

Fig. 3. EDX spectra, three-times sampling in one point, obtained for silvered coins with copper matrix core.

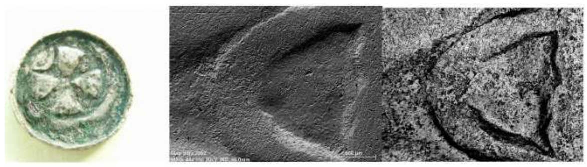

Fig. 4. From the left hand side: coin photo, SEM images (SE and BSE) of coin surface with surface ornamentation. The mild inequality indicate the use of hot stamping.

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.

Acknowledge

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Channelling study of Co and Mn implanted and thermally annealed wide band-gap semiconducting compounds

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The goal of the present search for spintronic materials is to develop a material with the properties necessary for the possibility of mutual interaction of the electronic and magnetic systems of the material (semiconducting and ferromagnetic properties) at room temperature for possible applications in practical devices [1]. Semiconducting compounds such as GaN and ZnO doped with transition metals (TM) are well-established candidates for meeting this goal. Although many GaN and ZnO properties are similar to one another, manufacture of GaN is much more difficult and expensive than that of ZnO, so ZnO is a very attractive material for several new applications and is becoming a good competitor to GaN. Modication of semiconductor properties by ion implantation is a well-established technological process. During ion implantation defects are produced and they usually affect the optical and electrical properties of semiconductors. This might be detrimental for potential application devices, therefore recovery of crystal structure as the result of an annealing process is important. Moreover, the magnetic properties of TM-doped semiconductor strongly depend on both the concentration of the dopant and its lattice location in the structure[2].

In this work we present the defect build-up, recovery and also the lattice location of TM atoms in ZnO (0001) single crystals and GaN (0001) epitaxial layers after 120 keV Co-ion and 120 keV Mn-ion implantation to a fluence of $1.2x10^{16}$ ions/cm^2 in both cases and after thermal annealing. Thermal annealing was performed at 800C in argon ow. These processes were monitored by channelled Rutherford backscattering spectrometry (cRBS) and channelled particle-induced X-ray emission (cPIXE) measurements.

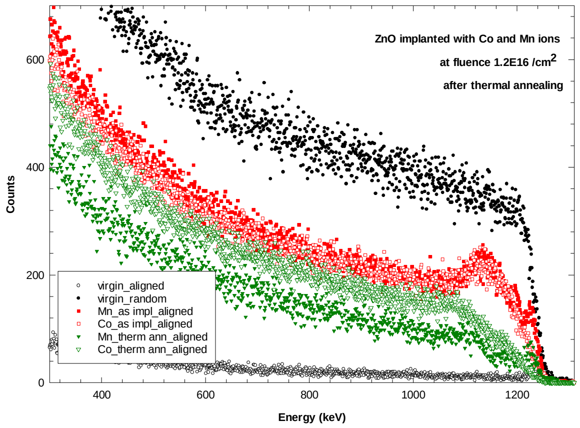

Fig. 1. The cRBS spectra obtained for ZnO before and after implantation with Co and Mn ions to a fluence $1.2x10^{16}$ ions/cm^2 and after thermal annealing at 800^{O}C.

Global cRBS studies supported by cPIXE measurements on ZnO and GaN single crystals implanted with Co and Mn ions were performed.

Our study shows incomplete amorphisation ofboth structures after ion implantation, and partial structure recovery after thermal annealing at 800^{O}C for ZnO only. We alsoobserved that Co-doped partial build in ZnO structure after implantation, and that the effect improved after the thermal annealing process. In turn, for GaN post-implantation damage remained unchanged after thermal annealing, and no Co-substitutions in GaN were observed [3].

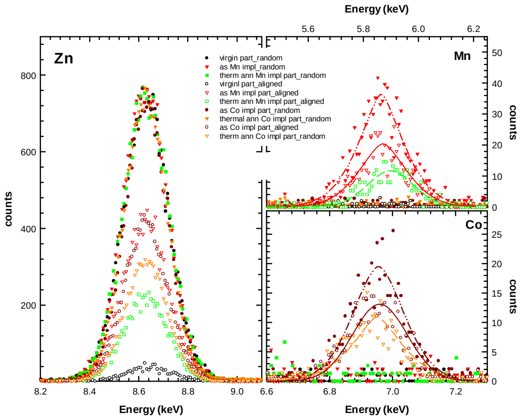

Fig. 2. The cPIXE spectra obtained for ZnO before and after implantation with Co and Mn ions to a fluence $1.2x10^{16}$ ions/cm^2 and after thermal annealing at 800^{O}C.

The cRBS and cPIXE studies for ZnO implanted with Co and Mn ions show the same post-implantation damage in both cases, but a much larger substitutive effect after thermal annealing for Mn-doped than Co-doped into ZnO. Many ZnO features are similar to GaN, but the GaN production is much more difficult and expensive than ZnO, so ZnO is a very attractive material for several new applications and is a good alternative to GaN. We obtained much better results for ZnO than GaN.[4]

This work was supported by the European Community as an Integrating Activity "Support of Public and Industrial Research Using Ion Beam Technology (SPIRIT)" under EC contract no. 227012 – project TNA 207. The project was awarded financial support by the Polish Ministry of Science and Higher Education from the Science Funds for 2013–2014 fiscal years for execution of co-financed international projects (Grant No 2786/SPIRIT/2013/0)

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Raman spectroscopy analysis of air grown oxide scale developed on a pure zirconium substrate

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Due to their high corrosion resistance and almost complete transparency to neutrons, zirconium and its alloys are used as cladding elements in the nuclear industry. High temperature oxidation of zirconium has been extensively studied for many years. It has been shown that the high temperature oxidation of zirconium leads to the growth of an oxide scale which consists of a mixture of tetragonal and monoclinic phases. It is commonly considered that the tetragonal phase promotes the protective role of the scale but the reasons for its stabilization are still under debate. Studies reported in the literature point to the conclusion that there are three possible phenomena responsible for the tetragonal phase stabilization, i.e.: crystallite size, point defects and the stress state generated during oxidation. Therefore, it has been demonstrated that:

- crystallites ranging from 20 – 30 nm are responsible for stabilization of the tetragonal phase close to the metal/oxide interface

- presence of lattice defects within the oxide which can be induced by the sub-stoichiometry of zirconia or by the presence of heterovalent cations in the zirconia crystal lattice can be responsible for stabilization of the tetragonal phase in the outer sub-layer of the post-transition oxide

- finally, one of the strongest candidates for stabilizing the tetragonal phase appears to be the internal compressive stress. However, when the distance from the substrate increases, compressive stress relaxation appears. The average stress in the oxide layer is about -2 GPa, following the experimental value obtained with XRD. Such a stress level has been confirmed by the numerical work of Parise. In conclusion, presence of high compressive stress near the metal-oxide interface has been confirmed, but this effect cannot be taken into account in the case of external sub-layer stabilization.

Raman spectroscopy seems to be a very suitable laboratory technique for qualitative studies of stress in the zirconia scale (both in internal and external parts). However, information about implementation of this technique in the zirconium/zirconia system at high temperatures are rather scarce. In addition, studies comparing results obtained *in-situ* and at room temperature on the same samples under the same conditions do not occur in practice. This approach seems to be justified because the temperature gradient causes phase composition change and the stress relaxation effect. One may note that these phenomena can be interpreted by tracking changes in Raman peak positions and intensities. In the present work, samples of

pure zirconium are studied using the Raman spectroscopy technique, during their oxidation at elevated temperatures under normal atmospheric pressure. Furthermore, these results are compared with Raman measurements performed at room temperature, after cooling. Special interest has been given to the een stress-free and stress-affected tetragonal phase.
positions, shifts and intensities of tetragonal zirconia peaks. These three parameters are used as indicators of the stress relaxation effect, and help in estimating the tetragonal phase content and finally support the distinction between stress-free and stress-affected tetragonal phase.

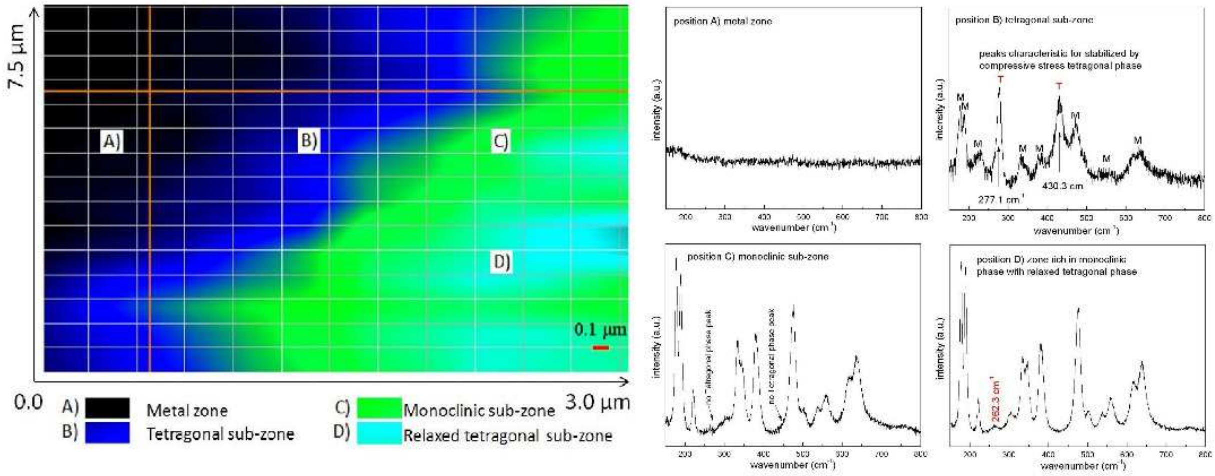

Fig. 1. Visualized cartographic distribution of four different sub-zones obtained due to Raman mapping analysis on a rectangular surface of 7.5 x 3.0 µm², and corresponding typical Raman signal representing each of the four different zones. Reported results concern a sample oxidized at 600°C for 10 h.

The work presented here consists of a characterization of zirconia scale using the Raman spectroscopy technique and aims to help understanding of the relation between the presence of the tetragonal zirconia phase and the qualitative representation of the stress state in the scale. In- situ Raman measurements conducted at 500°C and 600°C show the influence of growth and thermal strains on the peak positions of monoclinic and tetragonal phases.

Considering the surface scan on the sample cross section, it was possible to localize the information across the whole zirconia scale. The Raman analysis confirms the presence of a continuous layer located in the vicinity of the metal/oxide interface which mainly contains the tetragonal phase stabilized by high compressive stress. The effect of stress relaxation with increasing distance from the metal/oxide interface has been presented by the Raman peak shifts. The previously reported hypothesis concerning the existence of a tetragonal phase in the external part of the oxide scale has been confirmed by the present results. A significant amount of this phase has been detected by the mapping experiment. An HWHM calculation suggests that the phenomenon responsible for the presence of the so called "relaxed tetragonal phase" is neither stress nor grain size, but the stoichiometry in the oxygen sub-lattice in this part of the oxide.

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Molecular dynamics simulations of defect accumulation in MgO

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Ceramics are an important subject for the nuclear industry as the main material for nuclear fuel. All of them undergo the effects of radiation damages whether during their life-time in a nuclear reactor, or in long term storage. Depending on the structure they show very different behaviours under irradiation. Their response to irradiation varies from almost perfect resistance to complete amorphization, with possible phase transitions. Impressive progress in computers over the last decade makes it possible to perform simulations of ceramics by means of Molecular Dynamics. Previously we simulated defects caused by cascade displacement. This means one particle cause of many atoms being displaced from their positions in the cell. Now our interest is to see the simulation of small deviations of many atoms.

We used MD simulations to study the process of defect formation caused by irradiation in MgO ceramic. The present calculation has been done with the molecular dynamics (MD) program LAMMPS created at Sandia National Laboratory [1]. We used two potentials proposed by Uberuaga [2] and Akamatsu [3]. Both potentials are composed of a Coulomb term with full charges for both oxygen and magnesium and a Buckingham term.

Our goal is to explain the process of the formation of defects. We performed simulations of the molecular dynamics to get the same defect pattern known from experiment.

We performed calculations for the MgO system consisting of 373 thousands atoms. The size of the cell was 152x152x152 angstrom. We used periodic boundary conditions. For such a structure we performed calculations for zero pressure on the boundary. We used an "aniso" parameter, and this gives more flexibility of the cell for relaxation under pressure.

In figure 1 the status of the cell after 12.2 picoseconds of atom displacement process is presented.

Further work will be to find the conditions that give defects similar to those sean in experiment.

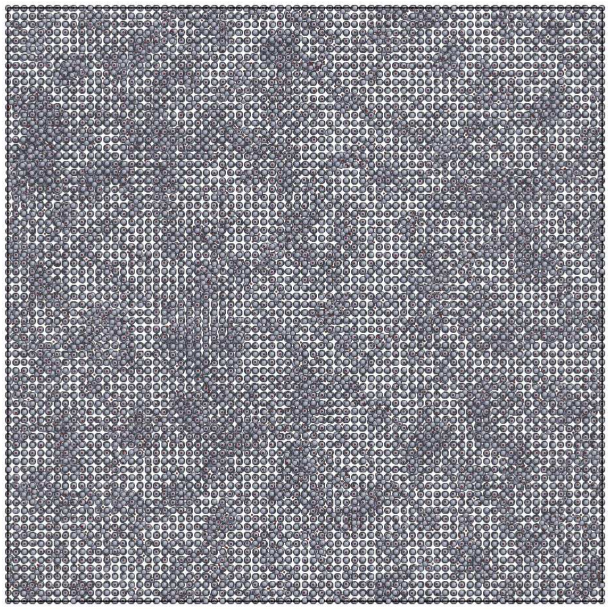

Fig. 1. The cell after 12.2 picoseconds of defect accumulation.

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NUCLEAR TECHNOLOGY IN ENERGY GENERATION

Assessment of silicon dioxide effect on criticality safety of a fuel assembly in a geological repository

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Spent nuclear fuel can be directly disposed of in a deep geological formation to prevent its impact on the human environment. The fuel assemblies placed in such a repository in steel storage tanks are surrounded by buffer clay material and rocks which can be a neutron reflector. The reflector of these materials can give greater reactivity effect than just a water reflector, which is usually used in criticality evaluations.

It is necessary to have validated calculation tools and nuclear data libraries to perform reliable criticality calculations of fuel assemblies in a direct repository with a reflector of these materials.

The Japan Atomic Energy Agency benchmark [1] objectives are criticality assessment of the fuel assembly surrounded by a reflector and confirmation that the various calculation tools and different nuclear data give a consistent reflector effect for the materials by comparing relevant important parameters, such as neutron multiplication factor or the reaction rate.

In geological disposal a candidate for the buffer clay material is a mixture consisting of 70% bentonite and 30% silica sand. The major component of the mixture is silicon dioxide and in the benchmark it is assumed 100% SiO2 for simplicity.

In the benchmark specifications three kinds of reflector material were considered:

- Dry silicon dioxide SiO_2, with no water,
- Wet silicon dioxide, where all soil pores are filled with water – a more realistic model,
- Water as a reference material in order to compare the reflector effect between SiO_2 and water.

The subject under consideration was 17x17 PWR fresh and spent fuel assemblies (burn-up 30 and 45 GWd/t, storage time 0, 30,000 and 20 million years) with a reflector of various thickness from 0 to 120 cm, Fig.1. The moderator region in the fuel and guide tube region is assumed to be filled with water or clay material containing water. The material compositions were supplied in the benchmark specification [1]. The following data were required for fresh fuel: effective neutron multiplication factor (keff), reaction rates inside the reflector region for O-16 scattering, Si-28 scattering, Si-28 capture, H-1 scattering, and H-1 capture, ratio of the absorption rate to the production rate in the system, thermal spectrum index in the fuel assembly region i.e. thermal to total neutron flux ratio. For the spent fuel only the effective multiplication factor was required.

As a numerical tool the 3-D Monte-Carlo SCALE/KENO-VI code with 238-group ENDF/B-VII.0 library was used. Calculation were performed using the following parameters: 50000 neutrons per generation, 250 generations and 10 skipped generations.

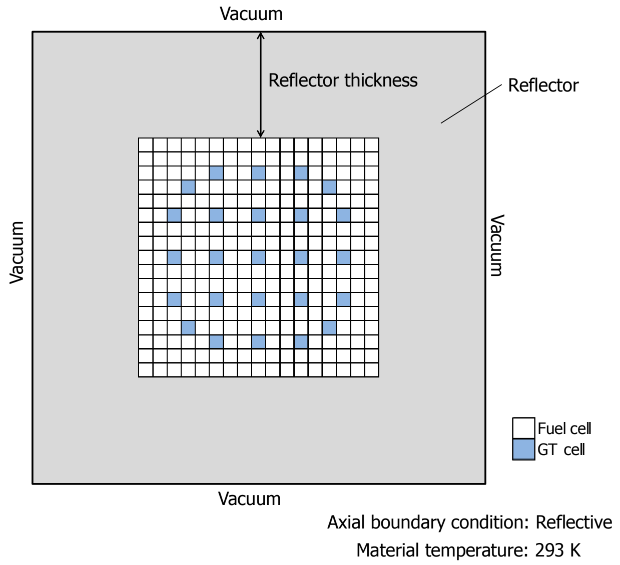

Fig. 1. Schematic geometrical model for the benchmark problem, [1].

The model of the fuel storage cask was 100 cm in length, mirror boundary conditions were used in the axial direction to model the infinite dimension of the assembly required in [1]. The vacuum boundary condition was applied in the radial direction.

Closest to critical state, k_{eff} above 0.99, were the cases with fresh fuel, water as a moderator and high thickness (90 and 120 cm) of dry SiO_2 reflector.

In all spent fuel cases k_{eff} was much less than 1. The largest neutron multiplication factors were obtained for newly unloaded fuel. The maximum k_{eff} has a value of 0.819 for 0-year storage time, water moderator and a SiO_2 reflector of 120 cm thickness, [2]. The k_{eff} coefficient is larger for wet SiO_2 than for dry SiO_2 with the same reflector thickness and storage time.

Calculations were also performed using MCNP and SERPENT Monte Carlo codes with ENDF/B-VII.0, continuous neutron energy, nuclear data library [3]. In the case of the MCNP calculations the following parameters were used: 10000 neutrons per cycle, 1000 cycles with 50 cycles skipped.

The highest effective neutron multiplication factor k_{eff} was obtained for the case with fresh fuel, water as a moderator and 120 cm of dry SiO_2 reflector. The k_{eff} reached 0.99376 for SERPENT calculations and 0.99513 for MCNP calculations. In most cases k_{eff} is much lower than 0.99. The difference between the results of the

MCNP and SERPENT calculations compared to the results of other participants are lower than 1%.

Collected results from all participants and conclusions of the benchmark will be published in 2016.

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MR-6/430 and MC-5/485 fuel element calculations for the MARIA reactor using the Apollo2 neutronic code

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The MARIA research reactor at the National Centre for Nuclear Research in Świerk, Poland was operated using two types of fuel elements: 19.7% U-235 enriched (LEU) and 36% U-235 enriched (HEU) fuel.

Based on the scheme of previous calculations with WIMS and REBUS, calculations for the MARIA research reactor were carried out with a new approach and the APOLLO2 software. The benchmarking calculations were done for elementary cells containing beryllium blocks with water gaps and a fuel element. Two fuel elements were considered: MC-5/485 and MR-6/430g as a reference with better studied characteristics. Calculations in APOLLO2 were made using the CEA93 172 energy group library, collapsed to 69 groups. Fresh materials, 20 operating cycles, including and not including and skipping outage periods between cycles. Reference calculations were done in MCNP.

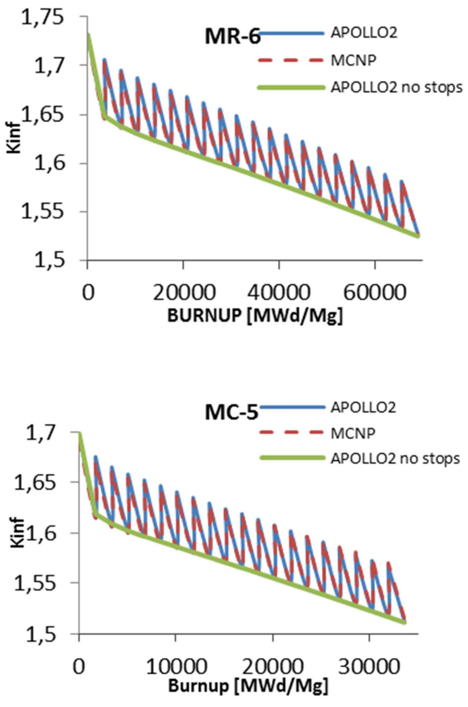

Fig. 1. keff results for MR-6 and MC-5 fuel.

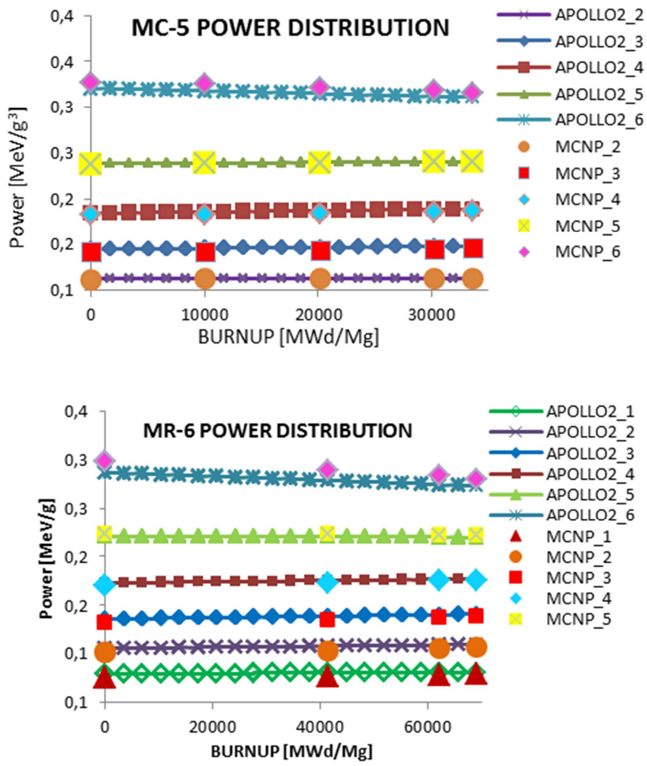

Fig. 2. Power distribution in fuel layers for both fuels and codes.

Conclusions

It was shown that the MC-5 fuel cycle has the same characteristics of multiplication factor evolution as the MR-6 fuel type. The differences in calculated values between both codes are very small and may by caused by the fact of using different calculating methods as well as cross section libraries. Another factor that may influence the discrepancies is the use of simplified geometry in the APOLLO2 self-shielding calculations. For APOLLO2 and MCNP, power distribution agreement is very good. The presented results show a slight, negligibly low, difference in flux values However, the flux distribution in the fuel element has exactly the same shape for both codes.

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Neutronic calculations for safety analysis of high-temperature reactors with pebble bed core on the example of HTR-10

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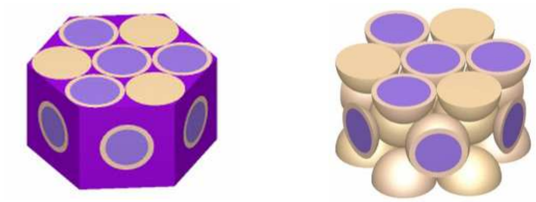
The aim of the project "Development of high temperature reactors for industrial purposes (HTR-PL)" was theoretical research on the physics and engineering of high temperature gas-cooled reactors (HTGR). One of the tasks was verification of the safety characteristics of pebble bed HTGR, using the technical data of the experimental Chinese reactor HTR-10. The goal of this study was the validation of the computer codes and the acquisition and reinforcement of the capability of their use for neutronic calculations of safety related parameters of pebble bed HTGRs.

The elements of the study of the safety features of HTR-10 were: dependence of the effective multiplication factor value (k-eff) on the number of pebbles and their temperature, power distribution in the core for operational conditions, calculation of temperature coefficient values, calculation of the control rod worth.

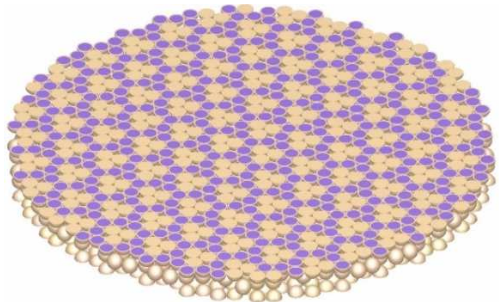
The neutronic calculations were performed with the SCALE/KENO-VI code system developed at Oak Ridge National Laboratory. HTR-10 fuel is composed of a large number of tiny tristructural-isotropic (TRISO) fuel particles embedded in a graphite matrix and shaped into spherical fuel elements – pebbles. The inherent double heterogeneity of such a fuel makes it more difficult to model and requires methods different from those used for e.g. LWR fuel.

The first HTR-10 reactor neutronic calculations by the SCALE/KENO-VI code were performed relying on the ORNL input published in NUREG/CR-7107 ORNL/TM-2011/161: Validation of SCALE for High Temperature Gas-Cooled Reactor Analysis. The input was based on the specifications of the Nuclear Energy Agency (OECD) benchmark in the framework of the International Reactor Physics Experiment Evaluation Project – IRPhEP.



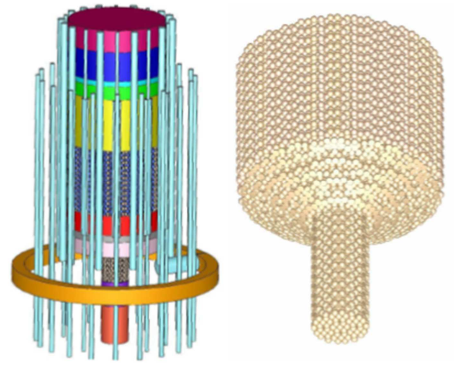
Unit cell of HTR-10 in the SCALE/KENO-VI model.

The original input contained a mixture of fuel and dummy pebbles only in the cylindrical part of the core – the configuration of the first criticality experiment. The remaining lower parts of the core i.e. the conus (hopper) and discharge tube were filled with graphite balls. To examine reactor behaviour during normal operation the model should be changed in such a way that the hopper and discharge tube contain a mixture of fuel and graphite balls. For this reason, many changes in the original input file were made.



Distribution of HTR-10 pebbles in the SCALE/KENO-VI model.

In the analyses performed, the HTR-10 reactor was considered mainly in its operating condition, therefore the space between the balls was filled with helium with a temperature-dependent density for reactor start-up – 20°C (critical experiment) and for a hot reactor – 920°C at a constant pressure of 3 MPa. Calculations were performed for three heights of the pebble bed: 104, 160 and 221.5 cm.



Model of HTR-10 in the SCALE/KENO-VI code.

A detailed description of this study and all results are collected in the final report [1].

The High-Temperature gas-cooled Reactor (HTR) is a promising concept for the next generation of nuclear power plants. The "HTR-PL" project included activities concerning the validation of computational tools and the qualification of models. The HTR-PL project was funded by the National Centre for Research and Development in Poland.

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Neutronic calculations of a PWR core with accident tolerant fuel

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The possibilities of accident tolerant fuel use in the EPR type core, based on neutron- physics calculations and available scientific data, were analyzed.

Five different enrichments of U-235 and three types of fuel cladding: molybdenum, SiC and M5 (reference) were chosen to perform burnup neutronic calculations for fuel elements and fuel assemblies. Based on these calculations six core configurations with SiC fuel cladding were proposed, An example of the core configuration is show in Fig.1[1,2,3,4,5].

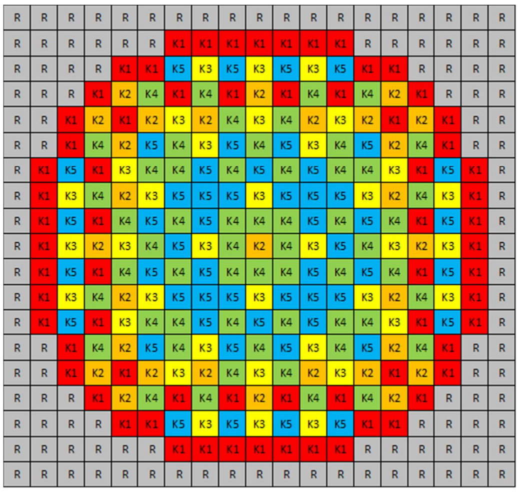

Fig. 1. An example of a core configuration, TEPR3.

Such results of the MCNP calculations as power distributions in the core, multiplication factor and the reactivity coefficients of the reactor core were obtained. Based on the US EPR Final Safety Analysis Report, values of the normalized power distribution in TEPR cores and EPR core were compared(Fig. 2). Calculations were performed for the following states of the reactor core: Hot Full Power, at the beginning of the fuel cycle and All Rods Out. Closest to the power distribution in the EPR core is the distribution for the following cores: TEPR2, TEPR3 and TEPR4. The EPR core, according to the technical specifications, has been designed with a multiplication factor for the state of the HFP and for a fresh core at the beginning of the nuclear fuel cycle equal to 1. In contrast, in the present work the designed configurations of the cores were prepared for a fresh core and for the HFP state with a small reactivity supply. Operational safety analysis of the nuclear reactors, from the neutron point of view, beyond the calculations of the multiplication factor value and power distribution include calculations of the temperature, reactivity and vacuum coefficients[6].

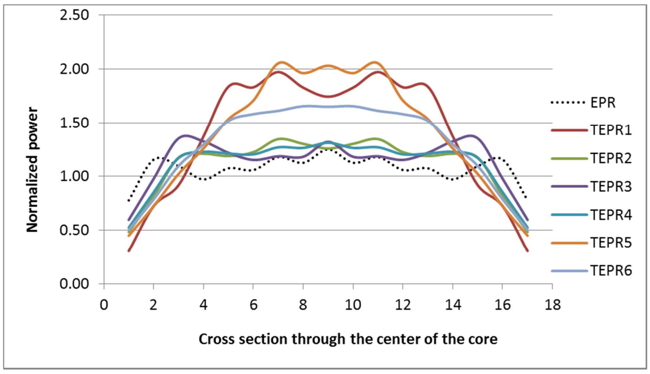

Fig. 2. Comparison of power distribution in various reactor cores.

As a result of these calculations it was proved that the designed TEPR core configurations would be safe in operation.

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Investigation of Np-237 incineration in the QUINTA setup

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There are two ways in which Np-237 may with neutrons – fission and capture. As shown in Figure 1 the capture cross section (CS) prevails over the fission one by about 10^4 times in the thermal range then both CSs come closer in the epithermal range until the fission CS becomes larger at an energy of about 0.8 MeV [1].

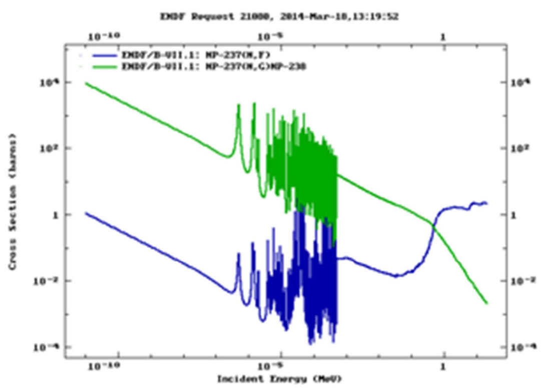

Fig. 1. Np-237 neutron caused fission (dark blue) and capture (green) cross section dependence on energy [2].

This dependence explains why actinides accumulate in existing power reactors. The only way to prevent this accumulation is to incinerate them in a high energy neutron field. JINR Dubna's spallation neutron source QUINTA's applicability for actinide transmutation is investigated in the framework of an International Research Project "E&T RAW". The QUINTA consists of 510 kg of natural uranium – Fig. 2 – left – surrounded by 10 cm of lead sheilding. The spallation neutrons were produced by bombardment of the QUINTA uranium core by a 660 MeV proton beam. This work was aimed at the determination of Np-2337 fission and neutron capture efficiency during irradiation by spallation neutrons.

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 actinide (Np-238), a result of neutron capture by Np-237, gave the number of captures.

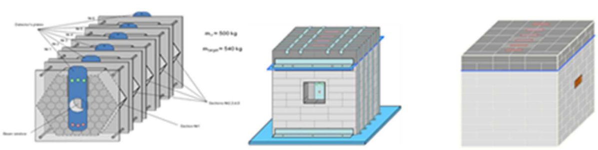

Fig. 2. QUINTA setup - internal core, front view and rear view.

The investigated Np-237 sample was irradiated in the side window marked in red.

Table 1. Gamma lines identified in Np-237 sample.

EG [KEV]	ISOTOPE	T1/2	IG [%]	Γ [%]
529,87	133I	20.87H	87	4.45
555,57	91SR	9.63H	95	2.67
630,19	132I	2.295H	13.3	3.98
641,28	142LA	91.1 MIN	47.4	4.5
657,94	97NB	72.1M	98.23	5.35
661,66	137CS	30.05Y	85.1	5.11
667,71	132I	2.295H	98.7	3.98
743,36	97ZR	16.744H	93.6	5.35
749,80	91SR	9.63H	23.61	2.67
756,72	95ZR	64.032D	54.38	5.54
772,60	132I	2.295H	75.6	3.98
954,55	132I	2.295H	17.6	3.98
1038,76	135I	6.57H	8.01	4.16
1131,51	135I	6.57H	22.6	4.16
1260,41	135I	6.57H	28.7	4.16
1383,93	92SR	2.66H	90	4.01
1457,56	135I	6.57H	8.73	4.16
1678,03	135I	6.57H	9.62	4.16
1791,20	135I	6.57H	7.77	4.16
923,98	238NP	2.117D	2.869	100
962,77	238NP	2.117D	0.702	100
984,45	238NP	2.117D	27.8	100
1028,54	238NP	2.117D	20.38	100

Table 2. Np-237 fission and capture rate per gramme and per beam proton final results

	WM	WME	WME [%]
fission	1,45E-05	9,78E-07	6,74%
capture	2,23E-05	2,14E-07	0,96%
fission/capture	0,65	0,04	6,81%

Reference

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Spent nuclear fuel management.
Analysis of options for the Polish Nuclear Power Programme

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The Polish Nuclear Power Programme assumes the commissioning of nuclear power plants with a capacity of 6000 MWe by 2035.

Table 1. Characteristics of the EPR, AP-100 and BWR after 60 years of operation.

Energy	TWh	2 775.2		
Unit		PWR		BWR
Net efficiency	%	33	36	34
Spent fuel	MgIU	6 400	5 813	7 290
Burnup	GWd	352 000	319 690	342 613
Uranium	Mg	5907	5365	6818
Neptunium	Mg	9.3	8.5	8.0
Plutonium	Mg	81.3	73.8	90.2
Americium	Mg	3.3	3.0	3.4
Curium	Mg	0.4	0.4	0.3

The construction of nuclear power plants in Poland will impose on the bodies responsible for management of radioactive waste, spent nuclear fuel, nuclear and radiological safety, as well as the operators of nuclear power plants an important task: selection of technology for spent nuclear fuel.

Currently three technologies can be analyzed, of which the first two are already used in the management of spent nuclear fuel:

1. The disposal of spent nuclear fuel without reprocessing in a geological repository - open fuel cycle -REPOSITORY,
2. The reprocessing of spent fuel to extract plutonium and fission products and produce from the recovered plutonium MOX fuel, then use of MOX fuel in reactor power, MOX spent fuel and waste generated during processing disposal -REPROCESSING.
3. A new technology (RECYCLING) of burning radiotoxic actinide isotopes contained in the spent fuel from water power reactors in fast neutron reactors.

The problem of spent nuclear fuel is the most significant challenge for all operators of nuclear power plants around the world. Each year, from civilian power reactors more than 10 000 MgIU of spent nuclear fuel is discharged. Undoubtedly, storage of suitably protected and "cold" spent nuclear fuel is the least costly and relatively safe for a few generations - approx. 1 000 years - technology to dispose of "nuclear garbage".

The National Programme for Spent Nuclear Fuel and Radioactive Waste Management should take into account storage of spent nuclear fuel in dry or wet storage with the possibility of the use of the recycling technology option in the future. In this option there is disposal of high level radioactive waste, but the size of the disposal and the necessary period of isolation of these wastes is incomparably smaller than that of spent nuclear fuel without reprocessing.

Table 2. Watts from nuclear fuel recycling

LWR reactors		PWR		BWR
Net power	MWe	6 000		
Fuel burnup	GWd/MgIU	55		47
Net efficiency	%	33	36	34
Electric energy	TWh	2 775.20		
Spent nuclear fuel	MgIU	6 400	5 813	7 290
Recykling Centre				
Blocks number	2xPRISM	6	5	6
Energy from recycking	TWh	1 668	1 515	1 783
Uranium from recycling	Mg U	5 886	5 346	6 790

Confirmation of the economic viability of the prototype Recycling Centre will mean that the construction of a Recycling Centre in Poland will be the next step in the development of the national nuclear energy programme.

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The need for development of gas cooled reactor technology in Europe

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Nowadays we are experiencing a renaissance of nuclear power and several initiatives for Gas Cooled Reactors have been begun. The main objective of these initiatives is to increase the research and technical potential as well as help the development of nuclear energy in several countries. Gas Cooled Technology is promising because of its high efficiency (about 47%), excellent passive safety features and the possibility of U-233 breeding from Th-232

The National Centre for Nuclear Research (NCBJ) in Poland is involved in the development of European platform of knowledge and collaboration - The Sustainable Nuclear Energy Technology Platform (SNETP). Two of the three pillars are projects linked to Gas Cooled Reactor Technology.

Fig. 1. Three pillars of the SNETP vision.

Cogeneration technologies could extend the low carbon contribution from nuclear fission to the energy system by directly providing heat for different applications like district heating, sea water desalination, process heat for many industrial applications as well as bulk hydrogen production, synthetic transport fuel production or even carbon capture and utilization (CCU). Potential deployment of HTGR technology to fulfill industrial energy needs created the Nuclear Cogeneration Industrial Initiative (NC2I). NCBJ was a leader of the supported project NC2I-R to study the feasibility of using nuclear reactors to produce electricity and heat.

One of the major charges against the implementation of nuclear energy is the high-level nuclear waste produced. Fast spectrum reactors with closed fuel cycles will allow a reduction in high-level nuclear waste radiotoxicity and volume. The use of fast reactors with a closed fuel cycle approach will allow more sustainable implementation of nuclear energy. ALLEGRO is the second line of the French-led FNR development – also an EU Euratom project under ESNII (one of the pillars of SNETP). This is a gas-cooled fast reactor (GFR), one of the six or seven designs promoted by the Generation IV International Forum. A 50-100 MWt experimental version is envisaged by 2025.

The main areas for research and innovation actions for the Gas Cooled Reactor are the following:

- Helium technology and components development,
- Fuel Development,
- Development & validation of analysis tools and qualification,
- Site selection & site permit, licensing issues.

Right now it is clear that development of GCR in Europe provides benefits:

- Low and stable price of electricity,
- Long term operation,
- No emission of CO2,
- Good floor area ratio per power,
- Reliable Power Supply.

However, new nuclear reactor technology has to address the following key challenges:Economics of new nuclear power plants,

- Safety design - adaptation of design to national requirements,
- Delay - time of licensing and construction,
- Risk of closure by political decision.

Gas Cooled Reactors can provide sustainable energy development in Europe and this technology is the key to the deployment of a large-scale closed fuel cycle. As a result of progressive deindustrialization and emissions limits for industry, GCRs can provide heat for energy-intensive processes instead of fossil fuels.

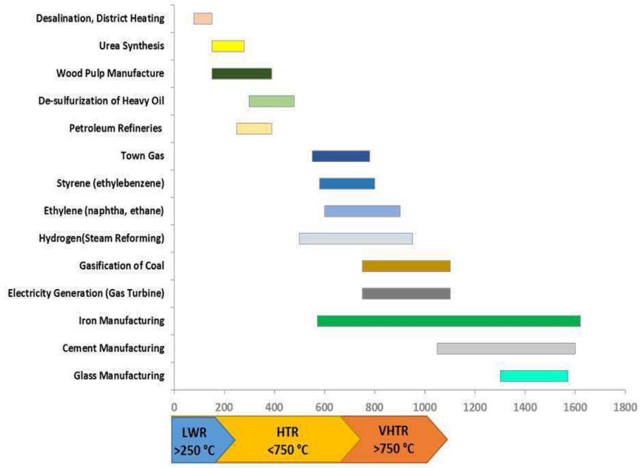

Fig. 2. Temperature range of different heat applications and needs covered by different types of nuclear reactor technology.

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Heat exchange modelling in a uranium fuel assembly

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The main aim of this work was focused on modelling heat transfer phenomena and defining safety margins of assembly operation. In order to achieve this goal, modern Computation Fluid Dynamics (CFD) methods have been applied. The most crucial safety issue is the appearance of boiling in a reactor, which impairs heat exchange between the assembly and coolant and in extreme cases may lead to severe accidents i.e. a fuel plate meltdown.

The investigation was focused on determining the Onset of Nuclear Boiling Ratio – ONBR. This factor describes the safety margin of the reactor operation and explicitly indicates the state when nucleate boiling in the fuel channels starts to appear. When boiling occurs reactor operation is forbidden due to safety reasons. The ONBR value depends on two crucial parameters: the dimensions of the slots between the plates in the assembly and the heat flux generated by the fuel. During this research, the relation between these parameters and ONBR was identified and approximated for a given range of slot thickness. The investigated relation was plotted in the form of a map of the operational area, presented in Fig. 1. Three domains are shown and characterized by 3 different scopes of ONBR. The linear relation between the points seems worthy of comment, because it allows easy prediction of the ONBR factor in the range of investigated scope by linear approximation.

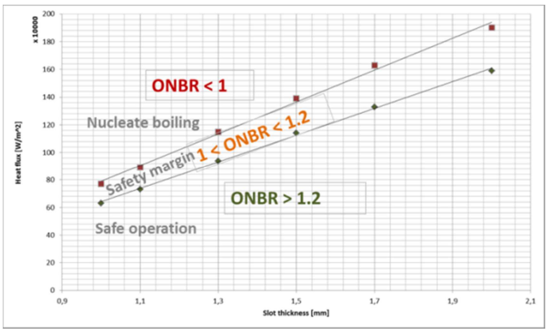

Fig. 1. Relation between ONBR, slot thickness and heat flux.

The ONBR ration was calculated according to the Forster-Greif correlation [1]:

$$T_{ONB} = T_{SAT} + 0.128\frac{q^{0.35}}{p^{0.23}}$$

$$ONBR = \frac{T_{ONB} - T_{in}}{T_{PCT} - T_{in}}$$

where: q – heat flux [W/m^2], p – pressure [bar], T_{SAT} – coolant saturation temperature, T_{PCT} – peak cladding/wall temperature, T_{in} – inlet temperature to the fuel element.

It is assumed that during normal operation mode, the ONBR should be larger than 1.2 in order to avoid steam creation on the cladding and to provide a sufficient safety margin [2].

The CFD simulation enabled all the thermo-hydraulic aspects and details of the flow pattern inside a uranium fuel assembly to be checked. Thanks to the conducted studies, a safe working domain of the assembly was defined for given geometry assumptions. Based on the investigation, the following conclusions were made:

- The results obtained can be used as a base for further neutronics optimization of the fuel assembly geometry on parameters of a neutron beam.
- In the case of a fuel assembly with a slot thickness varying from 1 mm to 2 mm, the heat flux vs. slot thickness relation can be approximated by a linear function in order to determine the boundaries of the same ONBR values (i.e. ONBR =1 or 1.2).
- 2D simplification of the problem may cause some discrepancies in relation to measurements of a real fuel assembly operation. However, a 3D model of the problem would consist of a coarser than 2D grid or would require significantly longer computation time. Considering branch calculation it is important to operate on the less demanding model (i.e. 2D), because a high number of cases has to be computed in a reasonable time.
- Further study of the problem may be devoted to cases concerning pressure losses or Loss of Flow Transient Accidents where coolant flow is limited. It is crucial from the safety point of view to provide adequate operation margins, especially for some abnormal occurrences.

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Hypothetical model of helium migration in UO_2 fuel during neutron irradiation

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It is known that large amounts of noble gases are retained in high burn-up fuel. Release of both helium and the fission gas xenon is similar during the annealing process. This enables us to infer that migration and release of helium from the fuel under irradiation is similar to that of the fission gas products - the same mechanisms controls these. Therefore, the hypothetical modelling of helium migration and release during irradiation is described by the defect trap model of fission gas behaviour published earlier [1,4,5].

Two stages of helium and xenon release from highly burned fuel during annealing are observed. The first stage starts at a temperature of about 900 K (627^{o}C) and the second stage starts at about 1350 K (1077^{o}C). The amount of gas released in the first stage is smaller in comparison with the amount in the second stage [1,4,5].

A helium atom located in the octahedral interstitial position of a perfect crystal of lattice of UO_2 is subjected to strong repulsive forces from the surrounding metal and oxygen atoms, which means that it is in a deep potential well of depth preventing it from any movement in the crystal even at very high temperatures. Thus the octahedral interstitial positions in uranium dioxide are effective traps for helium atoms [2,3].

Applying “Ab initio” calculations using the Wien2k program package we estimated the static energy barrier between interstitial sites in a perfect lattice of UO_2+He. as about 4.15 eV.

It is proved that the gas release in the second stage is controlled by grain re-crystallization which starts at a temperature of about 1100^{o}C for highly burned fuel [2,3].

According to our opinion in the analysis of the immobilization of helium atoms produced in the fuel, one should involve both the solid nuclear fuel material and its nano metre thick surface layer (see Fig. 1) – i.e. the total surface area of the fuel.

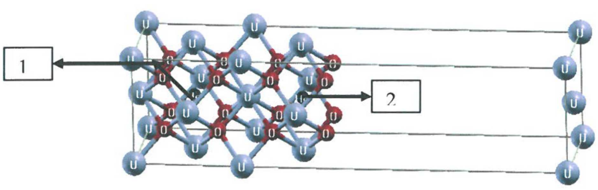

Fig. 1. Escape routes of helium through the metal urface(1)or oxygen surface (2).

Because the total surface area of the highly burned fuel is huge, the release of noble gases in the first stage is remarkable during annealing.

In the area of the nano superficial layer the only good places for the immobilization of helium atoms are closest to the metallic surface octahedral sites, for which the barrier height is V_0=1.9 eV, which corresponds to a temperature equal to about 600^{o}C, evaluated by “Ab initio” calculations [6].

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Measurements relevant to high energy neutron spectra by application of yttrium detectors in the quinta assembly using an 8 GeV deuteron beam from the JINR nuclotron (Dubna) and a 0.66 GeV proton beam from the JINR fazotron

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This work was done within the international project "Energy plus Transmutation of Radioactive Wastes" (E+T – RAW) for investigations of energy production and transmutation of radioactive waste from atomic energy.

Fig. 1. Quinta assembly

Y89 samples were located inside the ADS (Accelerator Driven System) assembly Quinta (uranium target). Two experiments were carried out. The foils with yttrium detectors were irradiated by a deuteron beam of 8.00 GeV from the JINR Nuclotron(2013) and by a proton beam of 0.66 GeV from the Fazotron (2014).

TwelveYttrium-89 activation detectors were placed in the Quinta assembly (Fig.1) on the detector plates in front of, between the five sections, and on the rear of the assembly in two positions at varying radial distances (4 and 8 cm). We attempted to evaluate the average high energy neutron flux inside the Quinta assembly using the threshold reaction (n,xn) in Y89. The measurement method was based on gamma-ray spectrometry

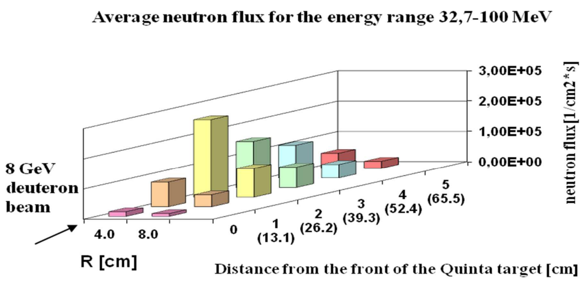

Fig.2. Spatial average neutron flux distribution in the Quinta assembly for the neutron energy range (32,7-100) MeV for an 8 GeV deuteron beam from the Nuclotron.

We have obtained the spatial distribution of Y88, Y87 and Y86 isotope production from (n,xn) reactions and also the average neutron flux in three neutron energy ranges (11,5-20.8, 20,8-32.7, 32,7-100 MeV) for the 8 GeV deuteron beam and the 0.66 GeV proton beam respectively (Fig.2,3). There are uncertainties in the measurements involving the total number of primary particles in each experiment. The overall errors of the experimental data were not less than 15%-20%.

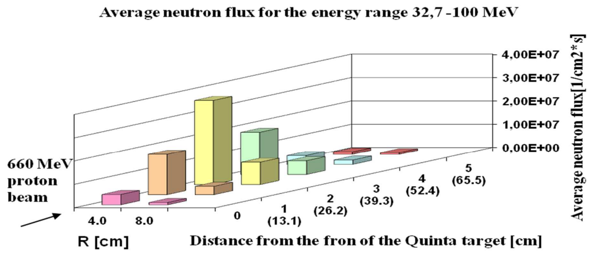

Fig.3. Spatial average neutron flux distribution in the Quinta assembly for the neutron energy range (32,7-100) MeV the 0.66 GeV proton beam from the Fazotron.

Our analysis has shown that the average value of the neutron flux density per deuteron for the 8 GeV deuteron beam in the maximum position (13.1 cm – distance from the front of spallation target) is about 10 times bigger (φ=1,01E-05 neutron/cm^2/MeV/deuteron for R=4cm) in comparison with the same position for the 0.66GeV proton beam (φ=3.06E-06 neutron/cm^2/ MeV/proton for R=4cm). The value of the neutron flux density at the end of the assembly (54.4 cm - distance from the front of spallation target) is about 80 – 100 times bigger.

This theme of research is planned to be continued.

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A method and computer library for determining changes in radionuclide concentration over time

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The developed method is based on a generalized solution of the differential equation of the radioactive decay law:

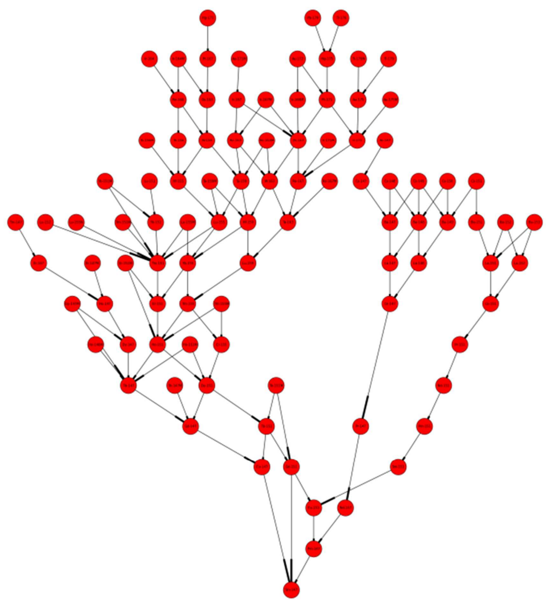
$$\frac{dN_n(t)}{dt} = \lambda_{n-1}N_{n-1}(\mathrm{t}) - \lambda_n N_n(\mathrm{t})$$

where N is the nuclide concentration and λ is the decay constant.

This method is similar to the methods described by Bateman [1] and Yuan and Kernan [2], but includes instances where the decay constants of two or more nuclides are equal, leading to infinities in the solutions of the equations.

Computer implementation of this method provides an accurate and efficient way to determine the changes in the concentrations of radionuclides over time. The library does not have predefined information about the nuclides, types of decay and decay constants, and can work with any database – for example ENDF. It also allows for inclusion of emitted particles and spontaneous fission product yields in the decay chains. The results of calculations can be used to determine the composition, activity and thermal power of the analyzed sample.

In the future, this method can be extended to the possibility of determining the energy spectrum of the radiation associated with radionuclide decays. It is also possible to use this method to create a more elaborate code, which will take into account nuclear reactions and will be able to predict changes in the composition of nuclear fuel during reactor operation.



An example of a chain of decays - Sm-147 and all predecessors. Based on data from ENDF-B-VII.1.

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Dynamic modelling of an actinide extractor from molten salt to molten bismuth

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The actinide extractor is supposed to be one of many elements of a MSR fuel online reprocessing unit [1].

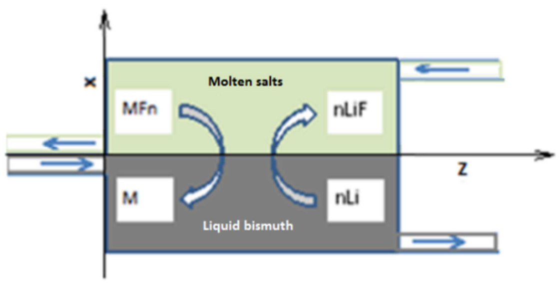

*Fig. **1**. Extractor 2D model.*

The extractor consists of two layers of fluid flowing in opposite directions. The lower one contains molten bismuth and the upper one contains molten salts. The horizontal arrows show the flow directions. The upper layer contains an actinide fluoride in ionized form($M^{4+}4F^{-}$) while the lower one (bismuth) contains metallic lithium (Li). The liquid bismuth does not dissolve the ionized atoms so the actinide extraction reaction of form

$$MF_n(s)+nLi(b)\text{-->}nLiF(s)+M(b)$$

takes place only through the contact surface. Here the index s means salt and b means bismuth. The metallic lithium from the bismuth becomes ionized or oxidized (loses an electron) on the exchange surface and goes to the salt while the actinide ion becomes reduced or neutralized (gains an electron) and goes to the bismuth. The curved vertical arrows show the lithium/actinide flow direction.

Generally speaking the extractor is a very complicated setup. To describe it one has to take into account fluid dynamics, thermodynamics, chemistry and electrochemistry.

To make the model as simple as possible the extractor has only a 2D (x,z) form and the fluid flow driven by the pressure gradient is assumed to be only in the z-direction. The fluids are viscous, the flow is laminar. Its profile is assumed to be of a constant shape. Flow is only possible in the x-direction thanks to diffusion and reaction. The energy conservation law is neglected. The reaction is limited to 2 components in bismuth (M and Li) and to 2 in the molten salts ($M^{4+}4F^-$ and Li^+F^-).

The conservation law equations making the model have the form:

$$\frac{\partial c_i}{\partial t} = \mp \lambda c_i - V_z \frac{\partial c_i}{\partial z} + D\frac{\partial^2 c_i}{\partial x^2} + D\frac{\partial^2 c_i}{\partial z^2}$$

$$\frac{\partial p}{\partial z} = \mu \frac{\partial^2 V_z}{\partial x^2}$$

$$c_i(x,z)\big|_{t=0} = c_{0i}(x,z)$$

$$V_z(x)\big|_{x=x_0} = 0$$

Here:

c – substance concentration

λ – reaction rate on contact surface

V_z - flow velocity in z direction

D – diffusion coefficient

p – pressure

This set of equations is solved with the FTCS method - central formula finite difference method for the space part and the forward in time (RK4) method.

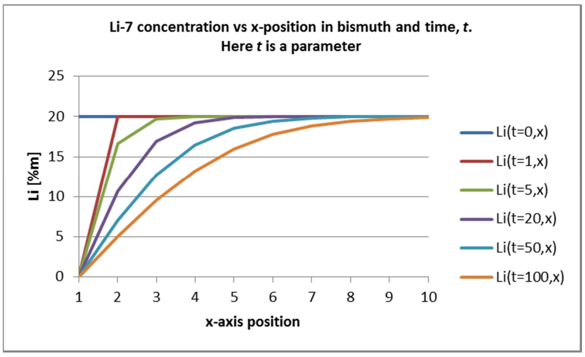

Fig. 2. Li(x,t) concentration in bismuth layer.

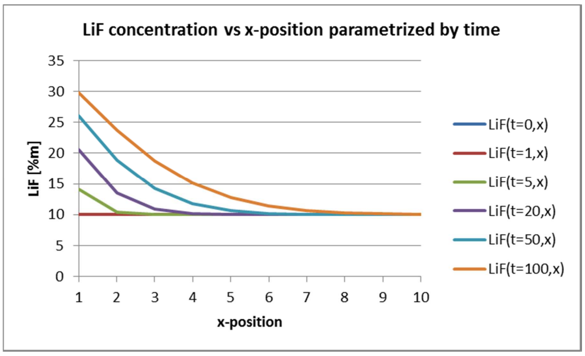

Fig. 3. LiF(x,t) concentration in molten salt layer.

The results presented above are based on dummy values. Many model improvements are still to be made.

Reference

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In vessel corium propagation sensitivity study of reactor pressure vessel rupture time with the PROCOR platform

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The problem of corium propagation for PWRs in the Reactor Pressure Vessel (RPV) and the time of the RPV failure is one of the main issues of study in the area of severe accidents. The PROCOR numerical platform created by the CEA severe accident laboratory models corium propagation for LWRs, its relocation to the Lower Plenum and RPV failure. The idea behind the platform was to provide a tool that will be sufficiently fast to be able to perform numerous calculations in a reasonable time frame in order to perform a statistical study. Therefore, work on the development of the models, describing in-vessel issues, is continuously performed through simplified phenomena modelling, verification and sensitivity studies.

Recent activities, within the scope of PROCOR development, involved cooperation between French CEA experts and Polish NCBJ specialists, who were engaged in the topics of core support plate modelling and analysis of the phenomena of thin metallic layers formed on the top of the corium pool. These issues were identified as strongly influencing on the course of a severe accident and the timing of an RPV failure. In some sensitivity studies performed on a given generic high power Light Water Reactor with heavy reflector, two groups of RPV ruptures were distinguished related to the two issues, which has given the motivation for further work on these topics.

To demonstrate the problem a sensitivity study with the PROCOR and URANIE platforms was performed. This study highlights how the uncertainty in the output of the model, in terms of its distribution, depends on the uncertainty of some input parameters. This calculation aims at illustrating the importance of two modelling issues, the thin metal layer heat transfer modelling and core support plate modelling. Fig 1 and Fig 2 show the results of the studies for the reactor case, in which the core damage propagated until formation of the pool. Two distinctive groups of Reactor Pressure Vessel rupture time (tvr) can be seen.

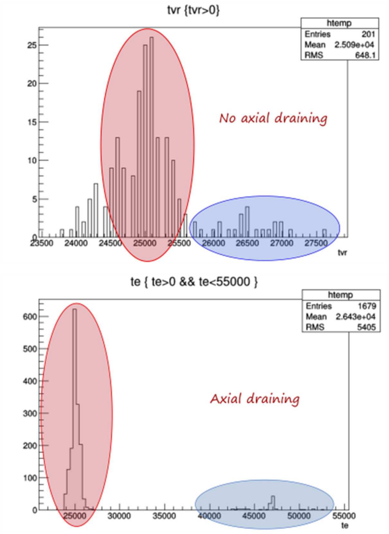

Fig. 1. Rupture time groups.

Calculations have shown that with different draining models we have less cases corresponding to RPV rupture when massive draining through the plate occurs. At present, the ”axial” and ”no axial” draining models in PROCOR are two extreme cases and a simplified thermal– mechanical model has to be introduce to have a realistic evaluation of the corium, that can drain through the plate.

From the analysis the conclusion is obtained that the majority of RPV failure modes are due to the presence of the focusing effecte. This earlier failure mode is directly connected to focusing effect appearance and the heat transfer model in the thin metallic layer. The overestimated value of the heat flux to the walls results in failures with lower masses of the formed pool and especially molten metal presented in Fig. 2. This suggests the need for the introduction of a new model enabling less conservative tvr estimation.

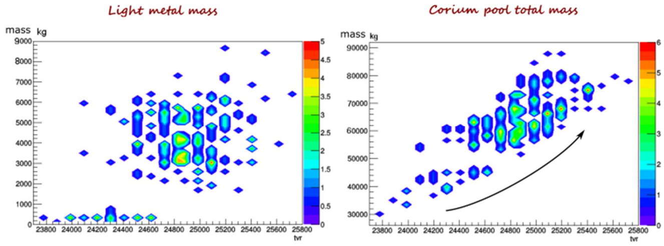

Fig 2. Relation of the rpv rupture time and light metal, heavy metal and oxide layer in the pool mass.

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Influence of the entrainment and deposition model on critical heat flux prediction by the CATHARE-3 system code

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In various boiling systems, such as water cooled nuclear reactors, the critical heat flux (CHF) phenomenon is one of the main design constraints, since it sets an upper limit to the possible power production. For the applications considered here CHF can be defined as a sudden temperature rise of the heater when a certain heat flux is reached. There are however several different mechanisms that may cause this temperature rise depending on the flow conditions. In a boiling water reactor (BWR) that operates with relatively high steam quality CHF is usually termed dryout and occurs when the thin water film on the heater rods evaporates and leaves the surface in direct contact with the vapour phase.

Analysed phenomena

The effect of different heating profiles on dryout occurrence was investigated and compared with the results of two entrainment-deposition phenomena models, namely, Hewitt and Govan and Okawa[1].

Current CATHARE-3 model – Hewitt and Govan:

$$\frac{D_{H-G}}{C} = 0.083 \max\left(0.3, \frac{C}{\rho_v}\right)^{-0.65} \sqrt{\frac{\sigma}{\rho_v d_h}}$$

$$\frac{E_{H-G}}{G_v} = 5.75 \cdot 10^{-5} \left(\left(G_f - G_{f,crit}\right)^2 \frac{d_h \rho_l}{\sigma \rho_v^2}\right)^{0.316}$$

Comparative model – Okawa:

$$\frac{D_{Okawa}}{C} = 0.0632 \left(\frac{C}{\rho_v}\right)^{-0.5} \sqrt{\frac{\sigma}{\rho_v d_h}}$$

$$\frac{E_{Okawa}}{G_v} = \frac{k_e f_i}{\sigma} \frac{d_h G_f}{4} \sqrt{\frac{f_w \rho_l}{f_i \rho_v}} \left(\frac{\rho_l}{\rho_v}\right)^{0.111}$$

CATHARE-3 model

One CATHARE-3 model was divided into 33 nodal points, each about 11 cm long which simulated the **entire** test section. The second one, divided in the same manner, simulated only the end of the test section (c.a from 2.85m) which corresponded to the first measurement points of the experiment.

Comparion of the results

The comparison of the results showed very interesting characteristics of the CATHARE-3 code, both models for entrainment and deposition and criteria for the annular flow in the system code.

A frist glance at the results showed what was observed in the experiment – generally, Okawa's model for entrainment and deposition and effectively for film and droplet modelling was better than the Hewitt and Govan model. However, they were far from perfect when one considers the environment of the CATHARE-3 system code.

Conclusiona

There are several aspects of the CATHARE-3 models that may be responsible for the discrepancies between the Okawa model and the experimental measurements. The reason why film flow is under-predicted lay in two issues. First - overestimation of the entrainment rate process and/or under-estimation of the deposition rate process in the flow.

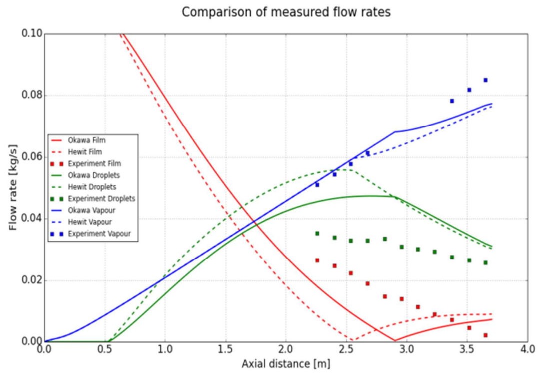

Fig. 1. Film, droplet and gas flow comparisons for experiment (dots), Hewitt-Govan (dash-lines) and Okawa (solid line) models.

Second the aspect of the flow that directly influences the calculation of the entrainment and deposition processes in CATHARE-3 is the criterion for the onset of annular flow. From an analysis of the results it is know that the CATHARE-3 system code predicts the onset of annular flow at around 1 metre. However, in the experiment it is believed that the annular flow regime does not start until c.a. 2.3 metre.

Last but not least an aspect of the CATHARE-3 film flow calculation is related to the pure numerics of the code. It must be noted that the current state of the numerics allows unphysical behaviour of deposition of water droplets on film while the wall temperature exceeds the Leidenfrost point. What is more, at different film thicknesess the re-wetting phenomenon occured – re-establishing the film flow on the dry-patch surface.

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Diffusion model for neutron-physics calculations of the HTR-10 reactor

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Introduction

In 2014 and 2015 a diffusion model was developed for neutron-physics calculations of the HTR-10, Chinese, Generation IV, high temperature, pebble bed test reactor.

Calculations of the HTR-10 reactor were performed in the past, also at the National Centre for Nuclear Research [1], using Monte Carlo codes. Such calculations give state of art results but are time consuming.

Calculations based on diffusion theory are less accurate, but consume much less time. The computational parameters used to describe the diffusion process are determined by the above mentioned transport codes.

The main purpose of this work was to develop a diffusion model of the HTR-10. However, the main issue was finding a method of calculation of its effective computational parameters (i.e. cross sections and diffusion coefficients).

The accuracy of the diffusion calculation results was evaluated by comparison with the results of the critical experiment on the HTR-10 reactor. The results obtained at NCBJ are comparable with those obtained in other countries [3].

Reference results

The accuracy of computational methods is evaluated by comparison with the experimental results obtained for simplified reactor critical assemblies. Pebble bed reactors can be assembled with pebbles arranged orderly or, more realistically, with pebbles arranged randomly. An example of an ordered critical assembly is the Swiss assembly PROTEUS [4, 5], where several configurations were realized. See Fig.1.

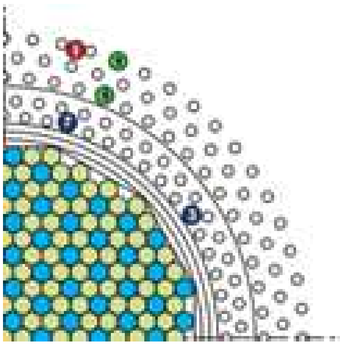

Fig. 1. ¼ of the sample PROTEUS assembly.

Experimental data for PROTEUS configurations 5, 7, 9, 10 are in the range: 1.0067 – 1.0142. State of the art numerical results obtained with Monte Carlo codes are:

- MCNP - from 0.99472 to 1.00261,
- KENO - from 1.00572 to 1.01610.

International calculations of PROTEUS with less accurate methods [2] required less computer time, but gave less accurate results:

- Deterministic transport code TWODANT – from 1.0090 to 1.0151,
- Diffusion code VSOP – from 0.99688 to 1.0318.

In short, the maximum error in k-eff, for the most advanced, Monte Carlo calculations is: 1.63% for MCNP and 0.48% for the KENO/SCALE codes. For the calculations with the deterministic transport code TWODANT, the maximum error in k-eff is 0.42%, which is less than for potentially more accurate MC codes. This may be the result of compensation of errors in the calculation of cross sections and global calculations. For diffusion calculations with the VSOP modular system the maximum error was 2.49%.

NCBJ diffusion calculations

In NCBJ diffusion calculations of HTR-10 were performed with the CITATION-2 code [6]. The effective diffusion equation constants for CITATION were calculated using the Monte Carlo code SERPENT [7].

The pebble bed in the HTR-10 reactor has very complicated geometry for the following reasons:

- pebbles are arranged randomly,
- two kinds of pebbles are used – fuel and graphite ones,
- each fuel pebble contains ca. 8300 fuel grains,
- each fuel grain consists of a UO_2 spherical core and 5 concentric layers of graphite and silicon carbide,
- a large cavity is present above the pebble core, which creates a special problem in diffusion modelling.

As far as calculation of diffusion constants for CITATION is concerned, the geometry modelling options of SERPENT code are less versatile than needed to model the HTR-10 complexity. Therefore, it was necessary to develop simpler models of a typical fragment of a homogenized HTR-10 core. It is generally accepted that such a fragment is a fuel pebble with eight graphite balls around it. The MCNP code was used as a reference. Three models were investigated:

- the generally accepted one,
- a fuel pebble surrounded with graphite from moderating graphite pebbles homogeneously distributed around it
- a fuel pebble in a graphite box with graphite volume preserved.

It was found that the diffusion parameters generated by the box model give satisfactory results.

Results

With the homogeneous pebble bed (red zone in Fig. 2) the k-eff from CITATION was equal to 1.081. Therefore, a complicated model of the pebble bed cells was developed, so that taking into account spectra changes in the core was possible, cf. Fig.3. With this model the number of spectral zones in pebble bed region was increased to 12, which resulted in k-eff equal 1.018144. This is equivalent to overestimate of the core height by 2.2 cm, and is comparable with the results of diffusion calculation of the PROTEUS assembly quoted above.

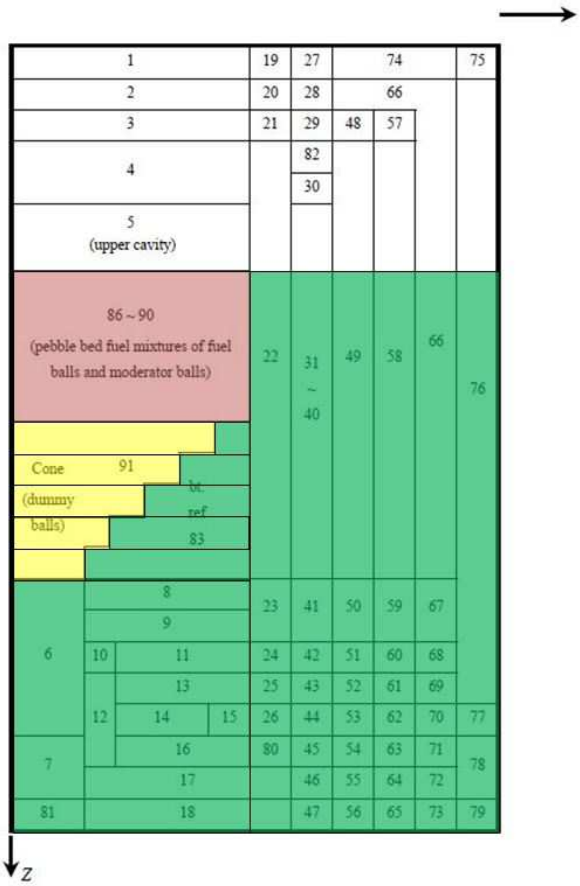

Fig. 2. Simplified, cylindrical model of HTR-10.

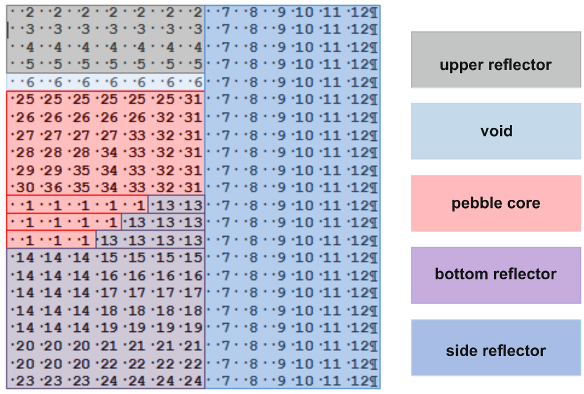

Fig. 3. Zone placement in CITATION model of HTR-10.

Conclusions

It was shown that a valid model of pebble bed HTR can be established on the basis of the SERPENT and CITATION codes. The model of typical fuel pebble bed cell was developed, which forms a basis for future calculations of pebble bed reactors at NCNR, including burnup and pebble movements.

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MARIA reactor operation

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The multipurpose high flux research reactor MARIA is a water and beryllium moderated reactor of the pool type with a 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.

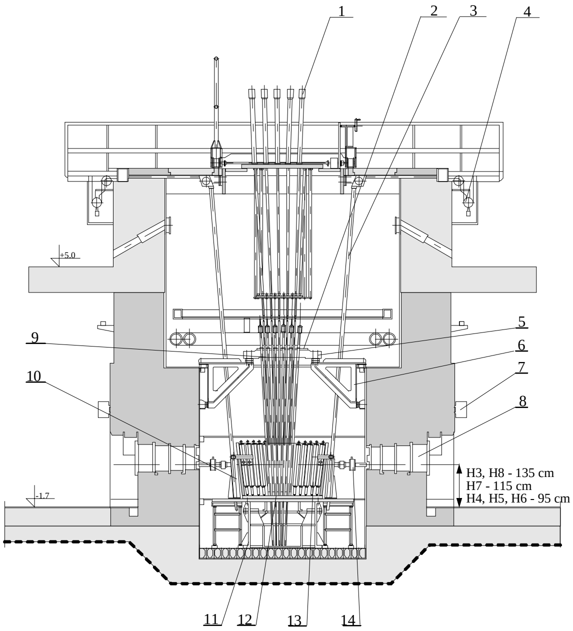

Fig. 1. Vertical section of the MARIA reactor. 1. control rod drive mechanism, 2. mounting plate, 3. ionisation chamber channel, 4. ionization chamber drive mechanism,5. fuel and loop channels support plate, 6. plate support console, 7. horizontal beam tube shutter drive mechanism, 8. beam tube shutter, 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 luminium
  - shape five concentric tubes
  - active length 1000 mm
- output thermal neutron flux

at horizontal channels $3\div5 \cdot 10^9$ 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.

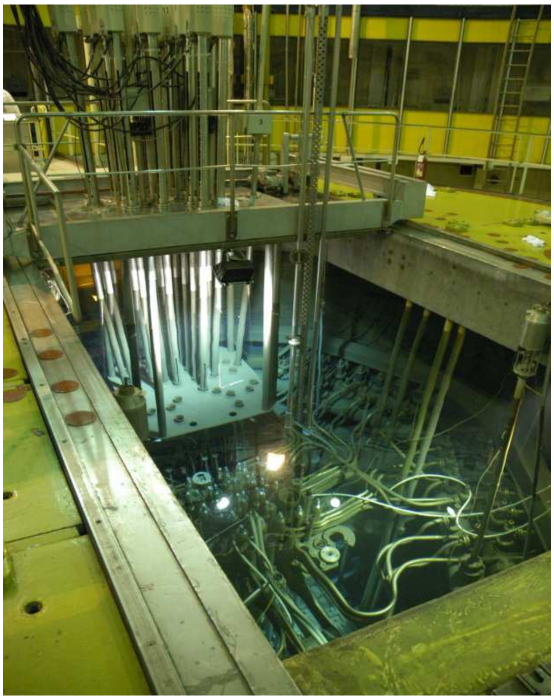

Fig. 2. View of the reactor pool.

The main areas of reactor application are as follows:

- irradiation of target materials in 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 2015 the reactor completed 36 operation cycles at power levels from 30 kW to 25 MW (Fig. 3). The overall operation time: 4776 h

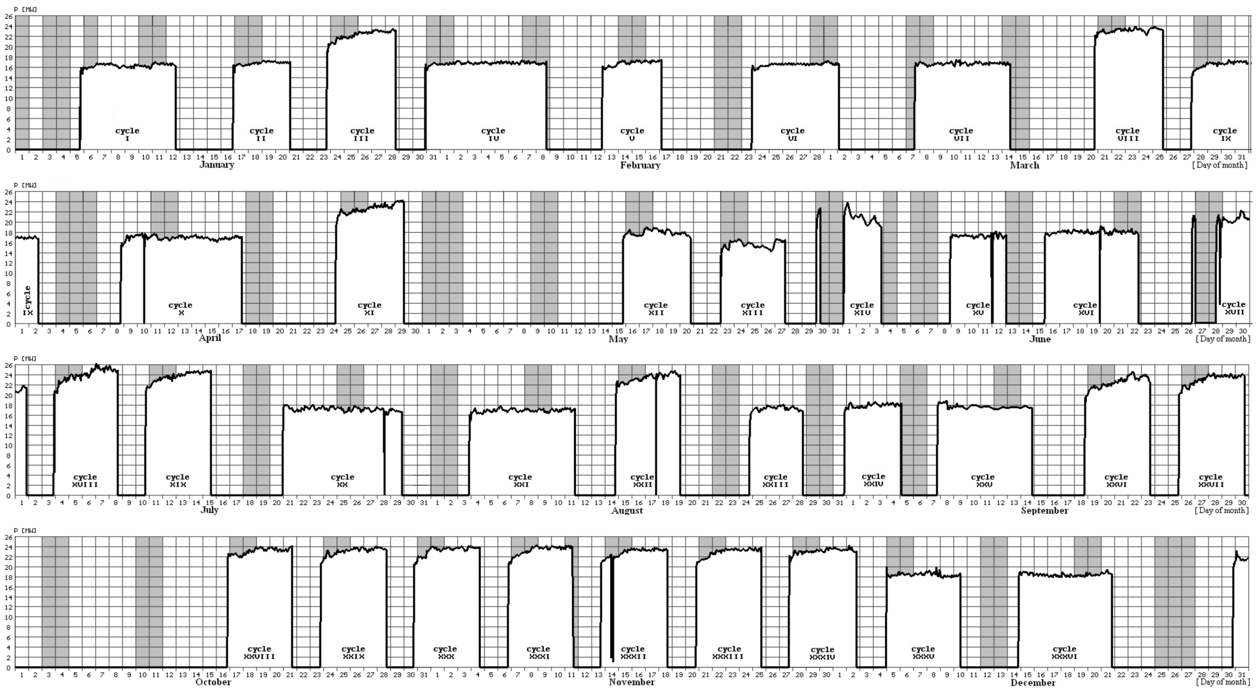

Fig. 3. Schedule of the ”MARIA” reactor operation in 2015.

The main activities carried out in MARIA reactor were focused on:

- irradiation of target materials at the vertical channels and in the rabbit system
- neutron scattering condensed matter studies with neutron beams from the reactor horizontal channel
- neutron radiography studies
- neutron modification of crystals and minerals
- training

In the last year the project GAMMA MAJOR realised in cooperation with the Commissariat a l'energie atomique et aux energies alternatives (CEA) and Aix-Marseille University was terminated. The principal aim of this project was an efficiency determination of the French codes Tripoli4 and Appollo2 used to simulate the transport of neutrons and γ photons. In September 2014 and November 2015 two experimental operational cycles of the Maria reactor were realised. The aim of these operations was to carry out many measurements using such devices as: the Karolina calorimeter, gamma-thermometer, ionisation chamber, rod and vanad self-power detectors, activating detectors and two French calorimeters.

In 2015, after the completion of the conversion process of Maria reactor core to low-enriched fuel with enrichment 19,75% in ^{235}U, only this type of fuel was used.

The core configuration has been changed several times because of fuel and irradiation requirements. The core configuration of December 2015 consisting of 26 fuel assemblies and 2 special channels for molybdenum ^{99}Mo production is presented in Fig. 4.

In 2015 the MARIA reactor was operated successfully. The reactor scram was activated 8 times and in two cases reduction of operation cycles was necessary due to water leakage from the primary cooling system.

Operational availability factors were as follows:

$$A1 = \frac{OT}{NH} \cdot 100\% = 98$$

$$A2 = \frac{OT}{8760} \cdot 100\% = 54{,}5$$

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 2015 the total emissions of radioactive materials to the environment were:

- inert gases (mainly ^{41}Ar): $9.3 \cdot 10^{12}$ Bq, i.e. 0,9% of the limit determined by the NAEA
- iodine: $3.2 \cdot 10^{7}$Bq, i.e. 0,6% of the limit determined by the NAEA

The yearly emissions of the noble gases and iodines are presented in Fig. 5, 6.

In 2015 ninety eight workers received measurable whole body doses from 0,15 to 5,44 mSv and 8 workers received skin doses from 1,25 to 2,12 mSv.

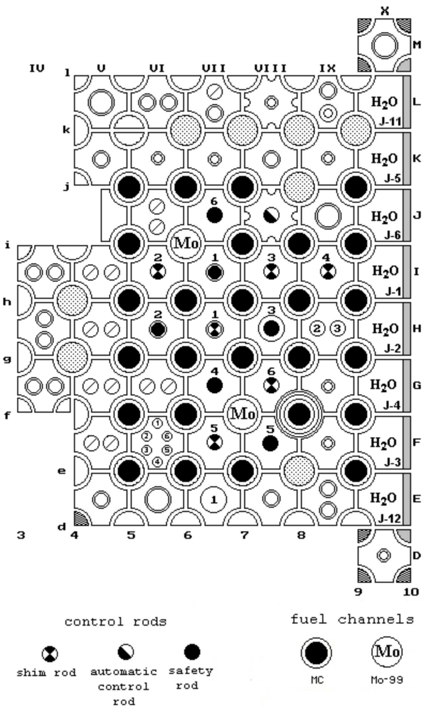

Fig. 4. Core configuration of December 2015.

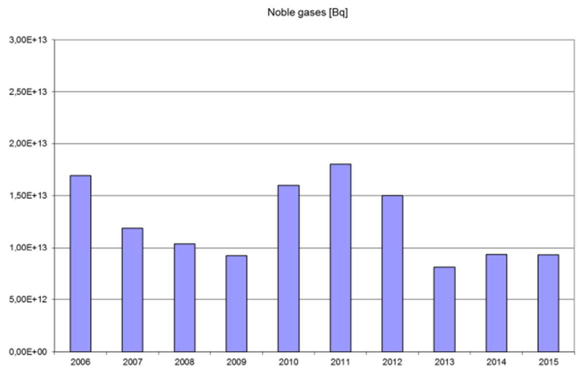

Fig. 5. Yearly emissions noble gases in the last ten years.

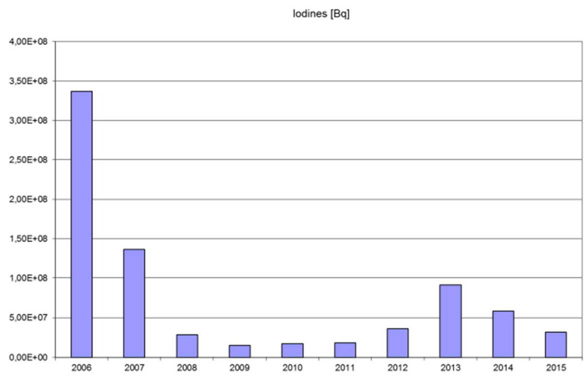

Fig. 6. Yearly iodines total emissions in the last ten years.

Neutron irradiation services

Neutron irradiation services provided at the MARIA research reactor include radioisotope production, neutron activation analyses and biomedical technology.

The 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 in 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, $SmCl_3$ and KCl were irradiated (Fig. 7). Most of them were produced for the Radioisotope Centre 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 1480 TBq in 2015.

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

Nuclear reactors remain a key component in the production of useful isotopes mainly for nuclear medicine treatments. A key medical isotope is ^{99m}Tc, which is a decay product of ^{99}Mo. One possible source 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 plate for ^{99}Mo production was carried out at the MARIA reactor in 2015 within 17 reactor operation cycles. Since July 2015 uranium plates have been irradiated on the three positions inside the irradiation rigs. This means that one reactor operation cycle includes irradiation of 24 uranium targets. Average activity of ^{99}Mo at the end of irradiation (EOI) obtained from one irradiation channel was 260 TBq for loading 8 targets inside the channel and 360 TBq for a channel loaded with 12 uranium targets. Production of the radioisotope ^{99}Mo by irradiation of highly-enriched uranium (HEU) targets reached the level 10^4 TBq in 2015.

Following the shortage of the key medical radioisotope ^{99}Mo and its daughter ^{99m}Tc related to long-term reliability issues 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 performed under a collaboration with Mallinckrodt Pharmaceuticals and with the HFR (Netherlands) and BR-2 (Belgium) reactors. The programme includes safety analysis calculations, out-of reactor mechanical, hydraulic and vibration tests. At the same time a new programme dedicated to the irradiation at HEU cylindrical type targets for the Belgium company IRE has been started. Both hot tests in the MARIA core are expected in the first part of 2016.

Based on the feasibility study and experience in irradiation of ^{235}U targets in the MARIA reactor a new project for production of ^{99}Mo, known a as "Molybdenum Świerk Project" has been developed. The project for a production facility foresees the adaptation the existing infrastructure in the MARIA reactor and the infrastructure of POLATOM for ^{99}Mo/^{99m}Tc generator assembly. The new program dedicated to Mo-99 production we started in 2015 as a result of collaboration between MARIA and partners from the USA: NorthWest Medical Isotopes, (NWMI) and Mallinckrodt Pharmaceuticals. The programme covers the full technology of production of Mo-99 radioisotope from irradiation at the new type of targets to extraction of the Mo-99 radioisotope as a product of radiochemical processing of the irradiated targets. The first tests are planned for the first half of 2016 using the hot cell in the Radioactive Waste Management Plant (ZUOP) in Świerk adapted to the project.

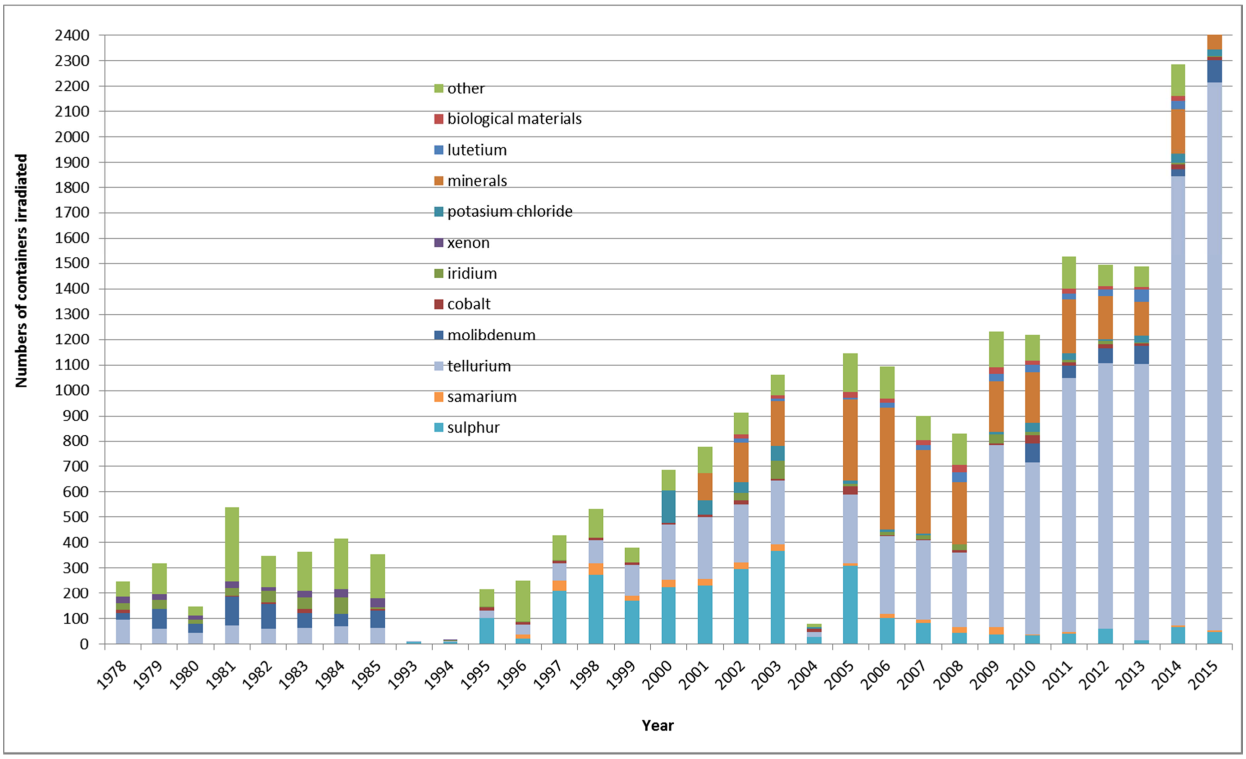

Fig. 7. Distribution of irradiated target materials.

Research stand for testing concrete shielding

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Studies of new concrete mixes are needed especially in the era of nuclear power development (two unexpected shutdowns of reactors and continuation of the Polish Nuclear Energy Programme). This stand is designed in order to find the best concrete mix for the construction of the first Polish nuclear power plant. The examination of the concrete shielding will be performed in the room at the outlet horizontal channel H2 at the nuclear MARIA reactor (National Centre for Nuclear Research - NCBJ, Poland). This place simulates the real conditions in which the concrete shielding will appear when produced for a power plant. During the design process it was taken into consideration that nobody may enter the research room during reactor operation (because of the radiation level) - only remote movement of concrete slabs is allowed; position control and configuration setting of the slabs are from the adjacent control room ensuring the safety of the operators.

The stand is composed of: a cast iron frame on the rails that allows the whole construction to move along the beam; a detector (recombination chamber), fitted with a shield preventing detection of scattered particles; a linear guide system (consisting of 14 linear rails intended to move 14 slabs) that allows the configuration of the concrete slabs to be changed, that is insertion and removal from the reactor beam; and an optional concrete block between the detector and linear guide system if the 14 concrete slabs do not have be proper characteristics. Each slab will have dimensions of 420x420x50 mm and is made of high density concrete (about 4 g/cm^3/), which makes a single slab weigh about 35 kg. The whole construction was specially designed to hold equipment with 14 single slabs an extra concrete block doubling thickness of the tested shielding and detector shielded with concrete. (total carrying capacity more than 1 tonne)

The measurements are carried out with two ionization chambers: the first – measuring the dose rate, placed behind concrete slabs additionally encased by concrete, and the second – monitoring the reactor power. It is planned to use recombination chambers as detectors of gamma radiation (gamma attenuation) GW2 and neutron radiation (neutron attenuation) REM2-8. Distinguishing the neutron and gamma components is also planned for obtaining in the radiation quality factor [1], crucial from the radiation protection point of view . For low level radiation chambers containing boron and a high-pressure recombination chamber REM2-8 are used.

The measuring procedure begins with the execution of measurements with concrete slabs placed in the beam. Next, slabs are successively removed from the beam decreasing the thickness of the concrete shielding. These slabs will be moved by a system of lines running through culverts to room II, where one can safely operate the setting of the slabs. Any change of the configuration will be controlled through the vision system.

Currently we are performing measurements on this stand.

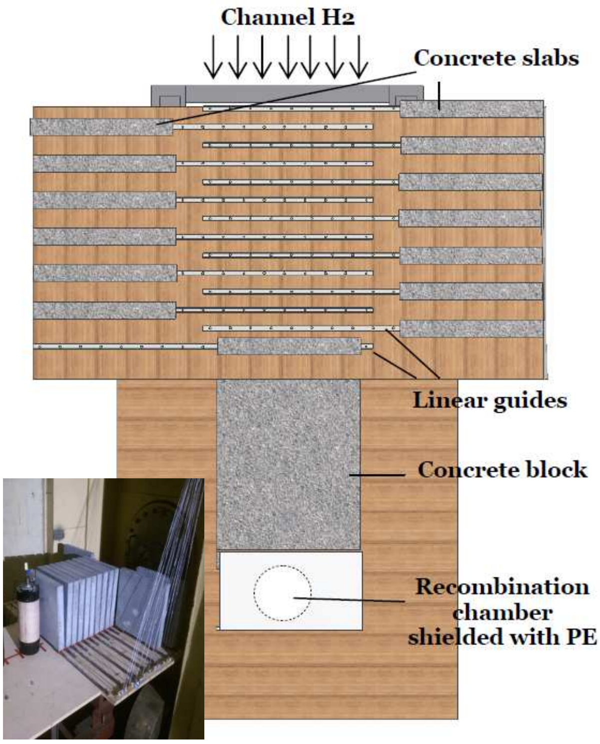

Fig. 1. Top view of the stand and operational photography at the H2 horizontal channel at the MARIA reactor.

Reference

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Participation in the ESS (European Spallation Source) project

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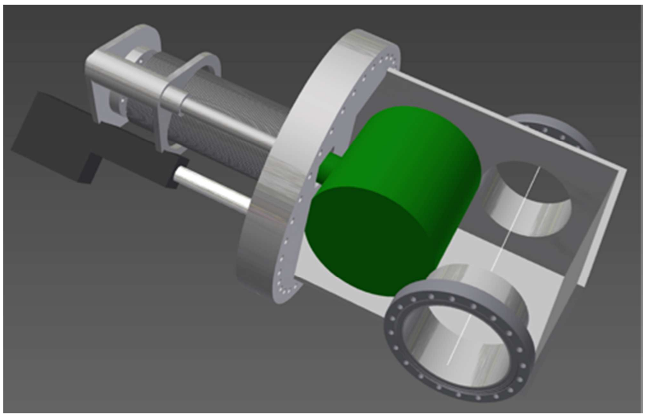
National Centre for Nuclear Research, Otwock - Świerk, Poland

The European Spallation Source (ESS) will shortly begin construction at Lund, Sweden. ESS consists of a linear accelerator that delivers a 2 GeV, 5 MW proton beam to a rotating tungsten target. By the end of this decade it will be generating long pulses of neutrons and aims to be the brightest source of neutrons in the world for scientific research. These will be used in parallel experiments that will foster major advances from aging and health, materials technology for sustainable and renewable energy, to experiments in quantum physics, biomaterials and nano-science. The ESS will be located in Lund, Sweden, co-hosted by Sweden and Denmark and will be funded and operated by a partnership of 17 European countries.

***The p**lanned ESS site [1].*

Since the beginning of 2015 collaboration between NCBJ and ESS was focused around the new project "Gamma Blocker System design". The main task of the system is to stop the backward gamma radiation inside the beam pipe during the beam off. Expected gamma radiation in the final accelerator-to-target region of the European Spallation Source, has been calculated using the Fluka [2] code. The prompt background and the residual dose arising from activation of the beam components have been calculated as a function of time. The geometry of the accelerator and the target wheal have been prepared. The activation of the target wheel after 5 years during beam on and backward gamma radiation inside the beam pipe during beam off were calculated. Many Gamma Blocker (GB) thicknesses (1cm, 10cm, 20cm, 40cm) for a few materials were simulated and checked. Currently the most promising idea is a 20 cm GB thickness made of high purity stainless steel, due to the vacuum requirements and magnetic features, whereas the high cost of material and very difficult machining became an argument against tungsten. The most efficient GB shape will be discussed and selected during upcoming meetings.

Complete CAD drawings of the mechanical system were prepared. The gamma blocker as a vacuum chamber enclosing a movable GB core was designed. Movement will be manual only with mechanical locks of the spinal GB, due to long-term exposure to very high radiation doses.

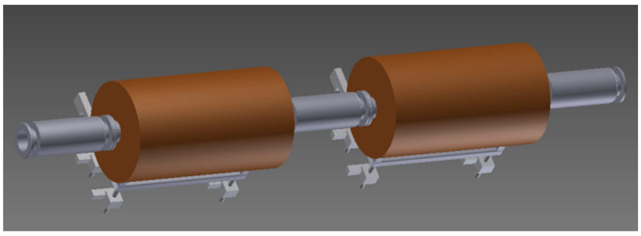


Gamma Blocker, mechanical design [3].

In 2015 **THE** Movable Collimators System (MCS) project **WAS COMPLETED**. The final design of the collimating scheme was aided by beam optics and energy deposition calculations performed by particle interaction codes (FLUKA) and thermo-mechanical analyses. The final system consisting of 3 collimating stations was integrated with **THE** High Energy Beam Transfer section of the accelerator system at key locations. Each station contains 2 cylindrical movable subunits, made of copper, equipped with L-shaped jaws. Special attention has been paid to accident scenario**S**, when **THE** full proton bunch can hit the collimator.

Simulations of dose distribution around the stations were completed and final shape of the additional fixed shielding was established.

During normal ESS operation one collimation station is expected to accept 1 kW of the 50 MW, 2 GeV proton beam.



Movable Collimator System, mechanical design.

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NUCLEAR TECHNIQUES IN HEALTH AND ENVIRONMENTAL PROTECTION, MANAGEMENT OF HAZARDS

Laboratory of Radioactivity Standards of the Radioisotope Centre POLATOM – overview of activity

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The Laboratory of Radioactivity Standards (LRS) in the Radioisotope Centre POLATOM, National Centre for Nuclear Research, in Otwock, is the only laboratory in Poland performing radioactivity measurements of α-, β- and γ-emitters by absolute methods and performing calibration of standard solutions and radioactive sources.

The President of the Central Office of Measures in Poland (GUM) established in 1999 the National Standard of Radionuclide Activity in Poland. 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.

The Laboratory of Radioactivity Standards is the only Polish manufacturer of standard radioactive sources for customers in this country and abroad. The LRS is also the only calibration laboratory in Poland that fulfills the requirements of the Regulations of the Health Ministry from 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.

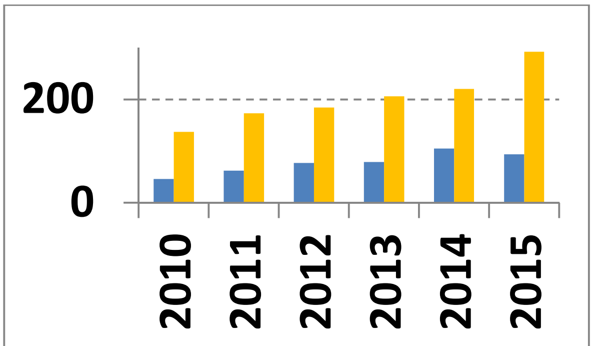

Fig. 1. Trends in customer requests for calibration of dose calibrators ■ and standard sources ■ in 2010-2015.

During 2015 maintenance and development of the National Standard was partially financed as a grant-in-aid by the Polish Ministry of the Economy. 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 the ISO/IEC 17025:2015 standard.

One of the main tasks performed by the LRS is the continuous improvement and expansion 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.

Fig. 2. Triple-to-double coincidence ratio system with additional gamma detector.

In 2015 a new system for absolute measurement of radionuclide activity was validated during a series of measuring campaigns of radionuclides with different decay schemes. Results from the TDKG system were compared with detectors working as part of the National Standard. Differences between measured values were not larger than 0.5%. Additionally a new detector was used with positive results during the international comparisons described below.

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 comparisons the LRS participated in during 2015 were:
- activity measurements of ^{68}Ge+^{68}Ga solution registered by BIPM as a key comparison,

- activity measurements of ^{131}I within the framework of the International Reference System (SIR) in the BIPM,
- bilateral comparison of ^{14}C and ^{131}I activity measurements with the Italian National Institute of Ionizing Radiation Metrology (ENEA-INMRI).

There has been increasing interest in the use of ^{68}Ge+^{68}Ga as a surrogate for ^{18}F in quality assurance of quantitative imaging, as well as in the use of ^{68}Ga for radionuclide-based diagnostics for certain types of cancers. Accurate administration of drugs using this radionuclide requires accurate standards against which instrumentation used in clinics and radiopharmacies can be calibrated. In order to provide a means for laboratories to substantiate Calibration and Measurement Capabilities (CMC) claims for this nuclide, a Key Comparison of ^{68}Ge was proposed. This proposal was initiated as an Action Item arising from a meeting of the Life Sciences Working Group (LSWG) of the International Committee on Radionuclide Metrology (ICRM) in which a delegate from LRS participated. ^{68}Ge+^{68}Ga solution delivered by NIST (USA) was standardized using absolute measuring methods in National Standard systems. Results from all methods were in good agreement. The final result was reported to the pilot laboratory. Data from this project are still under evaluation by the BIPM

A bilateral comparison between the Italian National Institute of Ionizing Radiation Metrology, belonging to ENEA (Italy) and named ENEA-INMRI, and the National Centre for Nuclear Research Radioisotope Centre POLATOM (Poland) on activity measurements of a solution of ^{131}I was organized in order to link both the ENEA-INMRI and POLATOM to the BIPM International Reference System (SIR). The project was declared as a EURAMET.RI(II)-K2.I-131 key-comparison and was registered in the EURAMET database under the number 1383. An extra ampoule, prepared by the RC POLATOM from the same batch used for the bilateral comparison between the POLATOM and the ENEA-INMRI for measurements, was sent to the BIPM. The ^{131}I master solution has been standardized at both ENEA-INMRI and POLATOM using primary activity measurement techniques, based on 4π(LS)-γ coincidence and anti-coincidence counting, the triple-to-double coincidence ratio (TDCR) method and the CIEMAT/NIST efficiency tracing, with ^{3}H as a tracer, method. All results from both laboratories were found to be in agreement, as seen in Fig. 3.

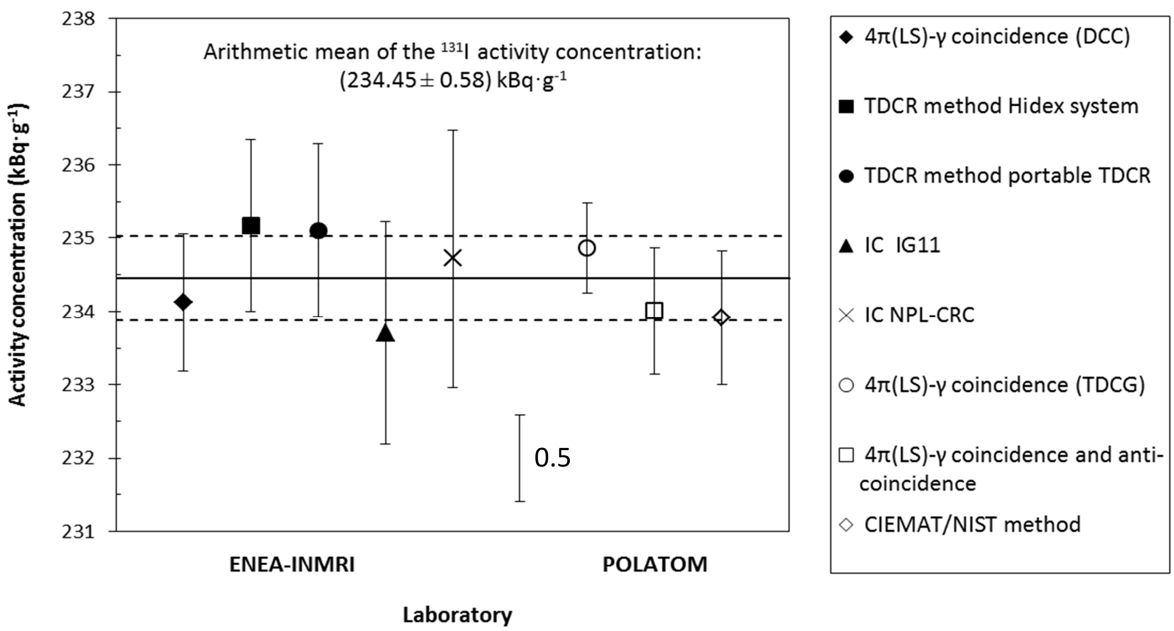

Fig. 3. Final results of the ^{131}I bilateral comparison of activity concentration. The arithmetic mean value is shown with its uncertainty.

Overview of the research department activities of the Radioisotope Centre Polatom

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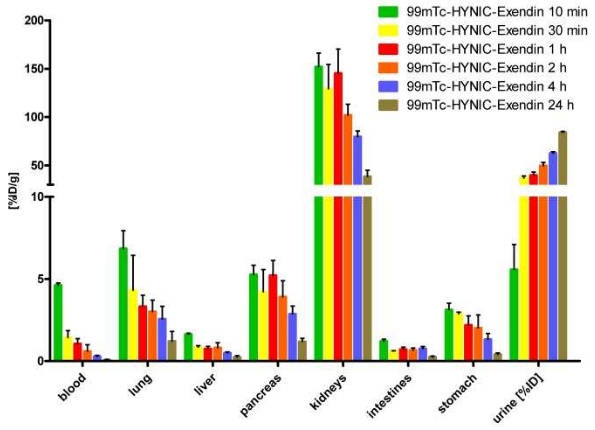
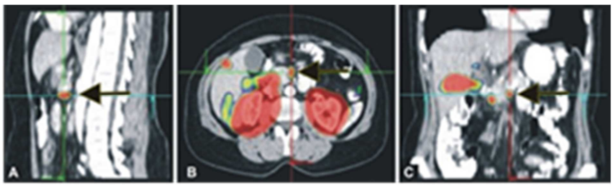
The R&D Department of the Radioisotope Centre POLATOM carries out research programme related to the application of radioactive preparations and radiolabelled compounds in various fields of medicine, research and industry. We carry out basic research as well as applied science. In particular, studies are related to the development of methods and technologies for high specific activity radionuclide production by neutron irradiation in the Maria Research Reactor and technologies for cyclotron produced radionuclides, new markers for diagnostics and radionuclide therapy based on active biological carriers, such as peptides and monoclonal antibodies; novel radiosynthesis methods of tracers for PET diagnostics; multifunctional markers based on nanoparticles, etc.; as well as development of analytical and biological methods for the evaluation of newly developed radiopharmaceuticals.



Preclinical pharmacokinetics of ^{99m}Tc-Exendin-4 in rats.

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. In 2015 GIF approved our laboratories for the manufacture of Active Pharmaceutical Ingredient (license No 117/WTC0348/API/15).



SPECT with ^{99m}Tc-Exendin-4. The examination has shown accumulation of the radiotracer in NET insulinoma tumour.

Currently, the R&D Department is involved in projects financed by the Polish grant institutions: the National Centre for Research and Development and the National Science Centre. The active projects are:

- NCN, No.UMO-2011/03/B/ST5/02734 “In vitro and in vivo investigations of the radiometals influence on the ability of CCK2R receptors imaging by the radiolabelled gastrin analogues” (2012 – 2015).
- NCBiR, No. PBS1/A9/2/2012 “Alternative methods of technetium-99m production” (2012 –2015).
- 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).

In recent years the R&D Department has participated in and is currently active in the IAEA coordinated projects:

- IAEA No. 16639 “Therapeutic radiopharmaceuticals based on ^{177}Lu- and ^{90}Y-labelled monoclonal antibodies and peptides: development and preclinical evaluations” (2011–2015).
- IAEA No. 17419 “Accelerator-based alternatives to non-HEU production of Mo-99/Tc-99m” (2012-2015).
- IAEA No. 18475/RO “Nanosized delivery systems based radiopharmaceuticals in Poland” (2014-2017).

Our representatives contribute to COST (European Cooperation Program of Scientific and Technical Cooperation):

COST TD1004 – Theragnostics Imaging and Therapy: An Action to Develop Novel Nanosized Systems for Imaging-Guided Drug Delivery (2011-2015).

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.

Development of the production of ^{99m}Tc from a ^{100}Mo target irradiated in a cyclotron

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^{99m}Tc is the most frequently used isotope for medical diagnosis. Till now practically the total supply comes from ^{99}Mo/^{99m}Tc generators, in which ^{99}Mo is the fission product of ^{235}U. The reactors in which ^{99}Mo is produced are mostly approaching their production lives [1]. There are alternative methods of ^{99m}Tc production. One of them is the nuclear reaction ^{100}Mo(p,2n)^{99m}Tc which can be carried out using a cyclotron with a proton energy in the range from 16 to 20 MeV.

The goal of the project was the development of a ^{99m}Tc production method using the reaction of protons with ^{100}Mo in a cyclotron.

The production of ^{99m}Tc consisted of a number of steps which are listed as follows:

1) Preparation of a ^{100}Mo target in a form suitable for irradiation.

2) Irradiation of the target in a cyclotron.

3) Transport of the irradiated target from the irradiation site to to the processing lab and its immediate dissolution.

4) Separation of ^{99m}Tc from molybdenum

5) Recovery of ^{100}Mo from the solution for later use

Target preparation: the Molybdenum-100 target was manufactured by pressing metallic molybdenum powder into pellets followed by its sintering. For pressing, a hardened, stainless steel matrix was used [2]. The powdered molybdenum was pressed for 60-90 minutes by a PLH-25 hydraulic press, with a pressure of 800 MPa inside the matrix. In order to improve mechanical strength, the pressed molybdenum pellets were sintered in hydrogen flow at a temperature of 1600°C for 60 minutes.

Target irradiation: the Molybdenum-100 target was irradiated in the GE PET-trace 840 cyclotron at the Heavy Ion Laboratory of the University of Warsaw. After irradiation the target was processed at POLATOM for recovery of ^{99m}Tc.

Target dissolution: the irradiated ^{100}Mo target was dissolved in 30% H_2O_2 at 90^{o}C in about 60 min. Concentrated NaOH or $(NH_4)_2CO_3$ were the added to the solution to obtain 2 M or 1.5 M solution.

Isolation and purification of ^{99m}Tc: for process optimization three methods of ^{99m}Tc separation from the excess molybdenum were evaluated: (1) anion exchange on Dowex-1x8, (2) adsorption on AnaLig Tc-02 resin and (3) C-18 column modified with PEG [3]. The separation yield for all three resins was above 75% but the highest concentration of ^{99m}Tc was achieved with the use of AnaLig Tc-02 resin. The sorption of ^{99m}Tc on AnaLig resin columns was studied as a function of NaOH and $(NH_4)_2CO_3$ concentration. This enabled the selection of the optimal procedure for ^{99}Tc separation. Using optimal conditions the irradiated ^{100}Mo was processed. After target dissolution ^{99m}Tc was separated in 3 columns connected in series containing AnaLig, Dionex H^{+} form and alumina A beds. The ^{99m}Tc recovery yields were above 75% and losses amounted to 8%, 13% and 2% at each column respectively. The time of these operations did not exceeded 100 min.

Recovery of molybdenum-100: due to the very high cost of ^{100}Mo, it should be recovered after ^{99m}Tc extraction. The first step of this process was precipitation of the insoluble molybdenum compounds. For this purpose 5M HCl was added to the solution of molybdenum in the mixture of perhydrol and ammonium carbonate. Decreasing the solution acidity resulted in precipitation of molybdenum. The solution was then evaporated and the precipitate dried at 120°C for 1 h, followed by annealing at 500°C for 2 h in order to remove residual volatiles and convert the precipitate to molybdenum oxide. The last step was the reduction of molybdenum oxide to Mo metal in a hydrogen atmosphere at 810°C. The comparative SEM/EDS analysis of the precipitates before and after reduction showed the presence of molybdenum and oxygen in the precipitate after annealing and only molybdenum in the precipitate after reduction. This confirmed the reduction of molybdenum oxide to metallic molybdenum. A similar analysis performed for molybdenum precipitated from 5M KOH detected the presence of potassium and oxygen.

Acknowledgements

This project was supported by the ALTECH PBS1/A9/2/2012 grant awarded by the National Centre for Research and Development in Poland within the Applied Science Programme. The collaboration with the Heavy Ion Laboratory of University of Warsaw is acknowledged

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Pharmaceutical development of dota-ANTI-CD20 monoclonal antibody for 177Lu and 90Y labelling

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The development of antibodies for cancer therapy has emerged as one of the most promising areas in oncology. Rituximab is a chimeric monoclonal antibody directed against human CD20 antigen, which is expressed on B-cell lymphocytes and on the majority of B-cell lymphoid malignancies. Rituximab's association with beta emitting radionuclides enhances the effectiveness of therapy of CD20 expressing tumours. Under the IAEA Coordinated Research Project "Development and pre-clinical evaluations of therapeutic radiopharmaceuticals based on ^{177}Lu and ^{90}Y labelled monoclonal antibodies and peptides" we investigated the potential of radiolabelled DOTA-Rituximab conjugates for RIT of tumours overexpressing CD20 antigens. In this study we report the results of the antibody conjugates preparation with chelating agent and the freeze-dried kit formulation for their radiolabelling with ^{177}Lu and ^{90}Y. Specific targeting of both radioimunoconjugates to CD20 antigen was demonstrated by in vitro studies in Raji cells and in vivo studies in normal and tumour-bearing mice. The two DOTA derivatives: SCN-DOTA and NHS-DOTA, were conjugated to anti-CD20 antibody and finally formulated as a freeze-dried kit as previously described [1]. ^{177}Lu-DOTA-Rituximab and ^{90}Y-DOTA-Rituximab conjugates were obtained with high radiolabelling yield (RCP>95%) and specific activities up to 600 MBq/mg. The conjugates were stable for 48 h in human serum and in 0.9% NaCl. However, a tendency towards aggregate formation was observed during storage. It was more pronounced for ^{177}Lu-DOTA-Rituximab, e.g. from 4.2% after 1 h to 17.3% after 48 h than for ^{90}Y-DOTA-Rituximab with 1.1% and 10.9% at 1 h and 48 h, respectively. For ^{177}Lu-DOTA-Rituximab the release of free radiometal was in the range from 0 to 4.2% up to 48 h, while for ^{90}Y-DOTA-Rituximab it was higher and reached a value of 6.6%. The specificity of ^{177}Lu-DOTA-Rituximab and ^{90}Y-DOTA-Rituximab towards CD20 antigen was evaluated by carrying out in vitro binding studies in Raji and Ramos cells (Burkitt's lymphoma). Both conjugates showed high specific binding to Raji cells (>88%). Slightly higher specific binding was observed for DOTA(NHS)-Rituximab than for DOTA(SCN)-Rituximab conjugates. Nearly 90% of ^{177}Lu- DOTA(NHS)-Rituximab and 95% of ^{90}Y-DOTA(NHS)-Rituximab were bound to Raji cells. However the immunoreactivity (IRF, Immunoreactive Fraction Assay) of both radioimunoconjugates using Raji cells as determined by Lindmo was relatively low - below 26%. Higher IRF, up to 39.4 ± 5.9 % was found when Ramos cells where used. Biodistribution of ^{177}Lu and ^{90}Y–labeled DOTA-Rituximab was determined in normal Balb/c mice and in tumour-bearing mice. For the preparation of a tumour model, male Rj:NMRI-Foxn1nu/Foxn1nu subcutaneously grafted with Raji cells (Burkitt's lymphoma) were used. All radiolabelled conjugates revealed high concentration in blood with slow radioactivity clearance after 72 h p.i. No statistically significant differences between the DOTA(SCN)-Rituximab and DOTA(NHS)-Rituximab were observed. Accumulation of activity was found in blood-rich organs such as: liver, lungs and spleen. Relatively high uptake was observed in the tumour reaching a maximum of 9.3 ± 1.0 %ID/g for ^{177}Lu-DOTA(SCN)-Rituximab and 6.9 ± 0.7 %ID/g for ^{177}Lu-DOTA(NHS)-Rituximab. Based on the detection of Cerenkov radiation, to noninvasively image the biodistribution of beta-emitting radionuclides in small animals, the PhotonIMAGER™ System (Biospace LAB) was applied. In vivo Cerenkov optical imaging of the ^{90}Y-DOTA-antiCD20 in tumour bearing mice confirmed accumulation of radioactivity in the tumour (Figure 1). High accumulation in the tumour tissue was visualized at 24 h p.i. The next 24 hours observation showed a decrease in non-target organs and retention of activity in the tumour.

Favourable results obtained with ^{90}Y-DOTA-antiCD20 and ^{177}Lu-DOTA-antiCD20 in radiochemical and biological studies hold the promise for success of radioimmunotherapy in tumour bearing mice

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Acknowledgements

This project was performed within the framework of the CRP on "Development and Preclinical Evaluation of Therapeutic Radiopharmaceuticals based on ^{177}Lu and ^{90}Y labelled monoclonal antibodies and peptides" by IAEA.

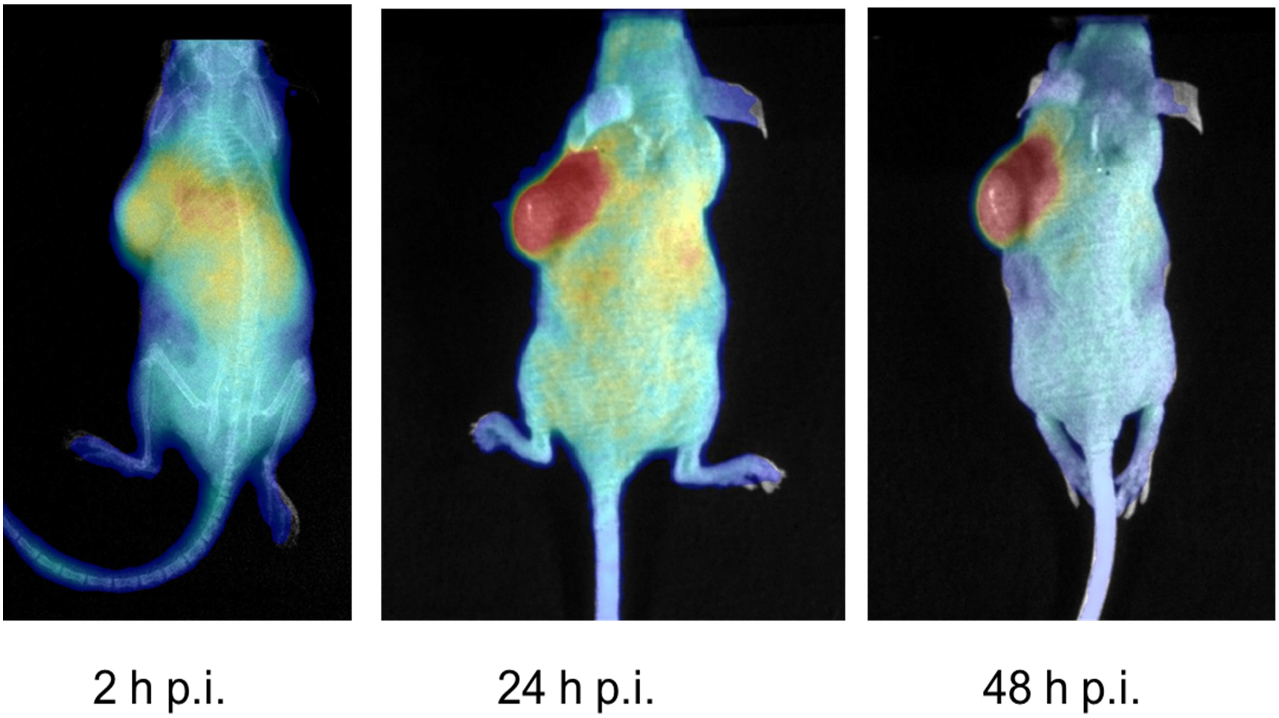

Fig.1. Cerenkov imaging of 90Y-DOTA-Rituximab accumulation in the tumour tissue (Rj:NMRI- Foxn1nu/Foxn1nu(Raji s.c.) mice; PhotonIMAGERTM System, Biospace LAB.

Air quality model WRF-Chem and emission processor SMOKE

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Over the past 2 decades, air quality forecasts have become standard in European countries. With constantly evolving models it is possible to predict concentrations of pollutants in the air such as those that lead to smog episodes. Knowledge of increasing pollutant concentrations is also an essential element of the decision-making process for example in crisis situations.

Nowadays, meteorological models are coupled with air quality models. These are called on-line models, because the weather and chemistry simulation is conducted at the same time. Changes in the chemical composition of the air can affect for example the air temperature, which in turn acts as a feedback on the chemical species. The aim is therefore to develop models towards an on-line feature.

One of the most popular on-line models is the Weather Research and Forecasting (WRF) [1]. It is mainly developed by institutions such as the National Centre for Atmospheric Research, the National Oceanic and Atmospheric Administration, the Air Force Weather Agency, and the Federal Aviation Administration. The applicability of the model is very wide. There are two dynamic cores of the model. One for the scientific issues, the other primarily for weather forecasting. WRF is effectively used in various European academic institutions and meteorological services.

No model is able to perform a reliable forecast if high-quality data is not provided to it. When forecasting air quality, not only data about the present state of the atmosphere is important, but also the atmospheric chemistry and emissions. Estimating time dependent emissions is a very difficult task because anthropogenic or any other emission is associated with a number of different factors.

One of the most famous emission preprocessors is called Sparse Matrix Operator Kernel Emissions (SMOKE) [2]. SMOKE interprets various data on meteorology, soils, population, and many other sources. The result of the calculation is an estimation of the time variation of emissions from various sources. These data can later be used by an air quality model.

Unfortunately, classification of emission sources in SMOKE is not directly applicable to European conditions. In addition SMOKE is not prepared to work with the WRF model. Furthermore SMOKE requires meteorological data at the time of forecast, which has yet to arise and without which it will not work. Thus, the combination of the SMOKE preprocessor and WRF model must be carried out in stages.

The SMOKE and WRF connection concept is based on the split in the forecasting process to two versions of the WRF. One with disabled chemistry and the second - with the chemistry enabled. In the first step the WRF carries out a meteorological forecast only for the area and at the same time as an air quality forecast. Then the weather forecast is used by SMOKE to estimate emissions. Finally, an actual air quality forecast with

SMOKE data is made by WRF-Chem which is an on-line model. This process does not prevent the use of other chemistry preprocessors while it allows the use of temporal variability estimated by SMOKE, which is often lacking in other programs for these purposes.

Data flow between SMOKE and WRF is done through input and output files. SMOKE and WRF are not designed to work with each other. Therefore, two applications were programmed to allow the necessary manipulation of data. The PREP_MET_DATA program is used in the first step, when WRF has already carried out a weather forecast. Then PREP_MET_DATA converts the weather forecast so that it is possible to be read by SMOKE. In the second step the SMOKE2WRF program is used, to put emission data from SMOKE into WRF-Chem input files so an air quality forecast can then be conducted.

The proposed combination of WRF and SMOKE with thePREP_MET_DATA and SMOKE2WRF programs implemented requires only slight changes in the WRF records and allows further development of the system.

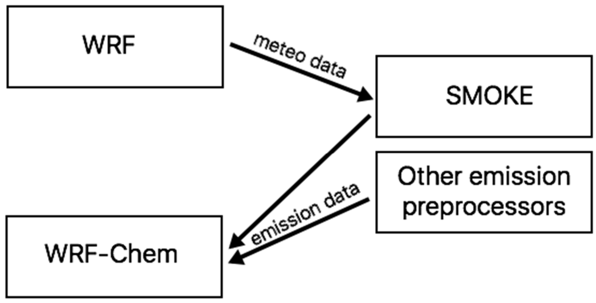

Fig 1. SMOKE and WRF data flow diagram.

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Assessment of external events risks resulting from natural hazards for the location of nuclear facilities

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A natural hazard is a naturally occurring event that may have a negative effect on a Nuclear Facility. After the Fukushima accident many international organizations and projects are currently discussing the possible influence of natural hazards on Nuclear Power Plants (NPP). One such project, ASAMPSA_E (Advanced Safety Assessment Methodologies: extended PSA), aims at examining in detail how far the PSA methodology is able to identify any major risk induced by the interaction between the NPP and its environment, and to derive some technical recommendations for PSA developers and users.

Natural hazards are usually divided into seven groups:

- Seismic and tectonic hazards
- Meteorological events: extreme weather
- Meteorological events: rare meteorological events
- Hydrological and flooding hazards
- Biological events
- Geological hazards
- Forest fires

Natural events often coexist simultaneously and they are correlated, which means that relation of two or more natural hazards can occur. For the analysis of hazard combination, a map of correlations with a list of all the risks resulting from the forces of nature is used. Correlations between hazards can be divided into two types: hazards related causally and associated hazards. This causal connection refers to the relationship of cause and effect, where hazard A has or may cause hazard B. A causal relationship is not commutative. There are two types of causal relationships [1]:

1. Hazard A can cause Hazard B (i.e. vibratory ground motion can cause a tsunami).
2. Hazard A is a prerequisite for Hazard B (i.e. low temperature and the formation of ice on a river).

The probability of causal connection (1) may be in the range from 0 to 1. The probability for a binding (2) is 1. Causal connections of type (1) are usually restricted by further requirements. In the example referred to, the tsunami occurs only under certain conditions, such as a defined magnitude and duration of the earthquake. The correlation table (see Figs. 1-2) lists only the immediate consequences of certain risks, causal chains are not taken into account. Related hazards are hazards that may occur at the same time, due to a common cause. Examples of related hazards are:

1. A cold front of a low pressure meteorological area: pressure drop, strong winds, lightning (storm), precipitation (torrential rain, hail).
2. High temperatures in the summer: the high temperature of the air and ground, the high temperature of the cooling water, low levels of ground water, drought.

These types of considerations have been included in the PSA methodology for external hazards.

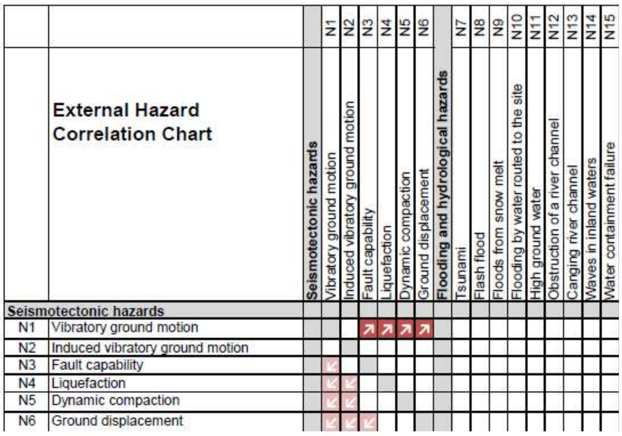

Fig. 1. Part of the correlation chart between hazards developed by the ASAMPSA project.

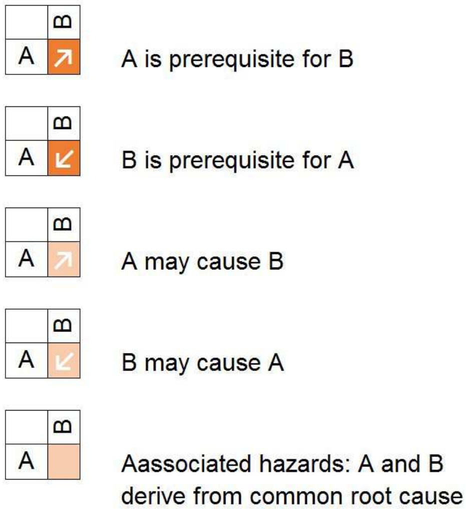

Fig. 2. Legend to the hazard correlation chart.

Reference

[1] Mieczysław Borysiewicz, Aleksej Kaszko, Karol Kowal, Sławomir Potempski, Grzegorz Siess "Ocena zagrożeń z zakresu zdarzeń zewnętrznych będących skutkiem działania sił przyrody dla lokalizacji obiektów jądrowych" Raport końcowy realizacji Umowy nr 12/F/2015/104 z dnia 22.04.2015

Localization of an atmospheric contamination source

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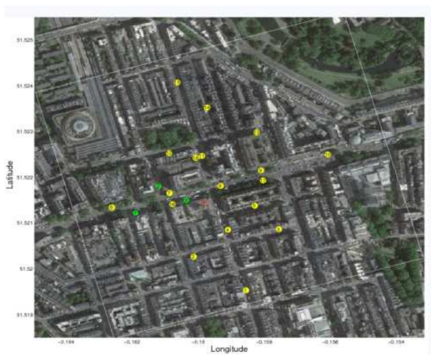
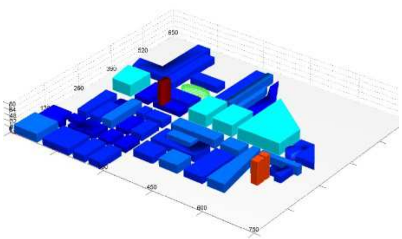
We have continued working on the localization of an atmospheric contamination source. The localization is done utilizing only the concentrations of the released substance registered by a sensor network. During this year, we have extended our study of the reconstruction of more complex terrain and scenarios. We have also applied new space scanning algorithms like the Sequential Approximate Bayesian Computation [1,2] algorithm, Genetic Algorithm [3] and Particle Swarm algorithm [4].

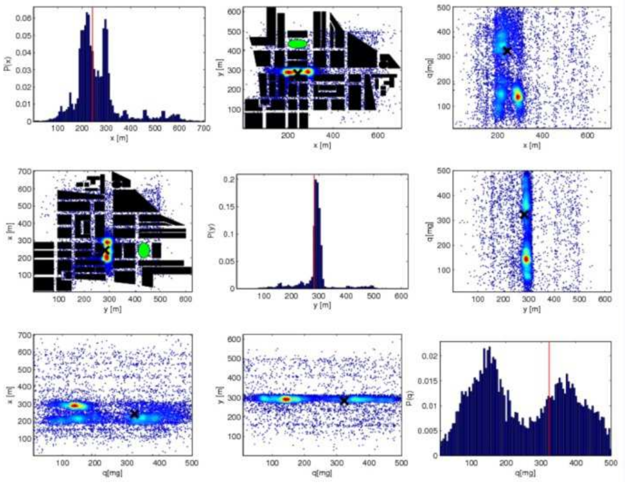
In [1,2] we presented in detail the Sequential Approximate Bayesian Computation algorithm and tested its efficiency in the estimation of the probabilistic distributions of the atmospheric release parameters of a moving gas source. We apply the developed algorithms to the data from the Over-Land Atmospheric Diffusion Field Experiment (OLAD) field tracer experiment and the Dispersion of Air Pollutants and their Penetration into the Local Environment in London (DAPPLE) experiment (see fig. 1abc). The online-arriving concentrations dynamically update the probability distributions of the searched parameters. As the forward model to predict the concentrations at the sensor locations, we use the atmospheric dispersion Second-order Closure Integrated PUFF Model (SCIPUFF) and the QUIC-PLUME MODEL. In [3,5] we applied Bayesian inference in combination with a Genetic Algorithm (GA) and Sequential Monte Carlo to the problem of the localization of a continuous contamination source in very complicated hilly terrain surrounding the Kori nuclear site.



a)



b)



c)

Fig. 1. a) The map shows the DAPPLE area of central London and is centered at the local intersection of Marylebone Road and Gloucester Place (at 51.5218N 0.1597W); b) 3D model of buildings designed in QUIC-GUI; c) Bivariate and marginal posterior distributions for source coordinates (x,y) and release strength (q). Probability density colours the plot, the reddest regions are the most probable. The red vertical line marks the target value.

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Adaptation of countermeasures AGRICP and ERMIN models from the RODOS system to Polish conditions

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The RODOS (“Real-time On-line DecisiOn Support) project was launched in 1989 and increased in size through the European Commission’s 3rd, 4th, 5th and 6th Framework Programmes [1]. The system was finally installed and is now being used in the Centre of Radiation Events of the National Atomic Energy Agency. This report is the result of work on the verification of the implementation and adaptation to Polish conditions of the models in the RODOS decision support system used for the selection and optimization strategies for dealing with accidental releases of radioactive material. It includes the following two models available in the system JRODOS (Java RODOS):

- AGRICP - to choose a strategy for late countermeasures mainly for food products,
- ERMIN - to choose a strategy of how to decontaminate inhabited areas.

Predictions of the effects of agricultural countermeasures are an important part of the decision making process following an accidental release of radioactive material into the environment. Food countermeasures may be implemented as early as a few days after the contamination occurred and may last over long periods of time. The exposure pathways of importance during these time periods are external exposure from deposited activity, inhalation of resuspended material and ingestion of contaminated food. The agricultural countermeasure model is designed to investigate - as early as possible - countermeasure options that could be effective in reducing activity concentrations in food.

The AGRICP model uses Postgres databases, software and data contained in the file production.dbf associated with a spatial data shapefile. In addition AGRICP also uses the results of the calculation dispersion model LSCM, especially from the module DEPOM calculating doses from various pathways.

The adaptation of AGRICP model to Polish conditions is strictly related to the implementation of a food dose model using data for radioecological regions. Seven such regions have been identified in Poland taking into account maps of soil, data on vegetation of cultivated plants and agricultural production. For the purpose of verification, a hypothetical accident at Świerk has been simulated using the sample source term.

The ERMIN model allows for estimation and comparison of different options for countermeasure strategies. It is focused on reverting to normal conditions in areas affected by an accident through the implementation of such countermeasures as decontamination or restricted access.

The countermeasures considered in ERMIN comprise a number of different recovery options including decontamination of urban surfaces, shielding of the population from radiation emitted by radioactive material on urban surfaces, fixing radioactive material to urban surfaces or relocation of the population. By interaction with the JRODOS mapping

facility, the user is able to consider options applied at different times and over different regions.

ERMIN consists of three sections: a “Grid” panel to specify a grid defining the area over which ERMIN analyses recovery countermeasure strategies, a “Nuclides” panel to control the radionuclides ERMIN considers in the calculation, and a “Deposition data” panel to allow deposition specifications to be entered directly for the calculation of nuclides.

The calculation results from ERMIN are presented to the user as maps and as summary statistics. Finally, ERMIN generates input files that can be used by the decision evaluation system. The implementation of the ERMIN model is related to the establishment of appropriate links between environmental monitoring data and application of detailed maps covering the areas of interest. A few examples of simulations have been performed for verification purpose.

Reference

[1] J. Ehrhardt, A. Weis (eds), RODOS: Decision Support System for Off-site Nuclear Emergency Management in Europe. European Commission, Brussels, Report EUR 19144, 2000

On relations between the energy resolution plateau variability and conventional avalanche counter spectrometric mode gas amplification at moderate specific ionization

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The energy resolution of conventional avalanche counters, i.e. parallel-plate avalanche counters (PPAC), may be evaluated based on only partial data (see e.g. ref. [1]). It should be fully realized, however, that the PPAC spectrometric properties depend upon not only the 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 spatial distribution, thereby deteriorating the detector energy resolution (ER). Therefore, investigation of the spectrometric properties of avalanche counters is also interesting from a cognitive point of view.

It has been found that at a moderate specific ionization in n-heptane (fig. 1) the empirical ER-curves of PPAC detectors have a plateau range that extends with an increase in both n-heptane vapour pressure (p) and the interelectrode gap (d) (see fig. 2). 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 strictly linear course, and the U_{sch}-voltage determines the beginning of the space charge effect in the PPAC).

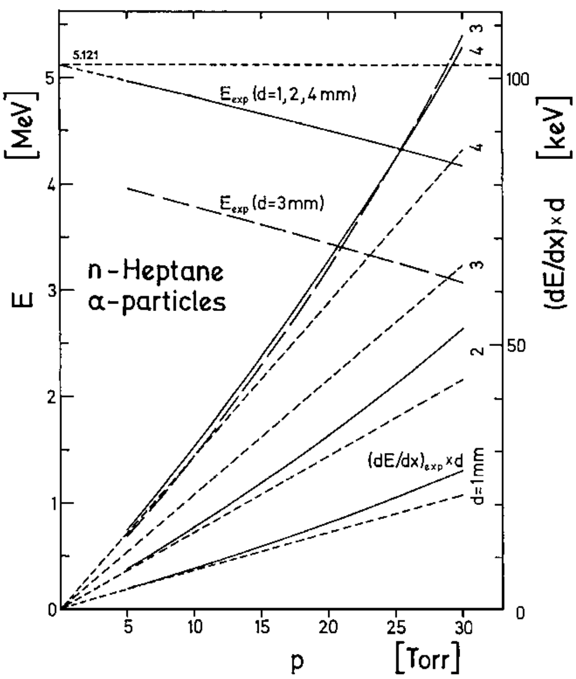

Fig. 1. Mean effective energy E of alpha particles and the corresponding particle energy loss in the PPAC interelectrode gas space, determined for actual measurement conditions. The plots apply to those alpha particles which follow paths perpendicular to the counter electrodes.

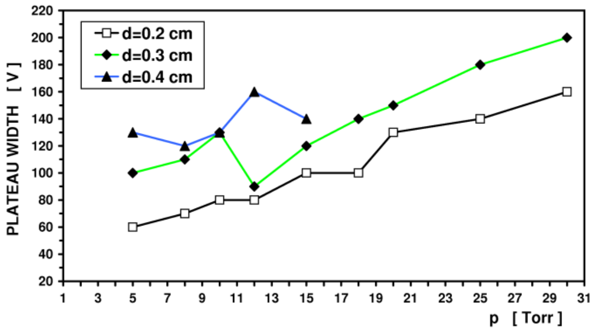

Fig. 2. Change in PPAC energy resolution (ER) plateau width vs. n-heptane vapour pressure.

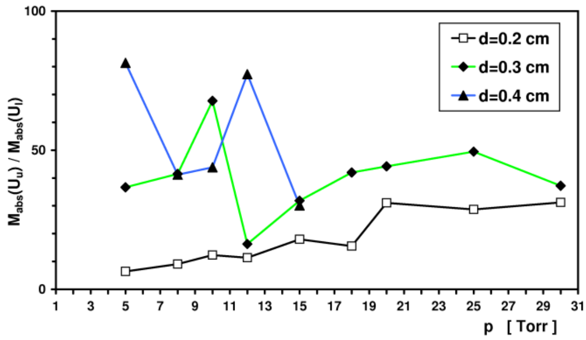

Fig. 3. Effective gas amplification variability dynamics within the PPAC ER-plateau range; the U_l-supply voltage relates to the lower end of the detector ER-plateau range, and the U_u-supply voltage relates to the upper end of the ER-plateau range.

This means that the fluctuations of the charge generated in the gas gain process are – within the determined ER-plateau – approximately constant. Thus, it is interesting to meet the M-values variability dynamics corresponding to the ER-plateau range of the PPAC.

The purpose of this investigation is to determine both absolute values the variability dynamics of the effective gas amplification (M_{abs}) connected with the voltages which correspond to the ends of the ER-plateau range of PPAC detectors and the M_{abs}-variability participation in the M_{abs}-maximum linear variability in a semilogarithmic coordinate system. General equations of the absolute gas gain characteristics, which are justifiable for a PPAC filled with n-heptane vapour, were used [2]. The equations are obtained, generally, under measurement conditions, which are typical for the majority of physical experiments in which the PPAC detectors are used.

The M_{abs}-values variability dynamics – for individual plateau ranges – are given in fig. 3. The determined dynamics values, generally lie between 6.4 and 81.4.

In fig. 4, the participation of the M_{abs}-change – within the ER-plateau – in the maximum linear M_{abs}-variability – in a semilogarithmic coordinate system – is shown.

Generally, the most dynamical variation of the gas gain occurs, however, at d=0.3 cm of the PPAC detector.

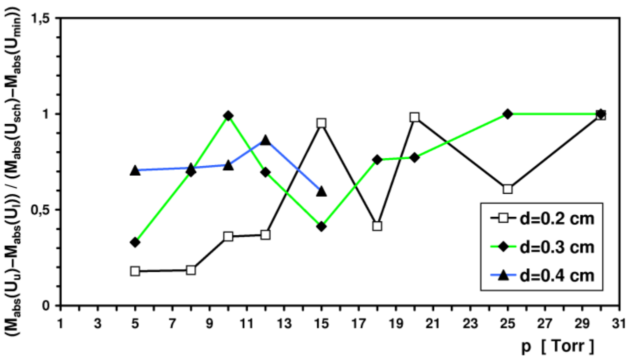

Fig. 4. Ratios of the effective gas amplification (M_{abs}) change within the PPAC ER-plateau range to the M_{abs} maximum change within the M_{abs} linear variability range in a semilogaritmic coordinate system; for the U_l and U_u-supply voltages see fig. 3, and for the U_{min} and U_{sch}-ones see text.

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Ambient air quality determination at different locations using the NCBJ mobile environmental measurements laboratory

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The NCBJ mobile environmental measurements laboratory (in short: mobile laboratory) is a dedicated mobile air conditioned container equipped with state-of-the-art analyzers for continuous determination and recording of the concentrations of common air pollutants related to health effects, such as: particulate matter (PM), nitrogen oxides (NO_x), carbon monoxide (CO) and ozone (O_3), as well as with meteorological stations for measurements of wind speed, wind direction, air temperature, relative humidity and atmospheric pressure. This monitoring station, which cost in the region of 900 000 PLN, was put in operation in 2014.

During 2015 the mobile laboratory tested the air quality in ten locations (Fig. 1).

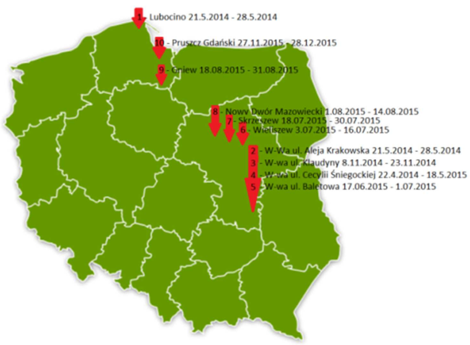

Fig. 1. Map of site locations of the mobile laboratory during tests performed in 2015.

Current legislation in Europe [1] requires the measurement of mass fractions PM_{10} (ambient particles with diameter <10 µm) and $PM_{2.5}$ (particles with diameter ≤ 2.5 µm) of suspended particulate matter in atmospheric air. The particulate matter results were integrated to give 24-hour average values for comparison with Directive 2008/50/EC limit values. For the PM_{10} mass fraction the 24-hour limit value is equal to 50 µg/m^3 which not to be exceeded more that 35 times per calendar year. Table 1 presentsthe statement of the results for the one-day value of PM_{10} mass fraction of suspended particulate matter in the ambient air determined at different locations.

The results of the PM_{10} and $PM_{2.5}$ value measurements at each location are presented in NCBJ Reports [2-11]. In the first location on each measuring day the recorded one-day PM_{10} mass fraction exceeded the limit value. In the other six locations the one-day PM_{10} values were lower than the limit value.

The last location was the Nad Radunią housing estate in Pruszcz Gdański (Fig. 2). The mobile laboratory was in place from 14-th to 27-th December 2015.

Fig. 2. Location of the mobile laboratory at the Nad Radunią housing estate in Pruszcz Gdański.

Fig. 3 presents the 24-hour PM_{10} and $PM_{2.5}$ values recorded during the measuring period.

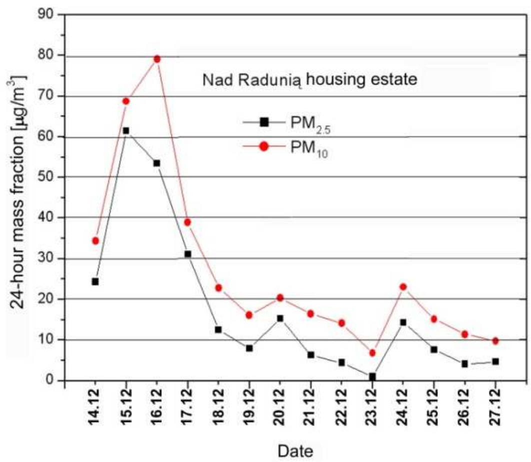

Fig. 3. The one-day PM_{10} and $PM_{2.5}$ mass fraction values recorded during the measuring period..

In the first part of measuring period high values of PM_{10} and $PM_{2.5}$ were recorded. The one-day PM_{10} value exceeded the limit value twice. During the measuring period strong atmospheric fronts occurred which caused winds with different speeds and directions, changes in air temperature and heavy rain fall. These atmospheric phenomenon occurred in the second part of measuring period. Their influence on the 3-hour average $PM_{2.5}$ mass fraction is presented in Fig. 4. In the first part of the measuring period, wind with low speed and southerly direction and low air temperature (near zero or negative) occurred. In this case high $PM_{2.5}$ values were recorded. When high wind speed with different directions and high positive air temperature arrived the lower 3-hour $PM_{2.5}$ values were recorded.

Table 1. Statement of results of the one-day value of the PM_{10} mass fraction of suspended particulate matter in the ambient air determined at different locations.

Location of measuring station	**Number of measuring days**	**Amount of days with one-day value of the PM_{10} mass fraction exceeded the limit value**
Warszawa, two-level crossing of Aleja Krakowska Str. with South Ring Road of Warsaw	7	7
Warszawa, cross-roads of Aleja Armii Krajowej Str. with Adama Mickiewicza and Klaudyny	16	-
Warszawa, Cecylii Śniegockiej 6 Str.	27	1
Wieliszew, Modlińska 65 Str.	14	-
Skrzeszew, Kościelna 74 Str.	13	-
Nowy Dwór Mazowiecki, Okunin 70 Str.	14	-
Warszawa, Baletowa 13a Str.	15	-
Gniew, Krasickiego 8 Str.	14	-
Pruszcz Gdański, Wschód housing estate	14	1
Pruszcz Gdański, Nad Radunią housing estate	14	2

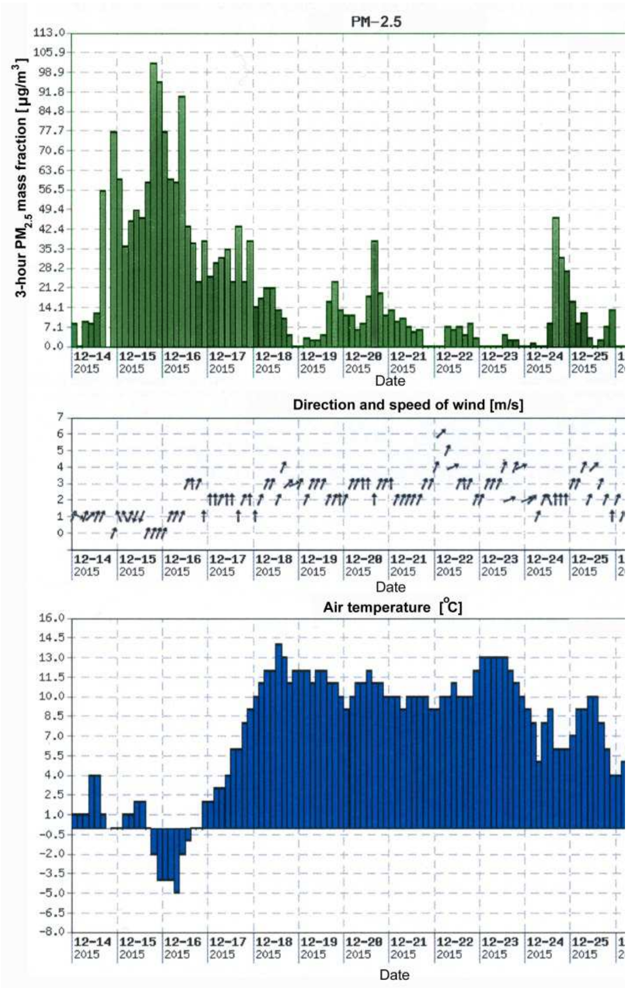

Fig. 4. The 3-hour average $PM_{2.5}$ mass fraction and 3-hour averaged information regarding wind direction and speed and air temperature.

References

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[2] Raport z pomiarów liczebności ultradrobnych i drobnych cząstek pyłu w powietrzu atmosferycznym w rejonie dwóch warszawskich węzłów drogowych we Włochach i na Żoliborzu. Raport NCBJ B-3/2015.

[3] Raport z pomiarów stężenia masowego frakcji PM_{10} i $PM_{2.5}$ pyłu zawieszonego w powietrzu na terenie Narodowego Centrum Badań Jądrowych w Świerku. Raport NCBJ B-5/2015.

[4] Raport z pomiarów stężenia masowego frakcji PM_{10} i $PM_{2.5}$ pyłu zawieszonego w powietrzu w rejonie węzła drogowego Alei Armii Krajowej z ulicą Adama Mickiewicza i ulicą Klaudyny w Warszawie. Raport NCBJ B-10/2015.

[5] Raport z pomiarów stężenia masowego frakcji PM_{10} i $PM_{2.5}$ oraz liczebności ultradrobnych i drobnych cząstek pyłu zawieszonego w powietrzu przy ul. Cecylii Śniegockiej w Warszawie. Raport NCBJ B-12/2015

[6] Raport z pomiarów stężenia masowego frakcji PM_{10} i $PM_{2.5}$ pyłu zawieszonego w powietrzu przy ul. Modlińskiej w Wieliszewie. Raport NCBJ B-15/2015.

[7] Raport z pomiarów stężenia masowego frakcji PM_{10} i $PM_{2.5}$ pyłu zawieszonego w powietrzu przy ul. Kościelnej w Skrzeszecie. Raport NCBJ B-17/2015.

[8] Raport z pomiarów stężenia masowego frakcji PM_{10} i $PM_{2.5}$ pyłu zawieszonego w powietrzu przy ul. Okunin 70 w Nowym Dworze Mazowieckim. Raport NCBJ B-19/2015.

[9] Raport z pomiarów stężenia masowego frakcji PM_{10} i $PM_{2.5}$ pyłu zawieszonego w powietrzu przy ul. Krasickiego 8 w Gniewie. Raport NCBJ B-20/2015.

[10] Raport z pomiarów stężenia masowego frakcji PM_{10} i $PM_{2.5}$ pyłu zawieszonego w powietrzu przy ul. Baletowej w Warszawie. Raport NCBJ B-26/2015.

[11] 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. Raport NCBJ B-4/2016

Economic and physical models for the Polish and European energy markets

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The Complex Systems Team (CST) was part of the Świerk Computing Centre Project (CIŚ) and its main studies were concerned with analyses of power systems and energy markets, which utilized CIŚ computing facilities. With the creation of the Department of Complex Systems in 2015, the CST members formed the Group for Energy Analysis and continue to work on the models of the European and Polish power systems.

The main topics of our research refer to nodal and zonal energy market planning, static and dynamic analysis of power systems, including modelling time dependencies of energy demand and power flows. We also deal with various forms of power system stability assessment, ranging from the detection of congested lines and the formation of loop-flows, to the possibility of blackouts.

Our computations use both commercial and noncommercial software dedicated to the analysis of power systems, as well our own algorithms, utilizing the HPC capabilities of CIŚ. We are also dedicated to building our own models, including those of transmission grids of higher voltages and databases of power plants of different technologies. Fig. 1 depicts our main objects of interest.

One of our goals is to obtain a long-term model, dependent on variable costs of energy generation related to the prices of fuels, emissions (e.g. CO_2) and their allowances, and the share of renewable energy sources (RES) in energy generation. The reliability of this long-term model is raised by coupling it with a short-term one, for the purpose of which we use the Market Coupling and Optimal Power Flow (OPF) method and calculate the Market Clearing Prices (MCP) and Locational Marginal Prices (LMP).

The LMP, reflecting the cost of delivering another MW to specific nodes of the grid, are used in the Bidding Zone Study that we are involved in. This is a project for aEuropean Network of Transmission System Operators for Electricity (ENTSO-E), which is considering the option of introducing a zonal energy market in Europe. LMPs are the necessary input data for our clustering algorithms, which lead to different divisions of the European energy market into zones.

Another topic reflects the need properly to assess the risk of power systems failures and to support operators' decisions and remedial actions. This is extremely relevant when the system is not in a "N-1"-stable state and another outage, caused by severe weather conditions, may lead to blackouts. In order to obtain the measure of such a risk, a detailed dynamic model of an exemplary power system is developed and its time simulations are performed. Extending this research for the Polish power system is planned for our future research purposes.

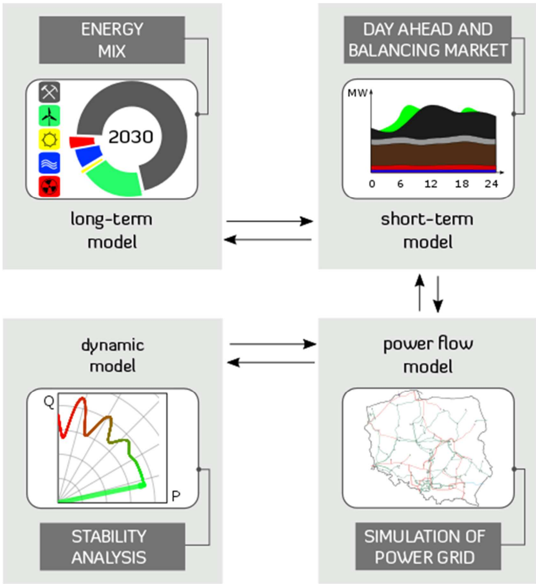

Fig. 1. Models of energy markets developed at NCBJ.

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Study of modern J-PET tomograph and investigations of radiopharmaceutical structures

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The Group for Bio-Medical Application is part of the J-PET collaboration that aims to construct a PET scanner from plastic scintillators which would allow for simultaneous imaging of the whole human body. The TOF resolution is improved due to the use of fast plastic scintillators. It was shown that Compressive Sensing theory can be successfully applied to the problem of signal recovery in a J-PET scanner. Finally, a statistical model that enables a theoretical value of the position error of the registered event to be evaluated has been developed. The predicted results are in good agreement with the experimental results obtained with the J-PET tomograph prototype.

Studies of a modern J-PET tomograph (Jagiellonian Positron Emission Tomography) based on plastic scintillation detectors have been performed. Simulations are based on the computing environment GATE (Geant4 Application for Tomographic Emission) and are performed at the CIŚ cluster. These simulations include geometry optimization and obtaining the characteristics of the J-PET tomography scanner. The methods of obtaining the characteristics are defined in the NEMA-NU-2 norm. One of these characteristics, scatter fraction, was investigated from October to December of 2015. Scatter fraction is a characteristic that describes the relation between true and scattered coincidences in a PET measurement. The smaller the number of scattered coincidences, the better the reconstructed image.

Secondary goals of the research are theoretical investigations using methods based on molecular electronic structure theory of radiopharmaceutical structures and interactions with receptors of cancerous tissues. Studies include the electronic structure of Fe-S clusters and modelling of Nuclear Magnetic Resonance (NMR) parameters of compounds containing transition metal atoms.

CP04 - the minigastrin analogue [DOTA-$(DGlu)_6$-Ala-Tyr-Gly-Trp-Met-Asp-Phe-NH_2] has been developed as a CCK2R targeting vector for radiolabelling with ^{111}In or ^{68}Ga for imaging, or with ^{90}Y and ^{177}Lu for therapy. However, as observed for somatostatin and bombesin analogues, the affinity of the chelator-peptide conjugates to the cell membrane receptors may vary depending on the metal incorporated into the complex. The main goal of the research conducted with POLATOM (prof. dr hab. Renata Mikołajczak and dr hab. Piotr Garnuszek) was a theoretical explanation of the experimental observation. Quantum chemical modelling of the structures of ^{68}Ga- and ^{177}Lu-CP04 complexes and simulation of their binding to the CCK2R receptor was performed. Significant changes in mutual orientation of the DOTA part and the binding site (-Trp-Met-Asp-Phe-) of CCK2R receptor have been found. All three geometric parameters (the two distance values and the dihedral angle) are significantly smaller for the Lu- than for the Ga-CP04 compound.

Paper in preparation.

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Concentration of cosmogenic and anthropogenic radionuclides in the ground layer of the atmosphere, in the polar and mid-latitudes regions - the continuation and extension of research (mechanical modernization and software upgrade)

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The most important source of atmospheric radioactivity is radionuclides generated as a result of the impact of primary and secondary cosmic radiation with nuclei of nitrogen and oxygen in the upper troposphere and lower stratosphere. This creates about thirty radioisotopes of more than twenty elements. For organisms the four most important are: ^{3}H, ^{7}Be, ^{22}Na, ^{14}C. The natural radionuclides, which are present in the Earth's crust, also settle on dust and particles of water vapour. By this means, derivatives of uranium and thorium, and long-lived ^{40}K get into the air. ^{137}Cs is the most widespread isotope that is introduced by humans into the environment.

Fig. 1. AZA-1000 station at the Polish Polar Observatory in Hornsund (Spitsbergen).

The high volume air sampler AZA-1000 located at thePolish Polar Observatory in Hornsund (Spitsbergen) is one of the radionuclide monitoring stations positioned close to the North pole and the most Northern of all (77°00'N, 15°33'E) – Fig. 1. Since 2002, it has provided information about the concentration of the following radionuclides: ^{7}Be, ^{40}K, ^{210}Pb, ^{22}Na and ^{137}Cs and the dustiness of the air.

Until now the aim of the installation was data gathering and comparison with data from mid-latitude regions (station ASS-500 at Świder at the Kalinowski Geophysical Observatory of the Polish Academy of Sciences, 52°07'N, 21°15'E, Fig. 2.). This contributed to a better understanding of the mechanisms of the phenomena of creation and propagation of radionuclides in the air. Ongoing work is dedicated to the modernization of the station, which will provide continuous monitoring of data. This will help to develop and increase our knowledge of the influence of multiple factors (for example: electrical parameters of the atmosphere, ionic phenomena, magnetic field changes, consistence of natural radionuclides in the soil), that introduce radionuclides in the ground layer of the atmosphere [1]. Due to the location of the station in a place away from sources of industrial pollution and traffic, the above issues can to be successfully analyzed.

Fig. 2. ASS-500 station at the Kalinowski Geophysical Observatory in Świder.

Recently i.e. in 2015, the ASS-500 station in Świder was modernized and restarted. Ongoing work focussed on setting up remote control systems for the Świder station and than the Horsund station.

*Fig. **3.** ASS-500 in Świder after modernization in 2015.*

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Recent activities in epithermal neutron beam construction at the MARIA research reactor

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Increasing interest in boron neutron capture therapy (BNCT) at the end of the 90s resulted in many national research programmes leading to the implementation of this type of treatment. The Polish BNCT programme [1] started in 2001 and was coordinated by the Institute of Atomic Energy POLATOM, In 2014 it was restarted by the National Centre for Nuclear Research in Świerk in collaboration with other institutions [2]. The general concept is to start the construction of an irradiation facility with an epithermal neutron beam and a research programme.

The NCBJ team continues designing the fission converter, which is to be located outside the reactor core [3]. The device will be located in the reactor pool, near the front of the H2 channel, instead of one of the reflector graphite blocks at half height. Core thermal neutrons will cause a fission reaction in the converter. This will result in the production of fast neutrons, which will be slowed down to epithermal energies in the filter/moderator system. At the end of the H2 channel i.e. at the entrance to the research room, the neutron intensity will be at least at the level required for BNCT (2×10^{9} n $cm^{-2}s^{-1}$). For other purposes the density of the neutron flux could be smaller. Thermal and neutron load of the fuel plates in the converter will be inhomogeneous. In order to equalize these loads, the converter should be designed in such way that it would be possible to change the order of the fuel plates. Moreover, replacing the number of plates gives the opportunity to obtain different fluxes of neutrons (quantitatively and qualitatively i.e. energetically). The project of the converter is based on Monte Carlo calculations of neutron production and on Computational Fluid Dynamics (CFD) i.e. flow and heat exchange modelling of the converter.

The next step in the project was to accomodate the space nearby the output of the epithermal neutron beam [4]. Three rooms were emptied (250 tons of old installations) and renovation documentation was prepared for the facility. It is planned to create a fully equipped complex facility enabling various experiments on the intensive neutron beam. An epithermal neutron beam enables development across the full spectrum of materials research, for example shielding concrete tests or improvement in the construction of electronic devices. Due to recent reports on the construction of the accelerator for Boron Neutron Capture Therapy (BNCT) it has the opportunity to become a useful and successful method in the fight against brain and other types of cancers not treated with well-known medical methods [5]. In Europe there is no such epithermal neutron source which could be used throughout the year for training and research for scientists working on BNCT which makes this installation unique in Europe [6]. Also our research group, which specializes in mixed radiation dosimetry around nuclear and medical facilities, would be able to carry out research on new detectors and methods of measurements for radiological protection and in-beam (therapeutic) dosimetry. Another group of scientists from the National Centre for Nuclear Research, where the MARIA research reactor is located, is involved in research on gamma detector systems. There is an idea to develop Prompt-gamma Single Photon Emission Computed Tomography (Pg-SPECT). This method could be used as an imaging system for compounds emitting gamma rays after nuclear reactions with thermal neutrons e.g. for boron concentration in BNCT.

The achievements of the past Polish BNCT programme give the opportunity toa prepare unique epithermal neutron irradiation facility for BNCT research and education. Research carried out on the converter facility provided experience for a new project based on plate-type fuel elements. The resulting irradiation station will serve as a research and training facility. Institutions involved in the project are willing to cooperate further, especially in studies on boron compounds and living cell irradiation. Unique recombination chambers and methods prepared for BNCT are being continually developed.

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EURADOS intercomparison exercise on MC modelling and measurements for the *in-vivo* monitoring of AM-241 in skull phantoms

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INTRODUCTION

The Radiation Protection Measurements Laboratory (LPD), as a member of EURADOS, participated in intercomparison on *in-vivo* monitoring of ^{241}Am in three skull phantoms. The intercomparison consisted of two different exercises (it was only possible to participate in one of them) – Monte Carlo modelling and measurement of skull phantoms.

The aim of this intercomparison was to calculate gamma radiation spectra and detection efficiency (by modelling) and to register the gamma radiation spectra (by measurements) for three different phantoms and for different geometries.

Participants who routinely perform skull measurements and have appropriate calibration could also determine the ^{241}Am activity.

MATERIALS AND METHODS

Three skull phantoms were used in this intercomparison: the USTUR Case 0102 skull phantom (Fig. 1), the BfS phantom and the CSR hemispherical phantom. All of them were filled with ^{241}Am. The voxel representation**S** were created from CT scans of the physical phantoms.

The detector used in the modelling was **AN** Ortec LO-AX encapsulated in PopTop, closed by **A** carbon-epoxy window and cooled with CFG-X-COOL-II. All **NECESSARY** data containing technical design were provided by the organizers.

There was a possibility to use the MC model of **OUR** own detector in one of **THE** three tasks but LPD did not have the data of **THE** Canberra detector used in **THE** whole body counter.

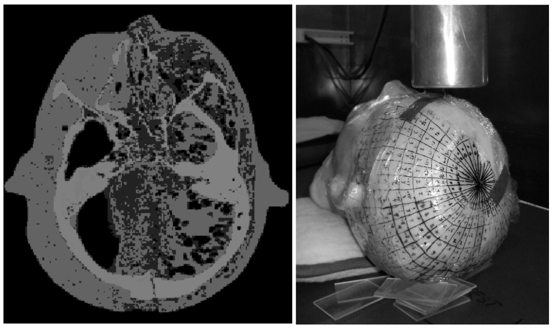

Fig. 1. USTUR Case 0102, one of the skull phantoms used for intercomparison – MC model (left) and physical phantom during measurements in the NCBJ WBC facility (right).

The NCBJ whole body counter facility was used for the measurement part of **THE** intercomparison. This facility is routinely used for the measurement of whole body internal contamination but not for particular organs (i.e. lungs, bones, skull). **THE** Radiation Protection Measurement Laboratory performs ^{241}Am measurements only by *in vitro* methods.

RESULTS

The results of both intercomparisons were presented as papers [1,2]. The calculations and measurements results obtained by all participants were presented. The result obtained by NCBJ is shown in the figure 2.

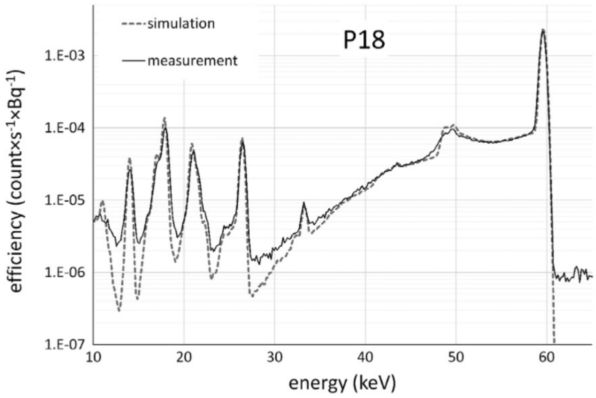

Fig. 2. One of the ^{241}Am gamma spectra calculated for the Ortec LO-AX detector and CSR skull phantom.

In the papers the common mistakes made by participants were pointed out.

CONCLUSION

The results obtained by LPD in both parts of the incomparison were in good agreement with the reference values, taking into account the capabilities of the equipment used.

LPD was not able to model its own detector used in the WBC because of the lack of the required technical data. Meanwhile, the data was bought from the manufacturer making it possible to model it in the future.

The NCBJ whole body counter facility is not recommended for this type of measurements because of the long measurement time (20-50 h).

In addition to the experience gained, this intercomparison also revealed some of the difficulties associated with the use of the USTUR and BfS skull phantoms and emphasized the need for the fabrication of a ”reference skull phantom” and the respective voxel model.

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