Science brings Nations together

Republic of Poland and JINR.

Long-term fruitful cooperation and future prospects

Contents

1. General information about Poland-JINR long-term fruitful cooperation

The Republic of Poland became a Member State of JINR immediately after its establishment by signing the Agreement on 26 March 1956.

Poland has always played an important part in the life and scientific activity of the Joint Institute for Nuclear Research since it was established. Many well-known Polish physicists of the elder generation made noticeable contributions to development of JINR. In its first years, the members of the JINR Scientific Council were such eminent scientists from Poland as L.Infeld, H.Niewodniczanski and A.Soltan.

L.Infelf (left), H.Niewodniczanski (center), A.Soltan (right)

In different periods of time Polish scientists Marian Danysz, A. Hrynkiewicz, A.Budzanowski, J. Bartke, etc.held high managing posts at JINR and its Laboratories. Today the group of Polish scientists at JINR is smaller than in the 1970–1980s. Now working at JINR are 21 specialists from Poland and their family members.

M.Danysz, A. Hrynkiewicz, A.Budzanowski, J. Bartke (left-to-right)

JINR has established good contacts with Polish scientific centers: now it maintains relations with 30 scientific organizations in Poland (among them 16 universities), cooperating with them in all its research fields. In 1998, on the initiative of the JINR Directorate, Chairman of the State Committee for Atomic Energy of the Republic of Poland Prof. H.Niewodniczanski, and Plenipotentiary of the Government of the Republic of Poland

Academician A. Hrynkiewicz, a relevant commission was established to boost and further develop their collaboration with JINR.

The majority of Polish scientists involved in joint activities with JINR carry out investigations at research institutes and universities in Poland using JINR techniques and developments and coming to Dubna on short-term scientific trips.

Poland was many times a host of JINR workshops. In 1990, the XIV International Symposium on Nuclear Electronics was held in Warsaw. There were also the 16th Max Born Seminar “Supersymmetries and Quantum Symmetries” in 2001, Summer School “Nuclear Physics Methods and Accelerators in Biology and Medicine” in 2003, and Workshops “The Use of Lasers for Investigation of Atomic Nuclei” in 2004 and 2006. Workshops on the use of lasers in nuclear physics are regularly held in Poznan. The eighth in this series of workshops, entitled “The Use of Lasers and Storage Devices for Investigation of Atomic Nuclei: Achievements and Prospects” was held in 2009.

In the 1970–1980s, many leading and young specialists from JINR participated as lecturers and students in the then popular schools on physics in Mikolaiki and Zakopane. At present, international schools and conferences held in Poland also attract attention of JINR scientists. Physicists from Dubna traditionally take part in international schools on physics held in Wrocław and seminars on the investigation of neutron scattering in condensed matter held in Poznan. In the year 2009 alone they came to Poland to attend 15 scientific workshops, including the 45th Karpacz Winter School in Theoretical Physics, International Symposium “Neutron Spectroscopy and its Applications”, 4th International Symposium on Vacuum Science and Technology, etc.

Every year over 100 JINR staff members go to Poland for participation in conferences and in connection with joint research.

Since the early 1990s the JINR Directorate has been paying much attention to **exchange of students** and organization of scientific schools and training courses for students. Students and postgraduates from various countries come to JINR to get acquainted with the institute, do practical work, write their graduation theses, and get training under special programmes; this also applies to students from Poland as the relations with Polish universities have become especially intensive within the educational programme.

The Bogolyubov–Infeld programme was established to support development and implementation of educational projects initiated by Polish universities and JINR; the programme is financed through a special grant of the Plenipotentiary of the Government of the Republic of Poland at JINR. Polish students carry out laboratory research and do their pregraduation and graduation practical work, which to a large extent is the merit of the JINR staff member from Poland W.Chmielowski, the Assistant Chief Scientific Secretary of JINR.

Scientists from the Republic of Poland take part in 31 out of 44 themes in all JINR research fields:

- **Theoretical physics** (collaboration in 5 themes)
- **Elementary particle physics and relativistic nuclear physics** (12 themes)

- **Nuclear physics** (in 6 themes)
- **Condensed matter physics; radiation and radiobiological research** (5 themes)
- **Networking, computing, computational physics** (2 themes)
- **Educational programme** (1 theme)

101st session of the JINR Scientific Council at Dubna. Left to right: Mieczysław Budzyński (Poland), A. Duisebaev (Kazakhstan), J. Ellis (Switzerland), A.Hrynkiewicz and J. Janik (Poland), V.G. Kadyshevsky.

JINR has established wide relations with Polish scientific centres. Its most active partners are:

- Warsaw University of Technology http://www.pw.edu.pl/
- Warsaw University http://www.uw.edu.pl/
- The Andrzej Soltan Institute for Nuclear Studies (Warsaw) http://www.ipj.gov.pl/
- Institute of Nuclear Chemistry and Technology (Warsaw) http://www.ichtj.waw.pl/
- The Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences (PAS) in Kraków http://chall.ifj.edu.pl/
- Jagellonian University (Kraków) http://www.uj.edu.pl/
- University of Lódz http://www.uni.lodz.pl/
- Maria Curie-Skłodowska University (Lublin) http://www.umcs.lublin.pl/
- Institute of Atomic Energy (Otwock-Świerk) http://www.cyf.gov.pl/
- Adam Mickiewicz University (Poznan) http://www.guide.amu.edu.pl/

List of collaborating organizations for 2011:

Warsaw:

- Nicolaus Copernicus Astronomical Center, PAS http://www.camk.edu.pl/
- Institute of Physical Chemistry, PAS http://ichf.edu.pl/
- Heavy Ion Laboratory, University of Warsaw http://www.slcj.uw.edu.pl/
- Electrotechnical Institute http://www.iel.waw.pl/

Kraków:

- AGH University of Science and Technology http://www.agh.edu.pl/
- Faculty of Physics and Applied Computer Science, AGH–UST http://www.agh.edu.pl/
- Academic Computer Centre CYFRONET AGH http://www.cyf-kr.pl/

Lublin:

- Lublin University of Technology www.pollub.pl/

Poznan:

- Greater Poland Cancer Centre http://www.wco.pl/
- Institute of Molecular Physics, PAS http://www.ifmpan.poznan.pl/
- Poznan University of Technology http://www.put.poznan.pl/

Wrocław:

- Wrocław University of Technology http://www.pwr.wroc.pl/
- University of Wrocław http://www.uni.wroc.pl/
- Institute of Low Temperature and Structure Research, PAS http://www.int.pan.wroc.pl/

Gdansk:

- Gdansk University of Technology http://www.pg.gda.pl/

Rzeszów:

- University of Rzeszów http://www.univ.rzeszow.pl/

Katowice:

- University of Silesia http://www.us.edu.pl/

Kielce:

- Institute of Physics, Jan Kochanowski University of Humanities and Sciences http://www.pu.kielce.pl/

Szczecin:

- West Pomeranian University of Technology http://www.ps.pl/

Since 25 June 2009 till now the Plenipotentiary of the Government of the Republic of Poland at JINR is **Michael Waligorski**, President of the Polish Society of Medical Physics.

Michael Waligorski (left) and Meeting with the Plenipotentiary, 6 July 2009 (right)

Michael Waligorski was born in Richmond in 1945. He is Candidate of Sciences (nuclear physics), professor, President of the Polish Society of Medical Physics since 2005. For over 15 years he has been teaching clinical dosimetry at the Faculty of Physics and Applied Computer Science of the AGU University of Science and Technology. His professional interests embrace radiobiology and hadron therapy of tumours.

2009. Dubna, 6 July. President of the Atomic Energy Agency of the Republic of Poland Michael Waligorski (centre) and Ambassador of the Republic of Poland to RF Jerzy Bahr (right) on a visit to JINR

At present, the **members of the JINR Scientific Council** are **Mieczysław Budzyński**, a professor of the Institute of Physics (Lublin, Poland), **Wojciech Nawrocik**, a professor of Adam Mickiewicz University (Poznan, Poland), and **Krzysztof Królas**, a professor of Jagellonian University (Krakow, Poland).

M.Budzyński, W.Nawrocik, K.Królas and W. Chmielowski (left-to-right)

Mieczysław Budzyński was born on 16 June 1946. Physicist, professor, Doctor of Sciences (physics and mathematics), graduated from Maria Curie-Skłodowska University of Physics and Chemistry in Lublin (1970), defended his Doctor of Sciences thesis there as well (1984). His **major research topics** are hyperfine interactions of radioactive nuclei; radioactive methods for solid state studies: perturbed angular correlations, Mössbauer spectroscopy. He is a Member of the JINR Scientific Council since 2008 till now.

Wojciech Nawrocik was born on 16 January 1938. Physicist, Doctor of Sciences (physics and mathematics), graduated from Adam Mickiewicz University in Poznan (1960), defended the Doctor of Sciences thesis at Poznan University (1980). **The same University?**

His **Professional career** includes JINR, FLNP (1980–1985), senior researcher; Institute of Physics, Poznan (since 1990), Director (1987–1991), Dean (1993–1999), Scientific Department (since 1993). His **major research topics** are experimental physics (investigation of liquids and gases using neutron scattering, spectroscopy of dielectrics, NMR spectroscopy, ferroelectrics). He is a Member of the JINR PAC for Condensed Matter Physics and a Member of the JINR Scientific Council since 2008 till now.

Krzysztof Królas was born in Krakow on 31 January 1944. His **major research topics** are environmental and technologically induced radioactivity, physics of power conversion processes. He is a Member of the JINR Scientific Council since 2008 till now.

The dominant spoken languages at JINR are Russian and English. However, many other languages can be heard in Dubna, including languages of the JINR Member States, when “fellow-countrymen”, that is, members of a national group at JINR meet.

Over the time since the foundation of JINR each **national group** has developed its inner traditions and forms of cooperation with other national groups. Playing an organizing part in the life of the national groups are their leaders appointed by the Plenipotentiaries of the JINR Member States.

Leader of the national group of the Republic of Poland is Chmielowski Wladislaw, assistant Head of the JINR Science Organization and International Cooperation Office. Maintaining contacts with the Plenipotentiaries, embassies of the JINR Member States, JINR Directorate and Offices, they take part in solving any problems that arise during the stay of the colleagues from their countries and members of their families in Russia, including everyday life and leisure. The Council of National Group Leaders periodically meets to discuss, among other things, problems that worry JINR staff members from the Member States. Representatives of the JINR Directorate and Offices are invited to these meetings, which allows the Directorate to take timely and adequate solutions.

National groups give receptions on their major state holidays. Arts and photo exhibitions are usually arranged for these holidays, contributing to better knowledge of the Member States, their people, and their culture.

Some of recent events

2009. Dubna, 18 March. Participants of the memorial seminar dedicated to the centenary of the birth of Marian Danysz

On 29 March – 2 April 2010 (Dubna–Warsaw–Bratislava), JINR Delegation visited Warsaw and Bratislava. JINR Vice-Director M.G.Itkis, JINR Director Assistant V.V.Katrasev and FLNP Director A.V.Belushkin participated in meetings of Poland and Slovakia Coordinating Committees on cooperation with JINR. As V.V.Katrasev said, the meetings were devoted to distribution of a part of these JINR Member States' fees to joint priority projects in the frames of the JINR Topical plan. For example, Poland is ready to direct 12% of its fee to JINR to such projects. This will form about 600 000 US dollars in 2010. Directors and leading scientists of scientific centers and universities are members of the Poland and Slovakia Coordinating Committees headed by plenipotentiaries of these countries to JINR. In Poland, President of the Atomic Energy Agency Mihał Waligurski coordinates cooperation with JINR. Professor Stanislav Dubnička guides this activity in Slovakia.

On 5-25 July 2010, International Students' Summer Practical Work for students from JINR Member States was hold in the JINR Univercity center.

On 11-18 April 2010, school “Radiobiology and nuclear safety”for Polish students from Lublin University (Poland) was hold in the JINR University Centre. The educational plans: during the week of their stay at JINR the students listened to lectures and got practical training in different areas of radiation and nuclear safety and radiobiology. On the last day of the school, they will visit Sergiev Posad.

Students from Poland who came to JINR for doing practical work, 2008.

On 9–11 November 2010, invited by Professor M. Budzynski, member of the JINR Scientific Council from Poland, Director of FLNP A.V.Belushkin and JINR and some other JINR staff-members took part in the extended scientific seminar held at the Institute of Physics of the Maria Curie-Sklodowska University in Lublin under the guidance of Professor Z. Korczak, Director of the Institute of Physics.

The seminar audience, which included chiefly students, postgraduates, and young scientists, heard with interest the presentations by the guests from Dubna, gaining an insight into the history of JINR and its today’s scientific policy, as well as into some of the prîmising avenues of research, associated, in particular, with the development of light spectroscopy methods and their use in biology and medicine. The JINR delegation, in its turn, got acquainted with the activities of the Institute of Physics and faculties of Lublin University.

On 19 November 2010, ***Mieczyslaw Sowinski***, Doctor of Science, Professor, Vice-Director of JINR in 1977–1983, Plenipotentiary of the Government of the People’s Republic of Poland to JINR in 1982–1989, celebrated his 80th birthday.

As a JINR Vice-Director and Plenipotentiary of the Government of Poland to the Institute, Professor Mieczyslaw Sowinski made a tremendous contribution to the development of nuclear physics, international cooperation, and improvement of JINR equipment base. Devoting active attention to training of young scientific staff, M. Sowinski attained the conditions when Polish students and postgraduates, as well as young people from other Member States, find JINR a reliable foundation for their scientific growth.

JINR staff members awarded with the jubilee medals “Poland at JINR: 50 Years” together with the Polish staff members.

2. Contribution of Poland Republic into scientific results of JINR

Cooperation between scientists from Bogoliubov Laboratory of Theoretical Physics and Republic of Poland

Scientists of the **Bogoliubov Laboratory of Theoretical Physics** (BLTP) over the years have accumulated unique experience of research in several fundamental areas of theoretical physics: quantum field theory and elementary particle physics, nuclear theory, theory of condensed matter and methods of mathematical physics.

The studies conducted at BLTP are interdisciplinary; they are directly integrated into international projects with the participation of scientists from major world research centres and are closely coordinated with JINR experimental programs.

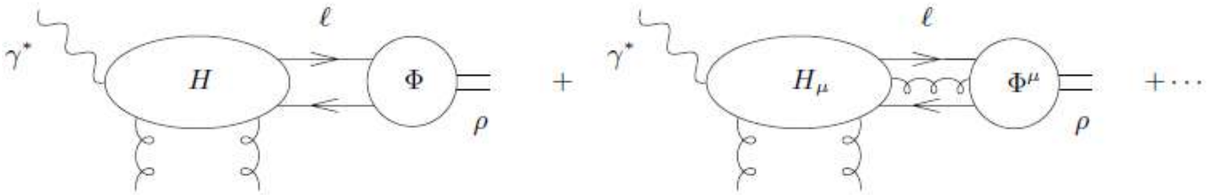
Cooperation between BLTP and Polish research centres is carried out within the Bogoliubov-Infeld Program.


N.N.Bogoljubov (left) and L.Infeld (right)

Within this program specific research projects and joint scientific conferences are supported by the grants of the Plenipotentiary Representative of Poland Republic. These grants constitute a part of the Polish contribution to the JINR budget. On average about 10 joint projects and 3-4 International conferences with participation of scientists from Poland were supported annually. The system of grants of Plenipotentiary Representatives of JINR Member States was established in order to concentrate the efforts and financial resources at the most important topics of research. Bogoliubov-Infeld Program plays the key role in organization of scientific cooperation between BLTP and Polish physicists.

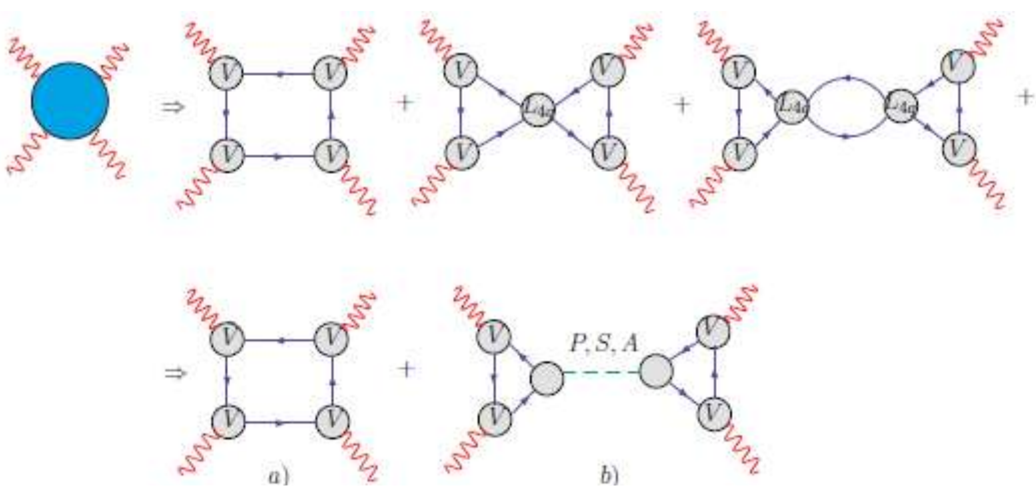
During recent years **c**ooperation between the scientists from Polish research centres and BLTP was carried out within the four JINR themes of the first priority. They are Theory of Elementary Particles, Nuclear Structure and Dynamics, Theory of Condensed Matter and New Materials) and Modern Mathematical Physics. Theoretical support of current and future experiments at JINR, CERN, GSI, DESY, and other physics centers was in the focus of investigations.

In the *Theory of Elementary Particle* the main objective of the common scientific programmes is development of the quantum field theory approach in the framework of the Standard Model of fundamental interactions and its extensions.



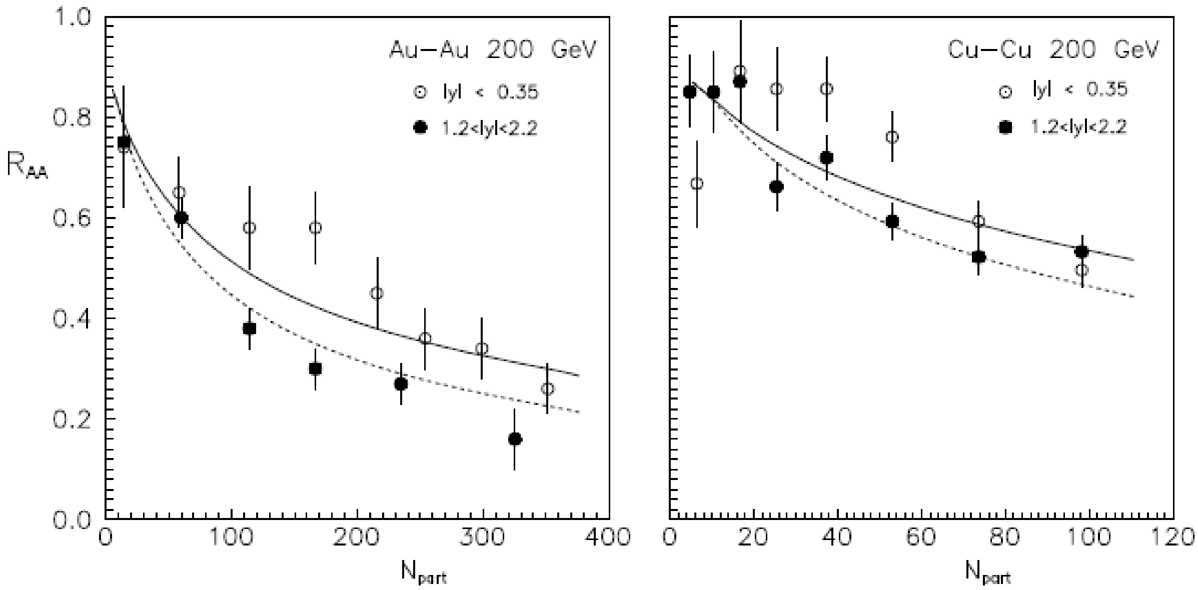
Two- and 3-parton correlators attached to a hard scattering amplitude in the example of the $\gamma \to \rho$ to impact factor, where vertical lines are hard t− channel gluons in the color singlet state [1-3].

There are theoretical predictions concerning the experimental observation of supersymmetry, the Higgs boson, investigation of the spin structure of the nucleon, *T*-odd spin effects, jet handedness, heavy flavor physics, vacuum structure in QCD, and hadron properties in dense and hot media. Furthermore an elaboration of new phenomenological models is under way to describe the hadron dynamics in the framework of general principles of quantum field theory incorporating basic experimental patterns.



The Light-by-Lighr scattering amplitude within the effective four-quark model in the leading $1/N_c$ approximation. It consists of the box diagram plus the iteration of the four-quark interaction term via the quark loop. The iterative terms sum up into a two-point meson correlator in the given channel (pseudoscalar, scalar, or axial-vector) From [4,5].

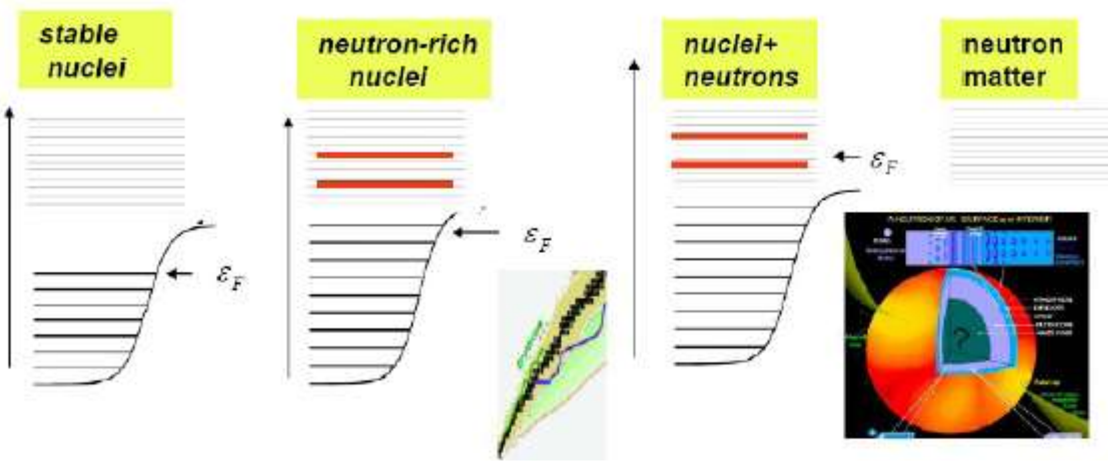
In the forthcoming years, the milestones in theoretical research in the field of particle physics will be determined by the physics programmes of major international projects (LHC, RHIC, FAIR, K2K, etc.) as well as by domestic experimental programmes, the NICA/MPD project at JINR first of all. The main attention will be paid to precision tests of the Standard Model and search for manifestations of the new physics beyond the Standard Model.



J/ψ nuclear modification factor versus centrality in Au-Au (left) and Cu-Cu (right) collisions. Lines are predictions of the model for midrapidity (solid) and forward rapidity (dashed). PHENIX data are used. From [14].

The hadron structure and spin physics, mixed hadronic phase and phase transitions in strongly interacting quark matter, spectroscopy and heavy quark physics, neutrino physics, the dark matter problem and astroparticle physics will be also in the course of common theoretical interests.

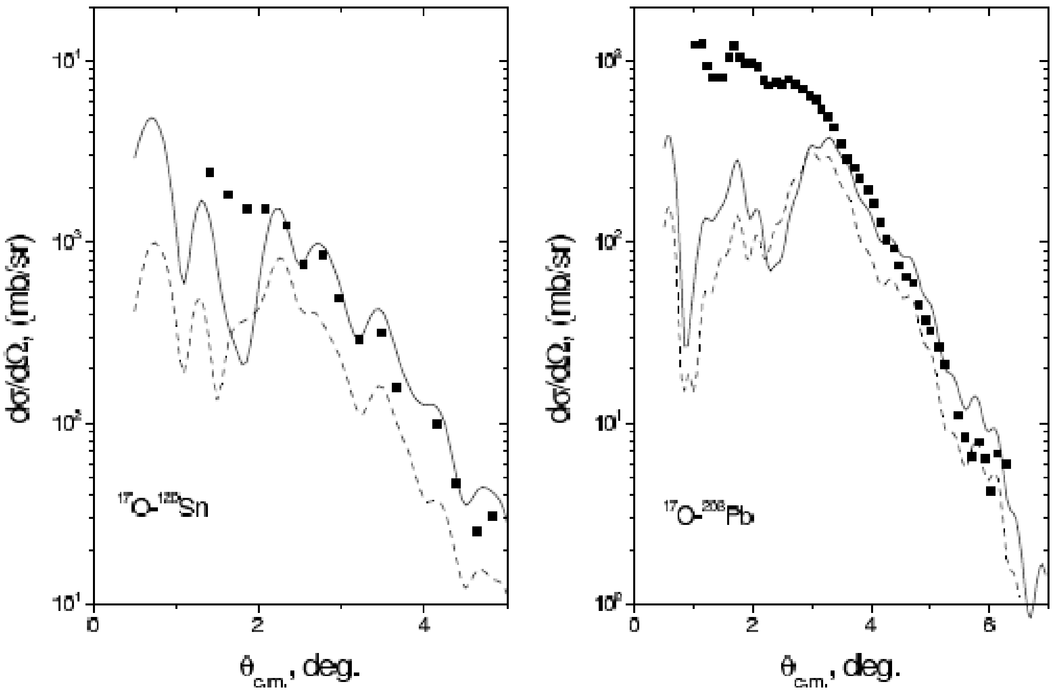
Under BLTP theme *Nuclear Structure and Dynamics* the properties of atomic nuclei at the limits of their stability as well as the dynamics of nuclear reactions and mechanisms of production of exotic nuclides are under common JINR-Poland inveastigations.



Nuclear Structures and nuclear dynamics studies in the Theoretical Nuclear Physics

The main stream of nuclear studies at low-energies during the nearest decade will be the properties of nuclei far from the valley of stability, i.e. the nuclei where the ratio of proton to neutron numbers is anomalously small or large.

The JINR project DRIBS as well as several already established or planned experimental projects in Europe, United States and Japan have as their main goal the study of unstable nuclei. To support experimental efforts, theoretical studies will be developed in the same direction.



Microscopic calculations of inelastic scattering differencial cross sections of the O-17 heavy ions at 1435 MeV on different nuclear targets with excitation of 2^+ collective states [17].

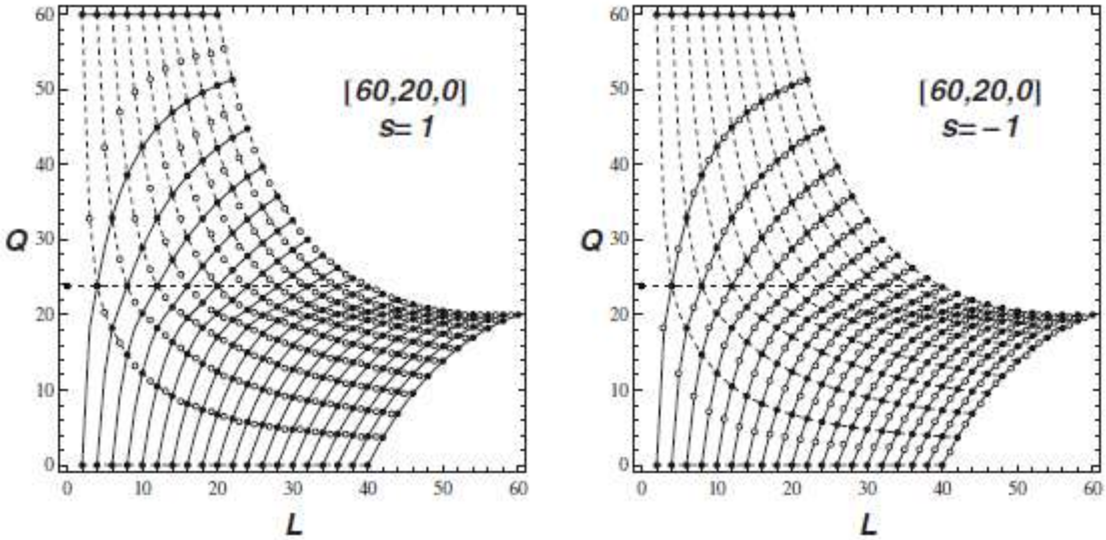
In the modern direction of *Theory of Condensed Matter and New Materials* specialists from JINR and Poland have under joint study the multiparticle models of solid materials taking into consideration the strong electron correlations, electron-lattice, and spin interactions. On the basis they describe spectra of quasiparticle excitations, phase transitions and kinetic phenomena in the solid materials.

The major focus of the theoretical research program in forthcoming years is the analysis of the mentioned above strongly correlated electron systems which involve the investigation of novel cooperative phenomena, new forms of order, low-dimensional magnetism and quantum criticality. Extensive experimental investigations of these materials performed by neutron scattering methods at the Laboratory of Neutron Physics at JINR also strongly motivate the development of theoretical investigations in the field.

Within the *Modern Mathematical Physics* the development of the theory of integrable systems, quantum groups and supergroups is carried out.

The main goal of the planned investigations during the next several years is to perform "realistic" calculations, by applying advanced theoretical methods, of various response functions measured in experiments that might illuminate the complicated interplay between electronic structure, magnetic and transport properties of the considered systems.

In particular, the reduced four-dimensional system of equations of motion describing the simple schematic Hamiltonian based on the volume conservation is obtained by M. Cerkaski at JINR in [18]. A new set of canonical coordinates regarding the separation of motion for independent modes is found with the help of the Jacobi approach. Bohr–Somerfield quantization of new momentum space (L,Q) is studied (see Fig. below).



Bohr–Somerfield quantization of new (L,Q) momenta. From [18].

An exhaustive study of Superstring Theory in different regimes requires search for classical and quantum superstring solutions, detailed investigation of the landscape of superstring vacua, application of modern mathematical methods to the fundamental problems of supersymmetric gauge theories, development of microscopic description of black hole physics, elaboration of cosmological models of the early Universe. Further development of the theory of classical and quantum integrable systems, quantum groups and supergroups, noncommutative geometry will play a crucial role in these integrated investigations in the forthcoming seven years.

During 2008-2010 about 20 young scientists from Poland took part in the DIAS-TH Schools organized within the project **DIAS-TH: Dubna International School of Theoretical Physics.**

Recent joint publications of JINR and Polish scienticts

1. I.V.Anikin, D.Y.Ivanov, B.Pire, **L.Szymanowski** and S.Wallon, ***"Exclusive electroproduction of rhoT meson with twist three accuracy"*** arXiv:1011.1854; ***"Hard exclusive electroproduction of rhoT at twist 3"*** PoS D **IS2010** (2010) 096.
2. I.V.Anikin, D.Y. Ivanov, B. Pire, **L.Szymanowski** and S. Wallon,***``QCD factorization of exclusive processes beyond leading twist: gamma*T → rhoT impact factor with twist three accuracy,"*** Nucl. Phys. B **828** (2010) 1; ***``Hard diffractive processes and non-***

perturbative matrix elements beyond leading twist: rhoT-meson production,'' arXiv:0909.4042.

3. I.V.Anikin, D.Y. Ivanov, B. Pire, **L.Szymanowski** and S.Wallon, ***``QCD factorization beyond leading twist in exclusive rho(T) meson production,''*** Acta Phys. Polon. B**40** (2009) 2131; ***``On the description of exclusive processes beyond the leading twist approximation,''*** Phys. Lett. B**682** (2010) 413; ***``gamma* -> rhoT impact factor with twist three accuracy,''*** AIP Conf. Proc. **1105** (2009) 390.
4. A.E.Dorokhov and **W.Broniowski**, ***``Pion pole light-by-light contribution to g-2 of the muon in a nonlocal chiral quark model,''*** Phys. Rev. D**78** (2008) 073011.
5. **W. Broniowski**, A.E. Dorokhov and E.R. Arriola, ***``Photon interactions and chiral dynamics,''*** arXiv: 0907.3374; ***``Transversity form factors of the pion in chiral quark models,''*** Phys. Rev. D82 (2010) 094001.
6. A.B.Arbuzov, B.M.Barbashov, R.G.Nazmitdinov, V.N.Pervushin, **A.Borowiec**, K.N. Pichugin and A.F.Zakharov, ***"Conformal Hamiltonian Dynamics of General Relativity",*** Phys. Lett. B 691 (2010) 230-233.
7. A.B.Arbuzov, B.M.Barbashov, **A.Borowiec**, V.N.Pervushin, S.A.Shuvalov, A.F. Zakharov, ***"General Relativity and Standard Model in Scale-Invariant Variables"***, Gravitation and Cosmology 15, No. 3 (2009) pp.199-212; ***"Is it possible to estimate the Higgs mass from the CMB power spectrum?"***, Physics of Atomic Nuclei 72, 5 (2009) pp.744-751.
8. S.V.Molodtsov, **T.Siemiarczuk**, A.N.Sissakian, A.S.Sorin, G.M.Zinovjev, ***"Towards light scalar meson structure"***, Eur. Phys. J **C61** (2009) 61
9. **P. Bydzovsky**, Yu.S.Surovtsev, **R.Kaminski**, M. Nagy, ***"Resonances in the isovector P wave of $\pi\pi$ scattering",*** Talk at the 11th International Workshop on Meson Production, Properties and Interaction, 10-15 June 2010, Cracow, Poland, Published by DjaF (http://www.djaf.pl), Krakow, Poland, 2010, p.129. To be published in Int. J. Mod. Phys. Axx , xxx (2011).
10. Yu.S.Surovtsev, **P.Bydzovsky, R.Kaminski,** M.Nagy, ***"Spectroscopic implications from the analysis of processes $\pi\pi \to \pi\pi$, etc"***, Int. J. Mod. Phys. A24, Nos. 2\&3, 586-589 (2009); ***"The light-meson spectroscopy and combined analysis of processes with pseudoscalar mesons"***, Phys. Rev. D81 (2010) 016001.
11. Yu.S. Surovtsev, **R Kaminski**, ***"The f_0- and f_2-families in processes with pseudoscalar mesons. Lower scalar and tensor glueballs"***, Proceedings of the XVIII-th Intern. Baldin Seminar on High Energy Physics Problems "Relativistic Nuclear Physics and Quantum Chromodynamics" (Dubna, Russia, September 25-30, 2006), Editors: A.N. Sissakian, V.V. Burov and A.I. Malakhov, Dubna, JINR, 2008, Vol.I,120-127.
12. D.Blaschke, **M.Buballa**, A.E.Radzhabov and M.K.Volkov, ***``Nonlocal quark model beyond mean field,''*** Phys. Part. Nucl. 41 (2010) 921.
13. **R.Lastowiecki** and D.B.Blaschke, ***``EoS and bulk viscosity of cold quark matter in a running coupling NJL model,''*** Acta Phys. Polon. Supp. 3 (2010) 753.
14. **L.Turko, D.Prorok** and D.Blaschke, ***``Charmonium Suppression at RHIC and SPS: A Unified Approach,''*** J. Phys. G 37 (2010) 094053.

15. D.B.Blaschke, F.Sandin, V.V.Skokov and **S.Typel**, ***``Accessibility of color superconducting quark matter phases in heavy-ion collisions,''*** Acta Phys. Polon. Supp. 3 (2010) 741.
16. **D.S.Zablocki,** D.B.Blaschke, R.Anglani and Yu.L.Kalinovsky, ***``Diquark Bose-Einstein condensation at strong coupling,''*** Acta Phys. Polon. Supp. 3 (2010) 771.
17. K.V.Lukyanov, E.V.Zemlyanaya, V.K.Lukyanov, Z.Metawei, **B.Sowinski**, K.M. Hanna, ***``Inelastic heavy-ion scattering at intermediate energies with excitation of nuclear collective states''***, Izvestija RAN, ser. fiz., 72, 387-391 (2008).
18. **M. Cerkaski**, ***``Ellipsoids of U(3) model'',*** J. Math. Phys. 50, 102703 (2009).
19. A.S.Fomichev, G.M.Ter-Akopian, V.Chudoba**,** A.V.Daniel, M.S.Golovkov, V.A. Gorshkov, L.V.Grigorenko, S.A.Krupko, Yu.Ts.Oganessian, S.I.Sidorchuk, R.S.Slepnev, S.V.Stepantsov, S.N.Ershov, V.K.Lukyanov, B.V.Danilin, A.A.Korsheninnikov, V.Z. Goldberg, **M.Pfutzner**, **I.G.Mukha**, H.Simon, O.B.Tarasov, N.K.Timofeyuk, M.V. Zhukov, K.Lawrie, R.T.Newman, ***``The suggested new fragment separator ACCULINNA-2''***, Acta Phys. Polon. B41 (2010) 475-480.
20. T.I. Mikhailova, A.G.Artyukh, M.Colonna, M. di Toro, B.Erdemchimeg, **G. Kaminski,** I.N.Mikhailov, Yu. M. Sereda, H.H.Wolter, ***``Competition of breakup and dissipative processes in peripheral collisions at Fermi energies''***, in the Proceedings of the Intern. Conference on Current Problems in Nuclear Physics and Atomic Energy (NPAE-Kyiv2008) (Kyiv, Ukraine, June 9-15, 2008), INR, Kyiv, 2009, pp.236-239 .
21. S.Fedoruk, **J.Lukierski**, ***"Purely twistorial string with canonical twistor field quantization"***, Phys.Rev. D79 (2009) 066006.
22. S.Fedoruk, **P.Kosinski, J.Lukierski, P.Maslanka,** ***"Nonrelativistic twistors and the realizations of Galilean conformal algebra"***, arXiv:1012.0480.
23. S.Fedoruk, E.Ivanov, J.Lukierski, ***"Galilean Conformal Mechanics from Nonlinear Realizations"***,Phys.Rev. D83 085013 (2011).
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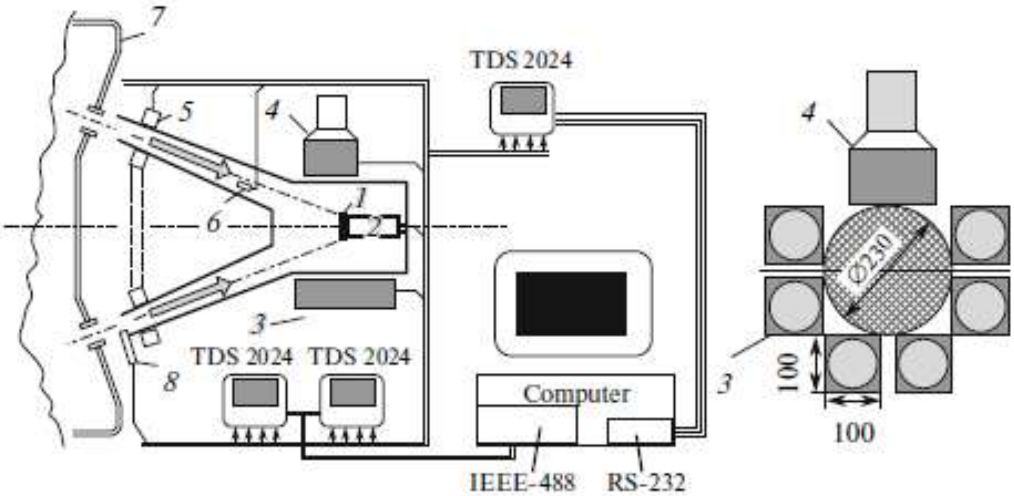
Collaboration of Dzhelepov Laboratory of Nuclear Problems with Republic of Poland

The collaboration between DLNP JINR and Institution of Poland exists in the frame of nuclear physics and applied researches.

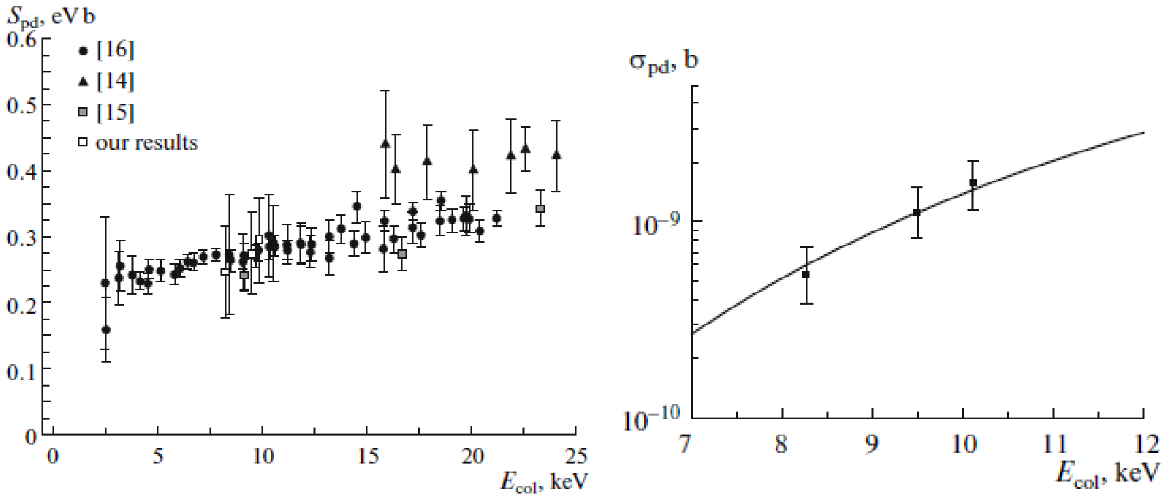
Nuclear physics

In the frame of **LESI project** ("Study of interactions between light nuclei in the astrophysical energy region") the DLNP physicists successfully works with scientists of Faculty of Fuels and Energy, AGH, University of Science and Technology (Krakow, Poland); Faculty of Physics and Applied Computer Sciences, AGH, University of Science and Technology (Krakow, Poland) [1-11].

The aim of the investigations is the measurement of the: astrophysical S-factors and effective cross sections for the reactions $pd \to {}^3He + \gamma$ (5.5 MeV), $dd \to {}^3He + n$ (2.5 MeV) and $d^3He \to p + {}^4He$ in the astrophysical energy region 2-15 keV; potentials of electron screening for dd – reaction in the deuterides of the Ta, Ti, Zr, Mg and Zn. The study of the reactions between light nuclei in the ultralow energy region is of great importance for physics of few-body nucleon systems because it could provide direct verification of fundamental symmetries in strong interactions and could also help to solve a number of astrophysical problems. For realization of the given investigations we have designed and created the pulsed ion source with the closed Hall current.



Experimental setup scheme: (*1*) deuterium D_2O (CD_2) target, (*2*) electrostatic multi_grid spectrometer, (*3*) plastic scintillator detector, (*4*) NaI(Tl) detector, (*5*) Rogowski loop, (*6*) Faraday cup, (*7*) Hall accelerator, (*8*) optical detector collimator.



Astrophysical *S*_factor (left) and cross section (right) dependences on collision energy for pd interaction

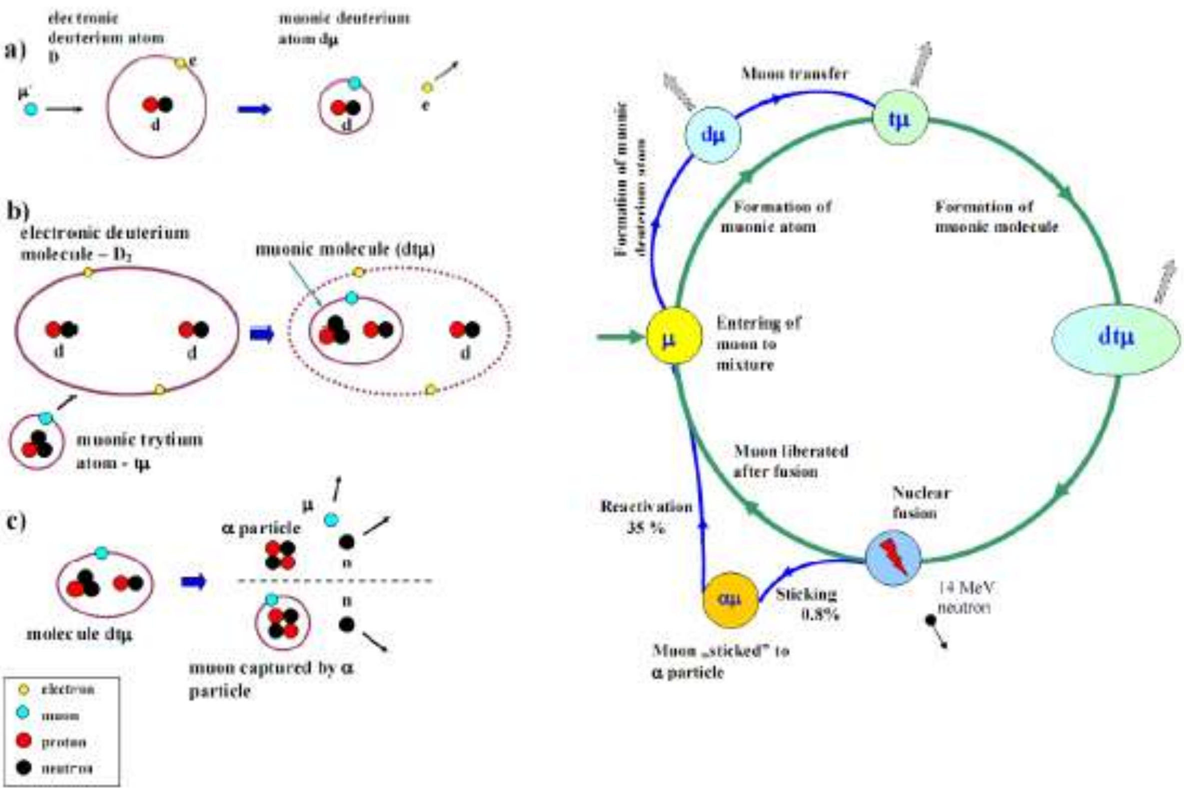
During next 7 years the collaboration plans to perform the modernization of the Hall accelerator, the development and creation of ZrD, ZrD_2, Ta_2D, TiD_2 targets by reactive magnetron sputtering, the development and creation of a technique of measurement of deuteron distribution in depth of targets using the ERD method and the method of the target surface research by means of the Auger-spectrometer. The investigations of the dd-, pd-, and d^3He-reactions in the region of ultralow collision energies of 2-8 keV using the Hall accelerator will be perform. Investigation of the dependence of the astrophysical *S*-factors for dd-, pd- and d^3He-reactions on the collision energy at temperatures of deuteride targets in the range from –50 °C to 300 °C will be done.

Our polish colleagues A.Gula (AGH, Krakow), A.Adamczak (INP, Krakow), M. Filipowicz (AGH, Krakow) have prepared their dissertation based on the scientific results which have been obtained in collaboration with JINR working in Dubna.

There was common experimental study of the same JINR-Polish group of the kinetics of the muon catalysed fusion (MCF) in solid hydrogen-deuterium mixtures (H/D) at a temperature of 3 K. The final results of the study are given in [12]. The experiment E742 was carried out on a TRIUMF meson facility in Canada.

Four exposures were performed at different deuterium concentrations in the H/D mixture: c_d = 0.0005, 0.02, 0.15 and 0.75. A simultaneous analysis of the measured time distributions of the 5.5 MeV γ-quanta and the 5.3 MeV conversion muons obtained from nuclear fusion in the *pd*μ molecule allowed to extract the values of MCF chain parameters in the H/D mixture: the fusion partial rates for different nuclear spin states of the *pd*μ molecule, and the *pd*μ molecule formation rate.

The experimental data fitting procedure was conducted in two ways: using solely the analytical formulae describing the kinetics of the MCF processes in the H/D mixture, and the detailed Monte Carlo simulation of the entire experiment. The results obtained by these two methods are consistent with each other and confirm the existence of the Wolfenstein-Gerstein effect.



Main processes of Muon Catalysed Fusion [13]

An analysis procedure for experimental data used theoretical functions generated by Monte Carlo. It was proposed by JINR-Polish team. Applying the classical chi(2) fitting procedure for multiparameter systems is in some cases extremely difficult due to a lack of an analytical expression for the theoretical functions describing the system,

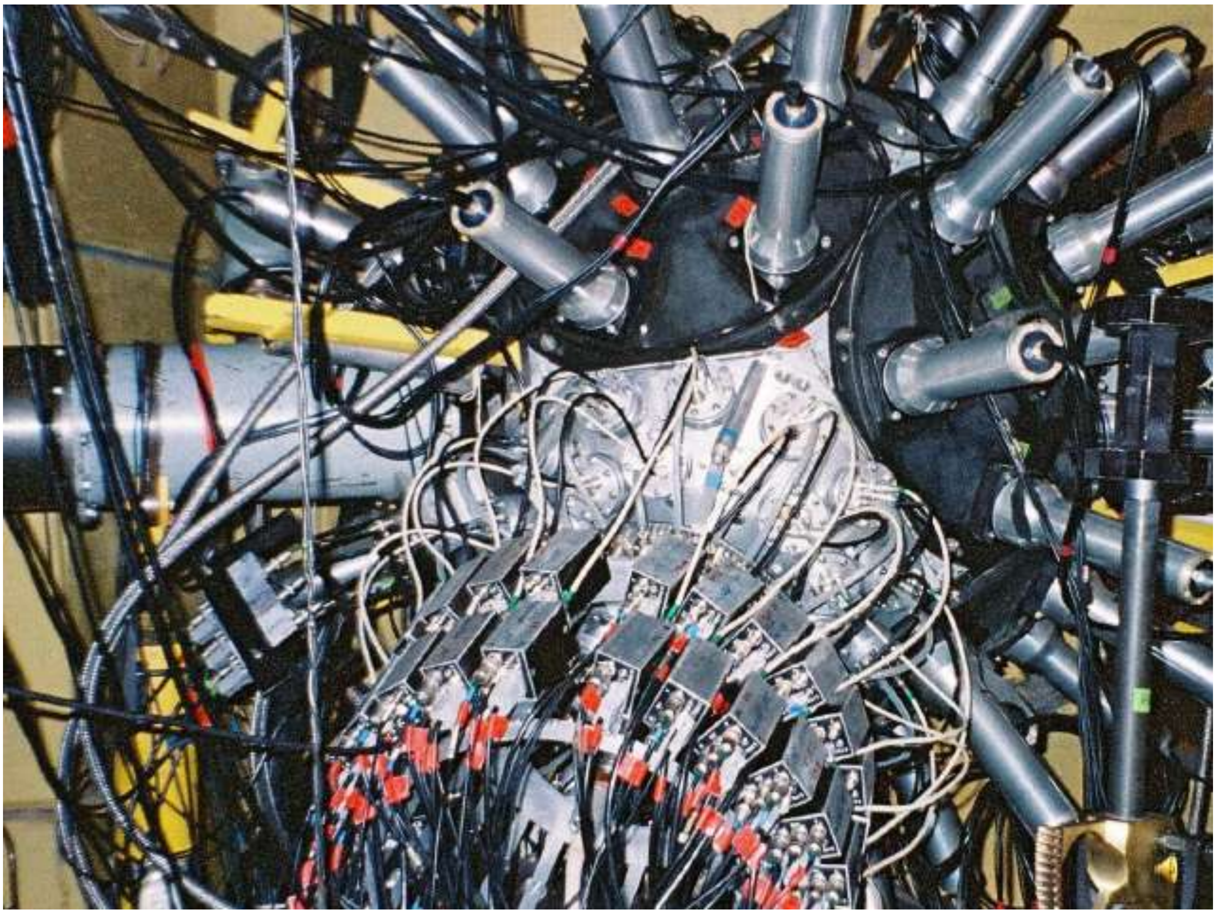
The proposed algorithm is based on the least square method using a grid of Monte Carlo generated functions each corresponding to definite values of the minimization parameters. It is used for the E742 experiment (TRIUMF. Vancouver, Canada) data analysis with the aim to extract muonic atom scattering parameters on solid hydrogen [13].

Furthermore the same group presented in [14] the experimental results of μ -atomic and μ -molecular processes induced by negative muons in pure helium and heliumdeuterium mixtures.

The experiment was performed at the Paul Scherrer Institute (Switzerland). The relative intensities of muonic x-ray K series transitions in $(\mu\ ^{3,4}He)^*$ atoms in pure helium as well as in helium-deuterium mixtures were measured. The $d\mu^3He$ radiative decay probabilities for two different helium densities in D_2+He-3 mixture were also determined.

Finally, the q_{1s}(He) probability for a dμ atom formed in an excited state to reach the ground state was measured and compared with theoretical calculations using a simple cascade model.

The **FASA** collaboration includes 3 participants from Poland (there are Protocols of collaboration, studies are supported by the Grant of RFBR and by Grant of Polish Plenipotentiary for the last 12 years) [15-22].



View in FASA 4π-apparatus

The main results obtained up to now are the following:

a) It is proved experimentally that thermal multifragmentation is a new, multi-body decay mode of very hot nuclei.

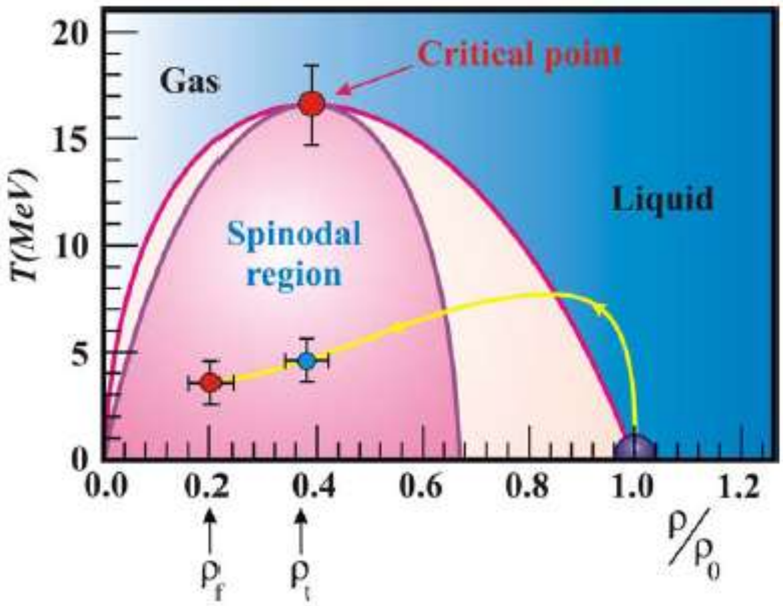
b) This process occurs inside the *spinodal* region of nuclear phase diagram. Characteristic density of the system is 3 times less than normal one; temperature is remarkably smaller than critical one. It is concluded that fragmentation is a result of the first order *liquid – fog* phase transition. This is a specific nuclear phenomenon.

c) The critical temperature for the *liquid – gas* phase transition is measured to be equal to $T_c = (17\pm2)$ MeV.

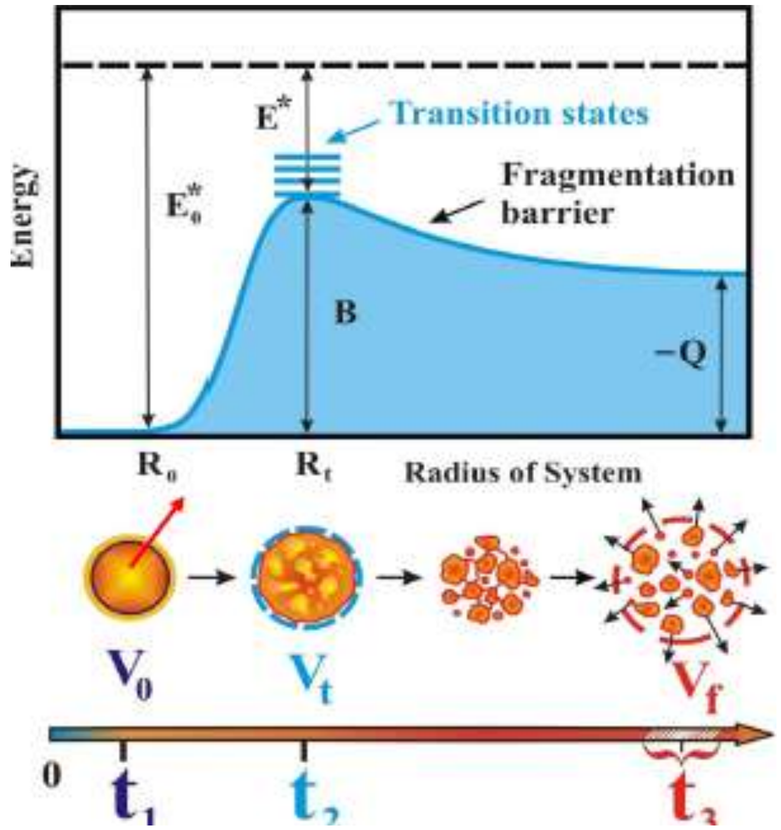
Further studies are planned to investigate in detail the space-time properties of the process. The upgraded 4π -setup FASA on the Nuclotron beam will be used. The fragment-fragment correlations in respect to the relative velocity and relative angle will be measured and analyzed in the frame work of the statistical and alternative models.

The total time scale (in the range 20 – 200 fm/*c*) will be measured. These data will be used to restore the dynamic evolution of hot nuclear system up to the break-up point.

The participation of the following scientists from H. Niewodniczanski Institute of Nuclear Physics (Cracow) was very productive: A. Budzanowski, I. Skwirczynska, W. Karcz, M. Janicki, and B.Chech. Several students from Jagiellonian University will come this year for the practice in FASA group.



Proposed spinodal region for nuclear system. The experimental points were obtained by the FASA collaboration. The arrow line shows the way of the system from the starting point at *T*=0 and ρ_o to the multi-scission point at ρ_f..



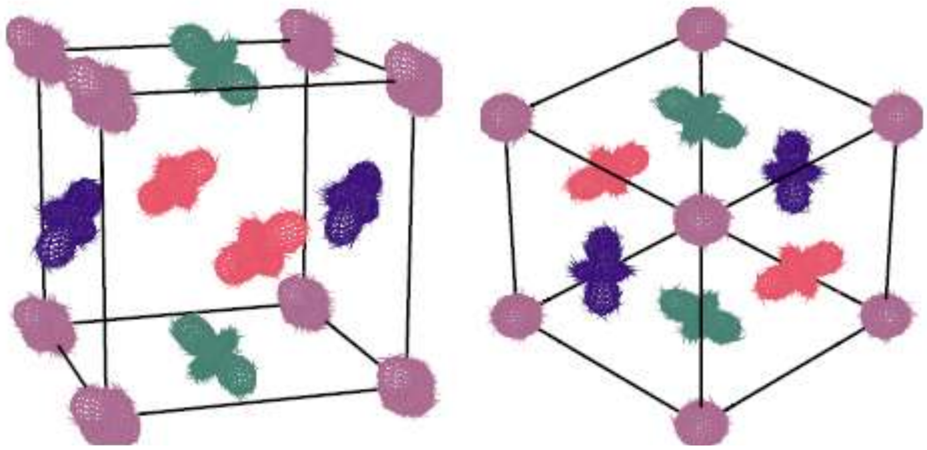
Fragmentation and its time scale – the goals of FASA experiment. Upper: qualitative presentation of the potential energy of the hot nucleus (with excitation energy E_o*) as a function of the system radius. Ground state energy of the system corresponds to E=0, B is the fragmentation barrier, Q is the released energy. Bottom: schematic view of the multifragmentation process.

The technique of **perturbed angular correlations (PAC)** allows one to study the essential characteristics of condensed matter physics methods with the help of nuclear physics. The modern approach to PAC measurement permits one to study changes occurring at hyperfine interaction in external effects on the sample. This is of great interest in developing methods for study of nanomaterial's, magnetic high-temperature superconductors, 2-dimentions materials, surface effects, etc.

In JINR a first PAC-spectrometer was established by the founder of this method Professor A.Hrynkiewicz. On the initiative of Polish scientists Ya.Vavryschuk, Ya.Sazhinsky, M.Budzynski the spectrometer was set up in DLNP in 70^{th} years. Grateful to this spectrometer, important results were obtained which allowed several employees of the University of Lublin to defend their candidate and doctoral dissertations.

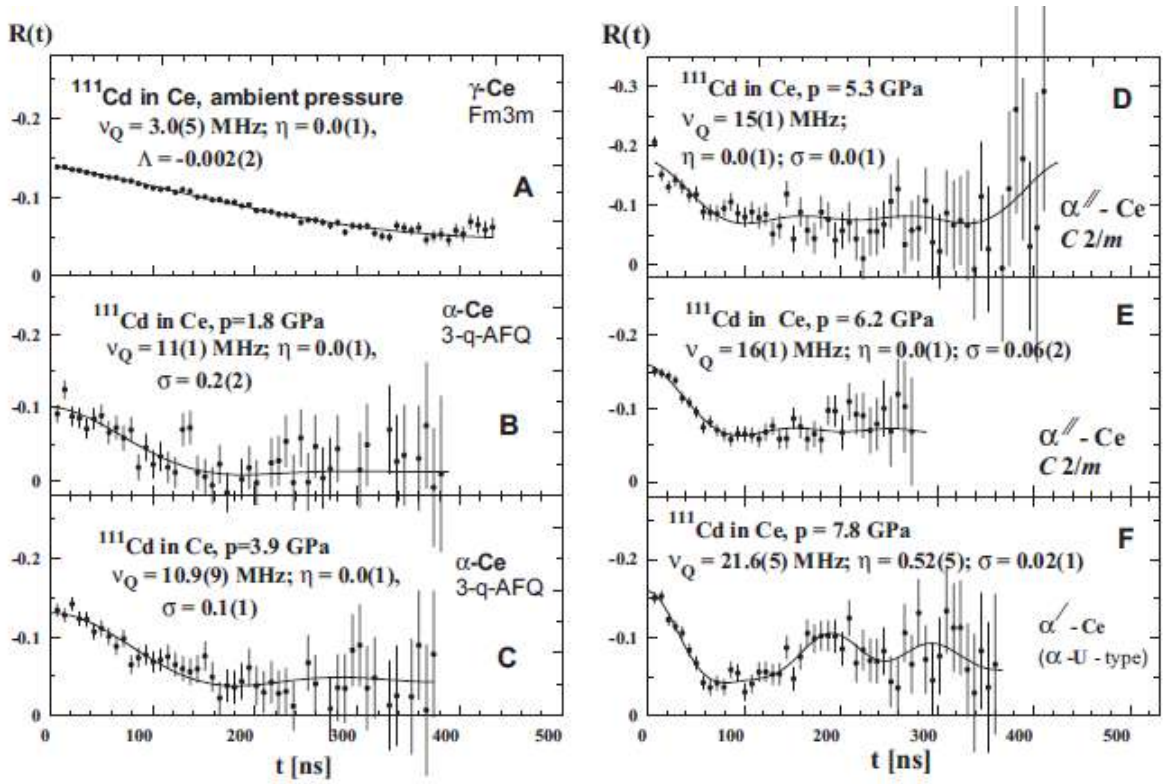
The modern version of the spectrometer has the world's best measurement capabilities: maximum detection efficiency with high accuracy, wide range of external extreme influences on the sample (high pressure to 25 GPa and helium temperature to 4.5K). A good illustration of spectrometer working can be joint project with Poland in 2010 year: **"Investigation of the relationship between the electric field gradient at the impurity nuclei ^{111}Cd and crystal structures of high-pressure phases of cerium metal using the TDPAC method**" [23-27].

Investigation of the phase diagram of cerium (Ce) and the physical properties of allotropic forms of cerium has always evoked great interest. It's has stayed one of the mysterious elements until now. Cerium is analogous to an extremely important element-plutonium. Earlier studies with cerium thought that was first discovered isostructural transition in the solid, which contradicted the theory of phase transitions.



Triple-q antiferroquadrupolar structure of α-Ce. Quadrupoles represent the l=2 valence electron (4f +5d6s^2) charge density distribution. Right panel is the view along the [111] cube diagonal demonstrating the trigonal site symmetry (C_3). From [23]

In above-mentioned project, the method TDPAC for the study of nuclear hyperfine interactions that occur in nuclei ^{111}Cd, embedded in metallic cerium was used. The joint JINR-Polish team has measured the electric field gradient (EFG) as a function of pressure. The measurements were made at pressures up to 8 GPa. It was found that a well-known $\gamma \rightarrow \alpha$ phase transition in cerium is not isostructural.

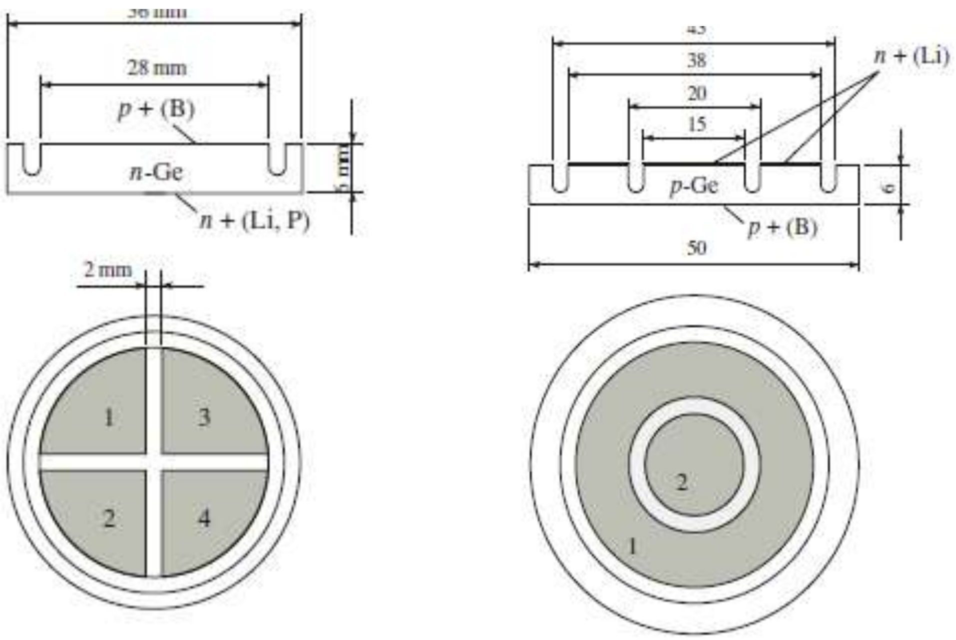


Room-temperature TDPAC spectra of ^{111}Cd in cerium under pressure. In pressure experiments the spectra contain a nonzero background component, which appears because of the scattering within a thin disk of Ce and pressure-transmitting media. The value of the background depends on specific activity of ^{111}Cd probes during measurements. From [23].

The ^{111}Cd probe nuclei in cerium fixed quadrupole electronic components in the α-phase, which is not in γ-cerium. This experiment has showed that the study of hidden quadrupole transitions in compounds with strong electron correlation (high-temperature superconductors, itinerant magnets, etc.) that are in extreme conditions (at low temperatures and high pressures) can be implemented by perturbed gamma-gamma correlations. Therefore, the development of this method and use of such advanced studies is an important fundamental problem of condensed matter physics in the coming decade.

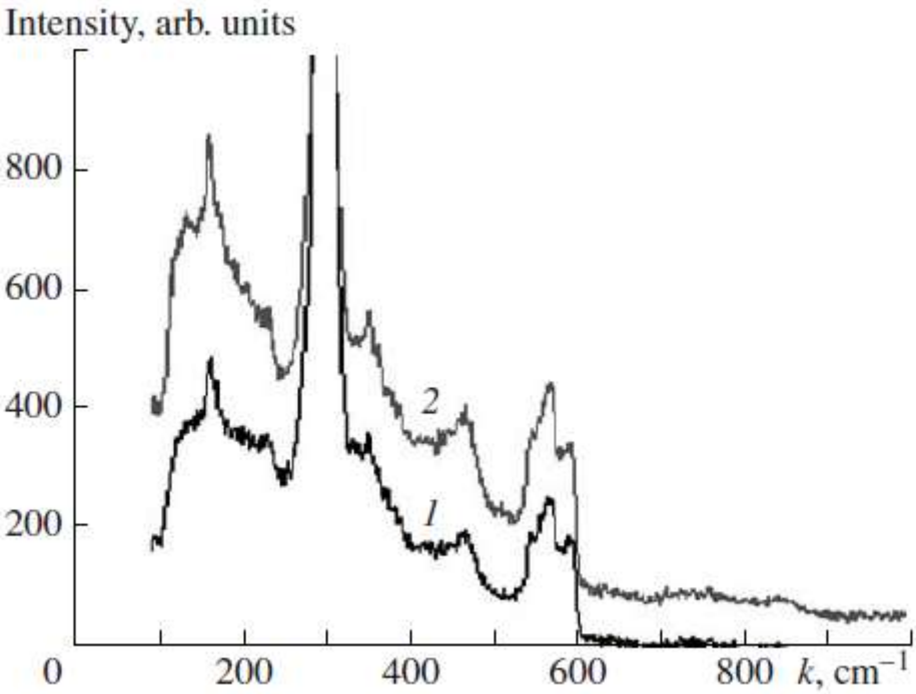
Polish scientists participate in the traditional for the DLNP development of new generation of sophysiticated systems for registration and very accurate detection of partricles and raditations. In particular at DLNP Department of Nuclear Dpectroscopy and Radiochemistry very accurate segmented planar high-purity germanium detectors were developed [28].

Segmentation of *p_n* junction for this system was performed by implantation of boron (for the *n*-type Ge) and mechanical grooving of the Li diffusion layer (for the *p*-type Ge). The electric and spectrometric characteristics of each individual segment and interactions between segments were investigated. The reliability and stability of the detectors were improved by using special passivation of the crystal surfaces.



Structure of the segmented HPGe detector with the implanted p–n junction: (1–4) numbers of detector segments (left). Structure of the segmented HPGe detector with the diffusion p–n junction: (1, 2) numbers of detector segments (right). From [28].

Protective oxide coating of *p–n* junctions in HPGe detectors was also investigated. Owing to this coating, HPGe detectors can be used, in particular, in liquid nitrogen environment without capsulation. A simple and practically feasible method for forming the protective layer by processing detectors in methanol is described. It is shown that this layer reliably protects *p–n* junctions of HPGe detectors from environmental impact. The characteristics of the protective oxide film are investigated using the Raman scattering method [29].



Raman spectra of the HPGe surface (*1*) before and (*2*) after its passivation. From [29]

Applied medical research

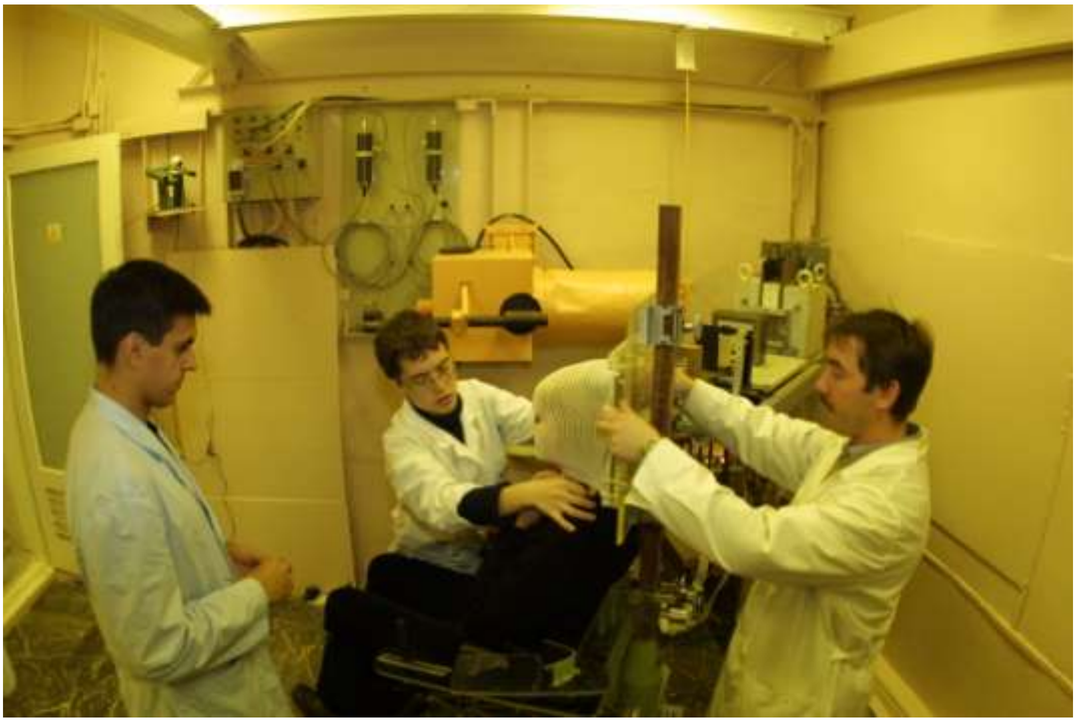
In collaboration with researchers from the Institute of Atomic Energy (Swierk-Otwock, Poland) – Drs M. Zielczynski, M. Gryzinski, and N. Golnik – the works on measurements of the dose fields of secondary particles background produced from the water phantom in the treatment room as well as radiation quality factor were performed (Protocol of collaboration № 3767-2/09) [30-32].

During the proton radiotherapy a patient is alone at the treatment room. This is fully justified in case of X-ray or gamma therapy. In case of proton therapy, the ambient dose equivalent, H*(10), around the patient is expected to be significantly lower.

Dose measurements around the irradiated phantom have been performed in the treatment room for proton therapy using protons of 170-MeV energy. The ratio of the ambient dose equivalent to the maximum absorbed dose in the phantom was equal to 0.05 mSv/Gy at 0.5 m distance from the phantom in the condition similar to real patient irradiation. The effective quality factor of secondary radiation is almost a constant in space around the phantom, its value is equal to 3.5. This value shows a predominating role of neutrons.

The obtained data should be taken into account if the possibility of presence of accompanying person in the treatment room is considered because of some medical or psychological reasons.

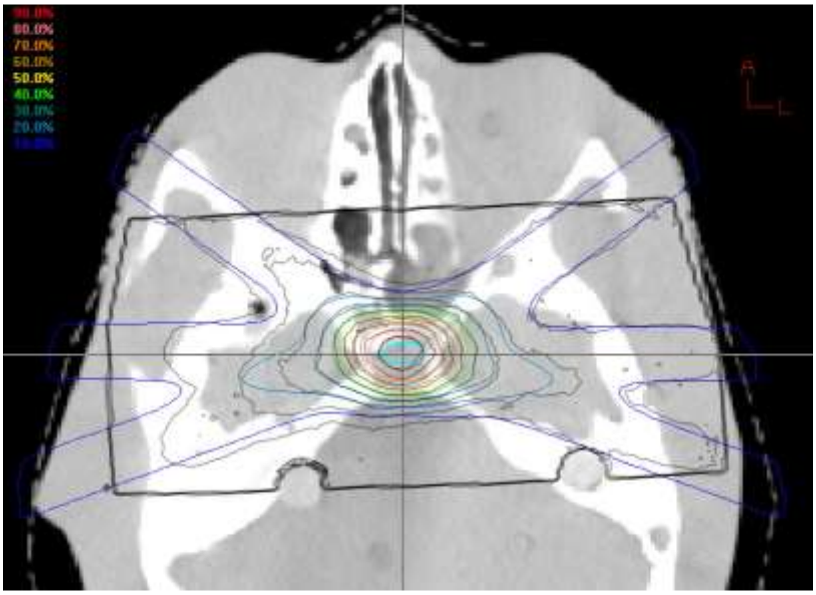
Radiation quality factor at the real session on proton therapy and the contribution of the high LET particles to dosimetric characteristics of the 170 MeV clinical proton beam were experimentally studied using ionization recombination chamber KR-13. The contribution of high LET particles to absorbed dose has been determined.



Young scientists of DLNP are preparing a patient for radiotherapy at the treantment room for the proton therapy in Dubna

The main goal of works with the Great Poland Cancer Centre (Poznan, Poland) is to check the technique of 3D conformal proton radiotherapy which is carried out in the Medico-Technical Complex (MTC) of JINR [30].

Several experiments have been done at the proton beam using radiochromic films and heterogeneous “Alderson phantom” simulating human anatomy to verify all technological stages of preparation and procedure of the patients’ therapeutic irradiation. The obtained



results testified high accuracy of matching of the maximum dose distribution with the irradiated target (Fig. below).

Estimated dose distribution in irradiation of the “Alderson phantom” from six directions, with the distribution measured with radiochromic film imposed on it. Matching in the region of high isodoses (50-100 %) is within few mm.

During 2010 a set of dosimetric experiments verifying the developed technique of bolus manufacturing of the machinable wax was made. The results of the experiments have proved the high accuracy of the proton beam dose formation with this technique that allowed us to use it in the treatment sessions carried out in the MTC. The research was started in 2004.

Since that time 4 student diploma works and 1 PhD were made based on the results of this work. The results were presented at different international conferences.

Nowadays very good results have been obtained in cooperation between the Cyclotron Section of Institute of Nuclear Physics Polish Academy of Science, managed by Mr. J. Sulikowski, and the DLNP group of Department of New Accelerators, managed by Dr. G.A.Karamysheva and Dr. I.V.Amirkhanov, the chief of the Devision of Computation Physics of LIT JINR.

The isochronous cyclotron AIC144 was used for eye melanoma proton radiotherapy of the first 9 patients. The successful irradinaton of those parinets was conducted between February and April 2011. This irradiation mode was calculated by means of the program complex developed by I.N.Kiyan (DLNP) uder direction of the Dr. R.Taraszkiewicz and Dr.

I.V.Amirkhanov. Due to the high accuracy of the calculations, the proton beam was successfully accelerated without any experimental iteration, empirical fine tuning of corrections of frequesncy of the RF-generator, and demonstrated very good stablility.

In Aptril 2011 the new, modified version of the code was installed on the AIC144 server and the optimal operation mode parameters were restored by I.V.Kiyan. The optimization of the isochronous magnetic field, the proton phase motion and the first harmonic of working magnetic field were also conducted. As important result, the extraction coefficient of the proton beam increased twice as compared with previous value.

The Scientific Deputy director of INP PAS, Pawel Oklo, has expressed his deep satisfaction on the results achieved during the cooperation in his letter to director of DLNP (see copy of the letter at smutz). He also strongly hopes that this fruitful collaboration will be continued and developed in the future.

Ricent common publications of the DLNP carried out with Polish scientists

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Collaboration of Flerov Laboratory of Nuclear Reactions with the Republic of Poland

Polish physicists take an active part in heavy ion investigations carried out at FLNR in JINR, in particular at the ACCULINNA fragment separator with the use of radioactive beams.

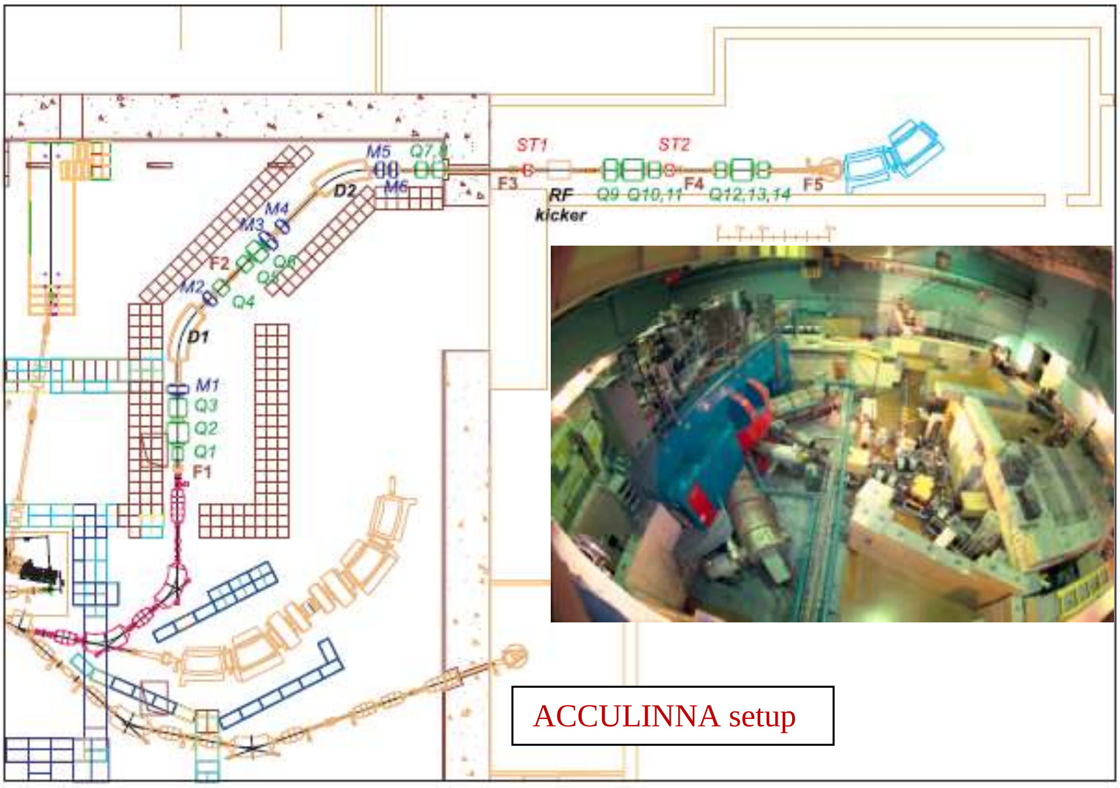
The ACCULINNA fragment separator is in operation since 1996. The achromatic ion-optical system is optimized for focusing fragments emerging from the production target, placed in the object plane, to the achromatic focal plane. The desired secondary beams are separated according to their magnetic rigidity with the aid of magnets. A wedge-shaped degrader installed in the intermediate dispersive focal plane helps to remove background from the selected beam [1-6].

The separator upgrade (in 2000) caused an extension of the beam line. This was implemented through the use of two doublets and one triplet formed by magnetic quadrupole lensses. The target intended for secondary beams, detectors and electronics were moved beyond the 2-m concrete wall of the U- 400M hall. As a result, the radiation background around the reaction chamber was reduced drastically. An important acquiring was the possibility to work with neutron detectors in the proximity of the reaction chamber.

In 2001 a tritium target (gas or liquid) was designed and manufactured to be used in the study of hydrogen and helium isotopes lying beyond the neutron drip line. A 4.0/0.4-mm thick tritium target cell (gas/liquid) was equipped with 10 μm stainless steel entrance and exit windows hermetically welded to the cell body. The diameter of target active area is 22 or 10 mm for the gas or liquid case, respectively.

Radioactive beams are available now. High intensity (1-5 pμA) primary beams of ^{7}Li, ^{11}B, ^{13}C, ^{15}N and ^{18}O with energies 32 ÷ 50 MeV/nucleon delivered by the U- 400M cyclotron were used for the secondary beams production. Triton beam (1 pnA) with energy 19.3 MeV/n was delivered directly by the U-400M cyclotron. The separator was used in this case for focusing a high quality beam on the physical target.

The typical two dimensional plots of particles identification in the ^{11}B (33 MeV/nucleon) + ^{9}Be reaction are available, the separator was tuned for ^{6}He production, the TOF measurement was provided by pair of plastic scintillators (BC404 type, 0,5 mm thick) coupled with the photomultiplier tubes XP-2252 (two units per each plastic).



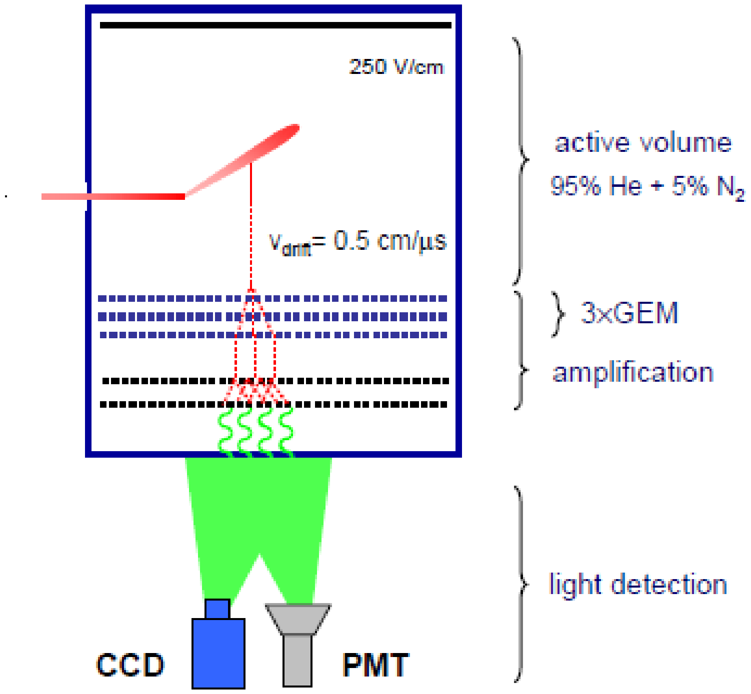
The FLNP experimental hall of U400M accelerator (given in picture insertion). The current ACCULINNA separator is located in the lower left corner of the picture and the ACCULINNA-2 separator is planned to be installed in the upper part of the hall.

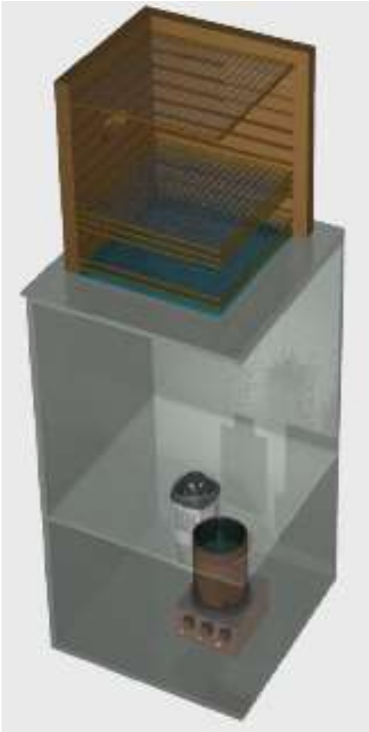
The electronics equipment and reactor chamber in the focal plate of the ACCULINNA setup

The group working at the ACCULINNA facility includes three Polish scientists (V.T.Vrublevski, L.P.Standylo and K.A.Sliva), two of which are successfully finishing the work on their candidate of sciences theses.

In the scope of the investigations of the structure of nuclei near and beyond the nucleon drip line the Flerov Laboratory of Nuclear Reactions maintains extensive and fruitful cooperation with the group of **M.Pfutzner** using their unique ***Optical Time-Projection Chamber*** developed at Warsaw University.

In the series of experiments carried out at FLNR with the beams of radioactive ions the proton decay of the ^{8}Li, ^{13}O, and ^{12}N nuclei was observed and new data on the structure of the exotic nuclei ^{8}He and ^{27}S were obtained.



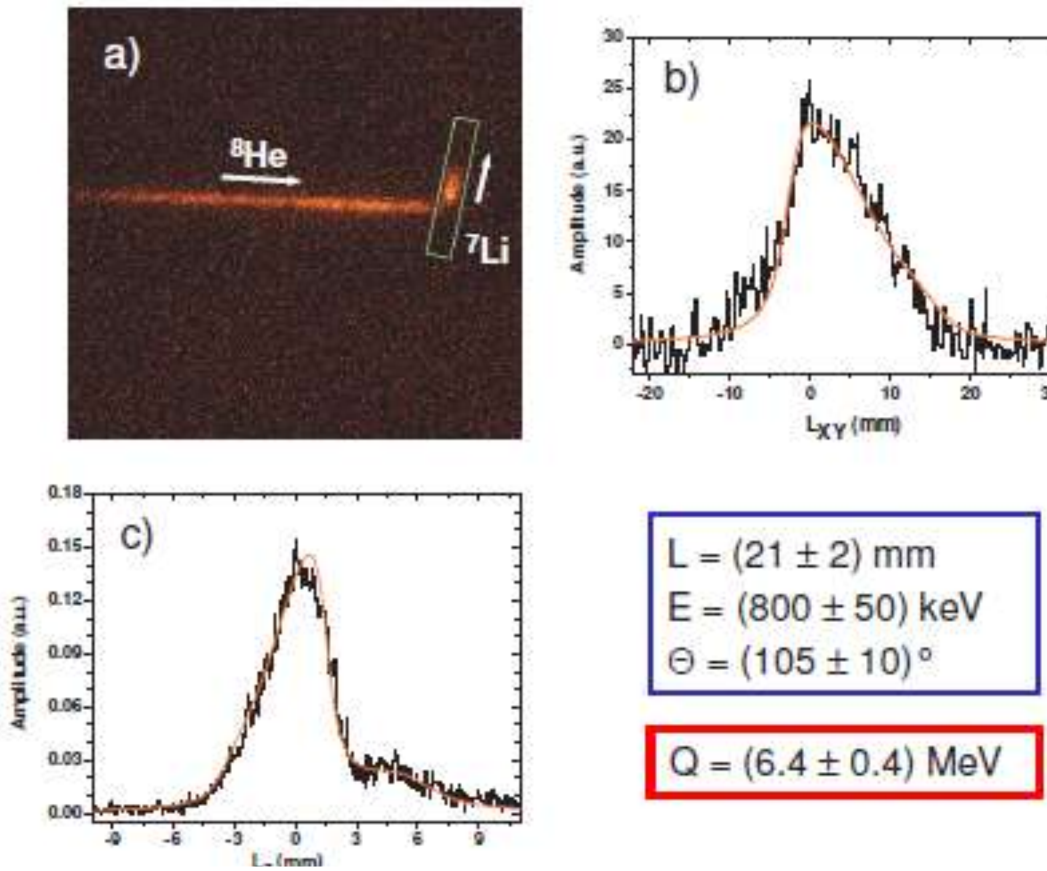


Schematic view (left) of the Optical Time Projection Chamber. From [7,8]

The results of these experiments underlie the candidate of sciences thesis defended at Warsaw University, and two more theses are under preparation now. Cooperation with Warsaw University also includes development of a similar optical chamber for FLNR.

In particular, the feasibility of the β-decay study of ^{8}He with the use of the time projection chamber has been investigated. It is shown that β-delayed neutron emission branches of ^{8}He can be identified by registration of tracks of the recoiling ^{7}Li nuclei.

Evidence for neutron emission from a highly excited ^{8}Li state was obtained. New possibilities to study β-decay of ^{8}He into the α+t+n continuum are demonstrated by showing that the full kinematics of such events can be reconstructed. Observed correlations will provide new insight into the mechanism of this decay process [7].

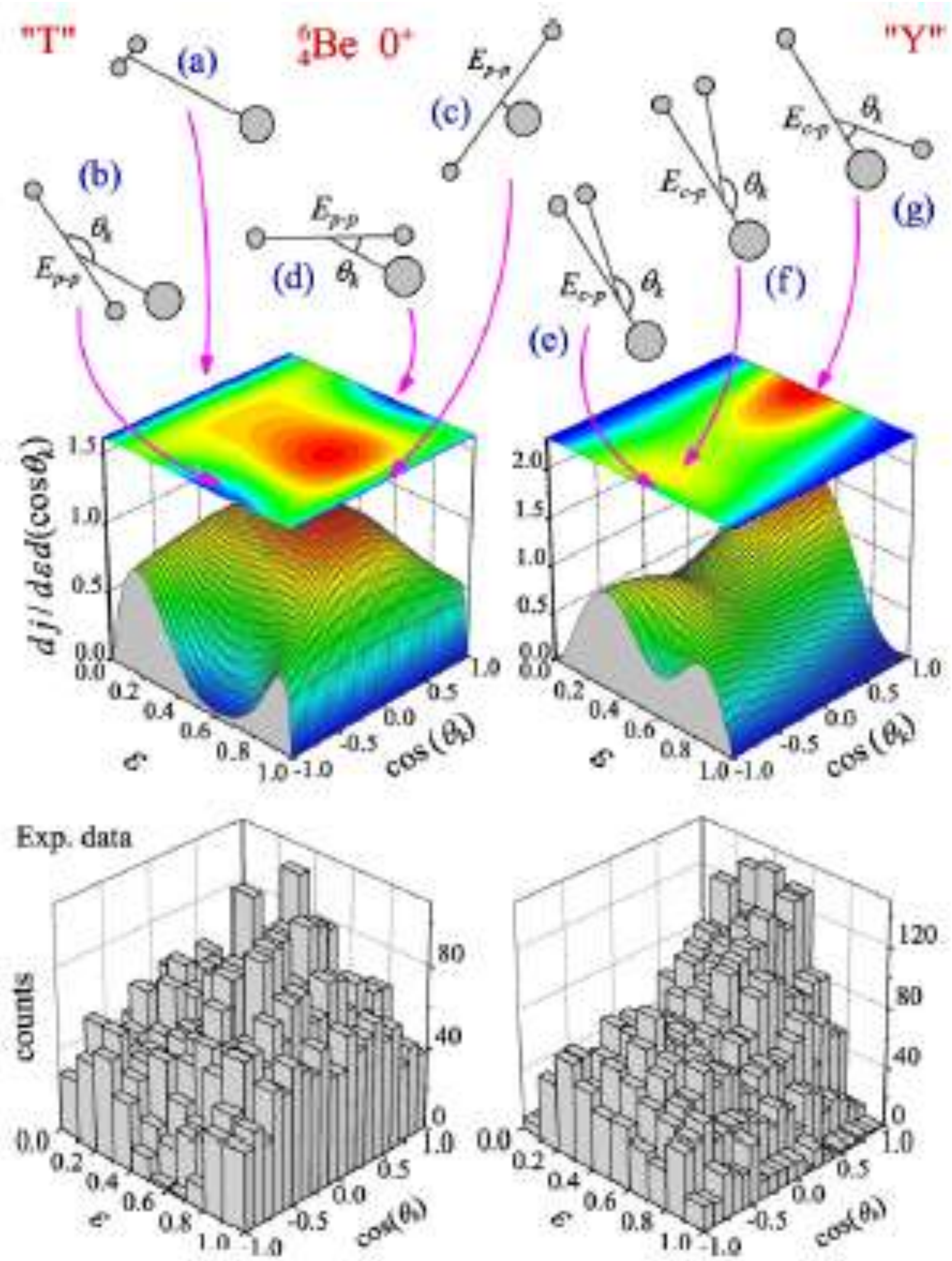


An example event of a beta-delayed neutron decay of ^{8}He. Panel (a) shows the image recorded by the CCD camera during a 1.2 s exposure. Plot (b) shows the distribution of the intensity of the CCD signal integrated along the ^{7}Li track. Plot (c) shows the time variation of the light intensity recorded by the PMT for the decay event. Time intervals were converted into the distance by using the drift velocity. Solid lines in plots (b) and (c) show the results of the fitting procedure. The obtained range, energy and emission angle of ^{7}Li recoil as well as the deduced decay Q-value are given in the bottom right part of the figure. From [7].

The complete correlation pictures of 2-proton decays for ^{6}Be and ^{45}Fe are measured (and ^{6}Be also calculated) for the first time in joint JINR-Polish collaboration. These correlations have common features as well as differences. High statistics data in ^{6}Be allows for a discussion of the fine details of correlation patterns. The ^{45}Fe data, despite the quite low statistics, indicate that certain improvements in the theoretical treatment of the process are necessary. Features of the three-body correlations are well reproduced by the quantum-mechanical model in a broad range of times and masses: from typical nuclear times ($\sim 10^{-20}$ s in ^{6}Be) to typical radioactivity times (some milliseconds in ^{45}Fe).

The quasiclassical expression can provide a reasonable approximation for certain distributions. However, it fails if one considers these distributions in fine details or if one looks on the whole correlation picture. Certain aspects of correlations can be highly sensitive to the fine details of nuclear structure. This makes the complete correlation studies of 2-proton emitters a promising tool for the structure research.

Theoretical models are further constrained when consistent description of the widths and correlations are made simultaneously. This provides a cross check of the extracted structure information which has never been accessible before [12,13].



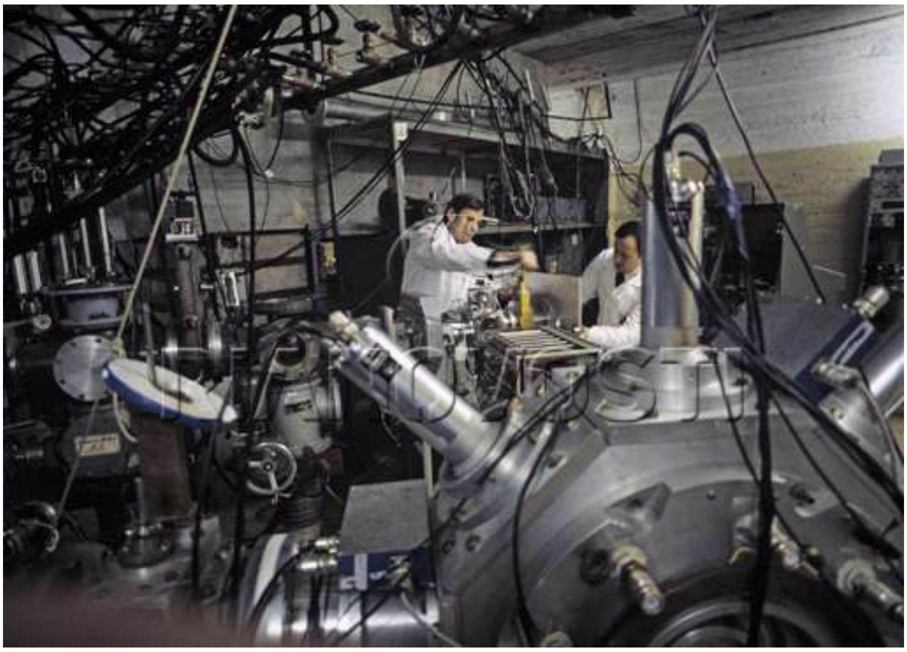
Complete correlation picture for ^{6}Be ground state decay, presented in “T” and “Y” Jacobi systems (left and right columns, respectively).
The upper row is theory, lower – experimental data [12,13].

In January 2011, a new beam diagnostics system developed at JINR FLNR was tested in the heavy ion beam of the Warsaw cyclotron. In the nearest future a similar system will be developed for the Heavy Ion Laboratory (HIL) in Warsaw.

Heavy ion cyclotron of Heavy Ion Laboratory in Warsaw

The HIL operates ***a heavy-ion cyclotron,*** which is unique not only in Poland, but also in Central Europe. The accelerator provides beams of gaseous elements and of elements available from gaseous compounds ranging from boron to argon with energies from 2 to 10MeV/amu. Since the commissioning of the cyclotron (1994) yearly beam-on-target time was steadily growing, reaching about 3000 hours/year.

In 2010, within the Polish programme, a new facility for irradiation of biological samples was developed at JINR and tested at the ACCULINNA separator. This work is a continuation of the biological investigations carried out by the Polish staff members of JINR at the GENOME facility.



JINR GENOME facility for irradiatioin of biological samples by ion beams

The GENOME installation was assembled at JINR for irradiating biological objects at heavy ion beams of the Laboratory of Nuclear Reactions. The main aim of this work was to study the mechanisms underlying the differences in the biological effectiveness of radiation in a wide linear-energy-transfer (LET) range.

Polish scientists successfully work [14-18] at COMBAS wide-aperture kinematic separator of FLNR which was assembled and put into operation in 1996-97. It may be used efficiently both as a high resolution spectrometer for study of nuclear reaction mechanisms and as a separator in "in-flight" mode for synthesis and for study of short-living nuclei near the border line of nuclear stability.

COMBAS wide-aperture kinematic separator of FLNR

Development of cooperation between the Flerov Laboratory of Nuclear Reactions and Polish institutes appears quite fruitful and promising in the applied investigations, especially in studying radiation hardness of structural reactor materials bombarded by heavy ions (Institute of Atomic Energy, Swierk) and effect of heavy ions on nanostructured materials like carbon nanotubes and metal and semiconductor nanoclusters in oxide matrices (Nicolaus Copernicus University in Toruń; Maria Curie-Skłodowska University, Lublin).

The major results of the cooperation between FLNR and Polish institutes in the field of accelerators are the construction and upgrading of the U200P cyclotron at HIL (Warsaw) and development of the U144 cyclotron at INP (Krakow). Currently conducted joint activities involve development of equipment for cyclotrons, including monitoring control, and power supply systems, and heavy ion source studies.

Recent common Polish-FLNP publications:

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2. G.M. Ter-Akopian, A.S. Fomichev, M.S. Golovkov, L.V. Grigorenko, S.A. Krupko, Yu.Ts. Oganessian, A.M. Rodin, S.I. Sidorchuk, R.S. Slepnev, S.V. Stepantsov, **R. Wolski**, A.A. Korsheninnikov, E.Yu. Nikolskii, P. Roussel-Chomaz, W. Mittig, V.A. Kuzmin, B.G. Novatskii, D.N. Stepanov. ***"Neutron excess nuclei of hydrogen and helium at ACCULINNA***" The European Physical Journal - Special Topics, ISSN: 1951-6355, Vol.150, N1, p.61-66, 2007.
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5. M.S. Golovkov, L.V. Grigorenko, A.S. Fomichev, S.A. Krupko, Yu.Ts. Oganessian, A.M. Rodin, S.I. Sidorchuk, R.S. Slepnev, S.V. Stepantsov, G.M. Ter-Akopian, **R. Wolski**, M.G. Itkis, A.S. Denikin, A.A. Bogatchev, N.A. Kondratiev, E.M. Kozulin, A.A. Korsheninnikov, E.Yu. Nikolskii, P. Roussel-Chomaz, W. Mittig, R. Palit, V. Bouchat, V. Kinnard, T. Materna, F. Hanappe, O. Dorvaux, L. Stuttge, C. Angulo, V. Lapoux, R. Raabe, L. Nalpas, A.A. Yukhimchuk, V.V. Perevozchikov, Yu.I. Vinogradov, S.K. Grishechkin, S.V. Zlatoustovskiy, ***"Correlation studies of the ^{5}H spectrum"*** Phys. Rev. C, Vol.72, N064612, p.1-17, 2005
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Sidorchuk, R.S. Slepnev, S.V. Stepantsov G.M. Ter-Akopian, ***“Imaging the decay of*** ^{8}***He”*** Acta. Phys.Pol. B 41 (2010) 449.

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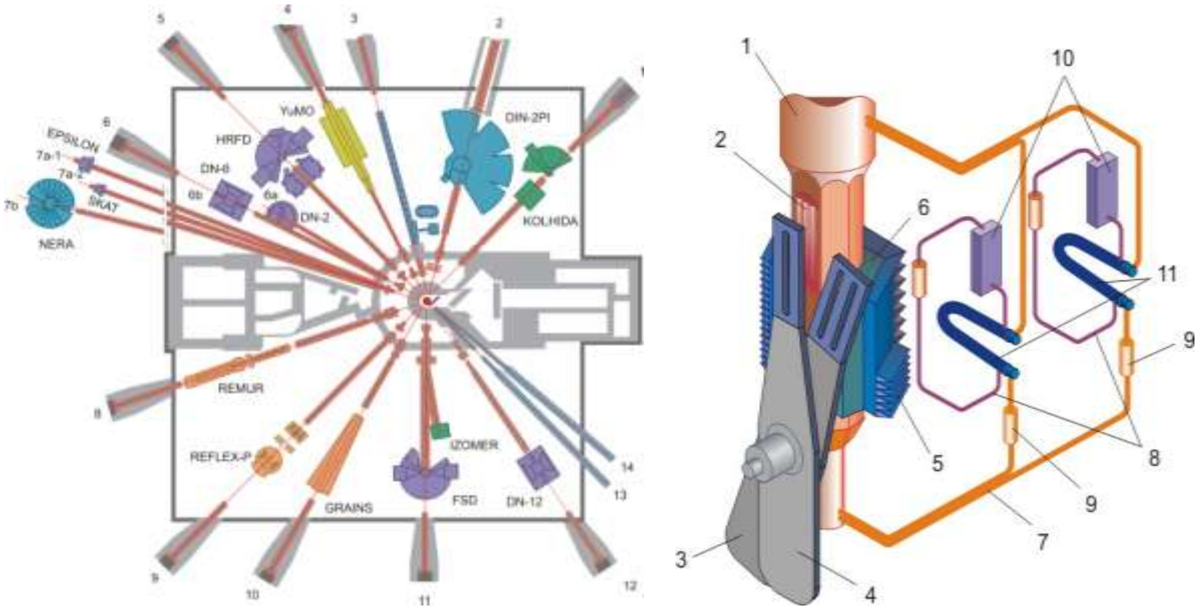
Collaboration on Frank Laboratory of Neutron Physics with the Poland Republic

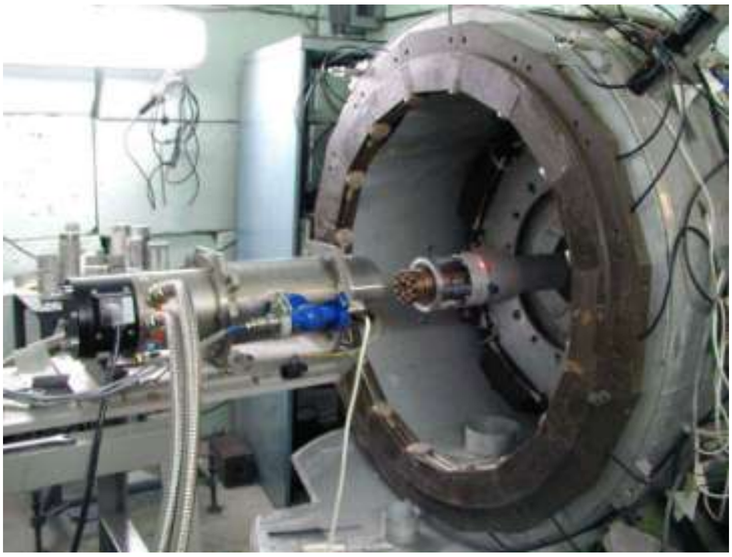
In 1960 a principally new source of neutrons - the IBR fast pulsed reactor of periodic operation - was created at FLNP under the leadership of Prof. D.I.Blokhintsev. The birth of this reactor gave rise to a new direction in the development of research neutron sources.

Today the IBR-2M reactor of Frank Laboratory of Neutron Physics (FLNP) is the most powerful research neutron sources on the territory of Eastern Europe, which besides is a centre of joint utilization and is available for carrying out a wide range of scientific investigations of the Polish scientists and scientists of other countries within the framework of the FLNP JINR user policy.



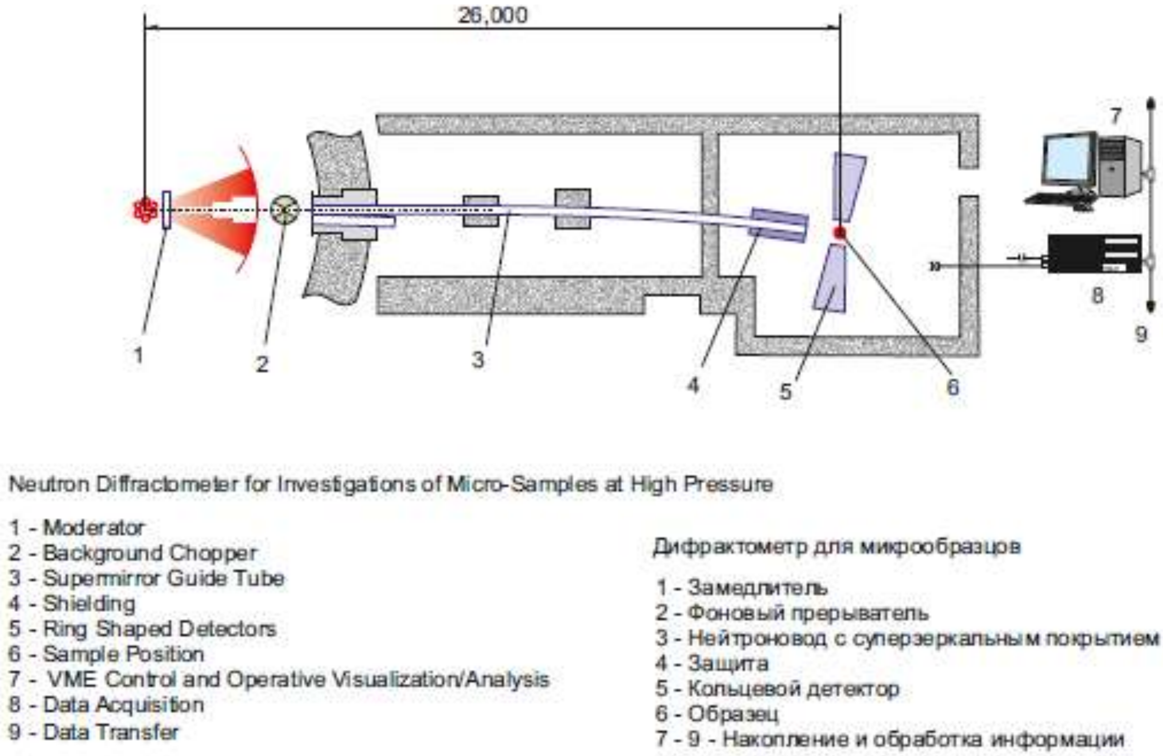
Beams of IBR-2M (left) and its drawing (right)

A number of neutron spectrometers of the IBR-2M reactor has technical characteristic surpassing those of the prototypes in other European centres (for example, inverted geometry time-of-flight spectrometer NERA-PR is for high resolution determination of structural parameters and phonon modes behavior in reactor materials, neutron diffractometer DN-12 is for micro samples investigation – wide range of simultaneously varied thermodynamic parameters, temperature 10-300 K and pressure 0–10 GPa), which makes the use of the spectrometers complex of the IBR-2M reactor really attractive for collaborative research.



DN-12 diffractometer of FLNP

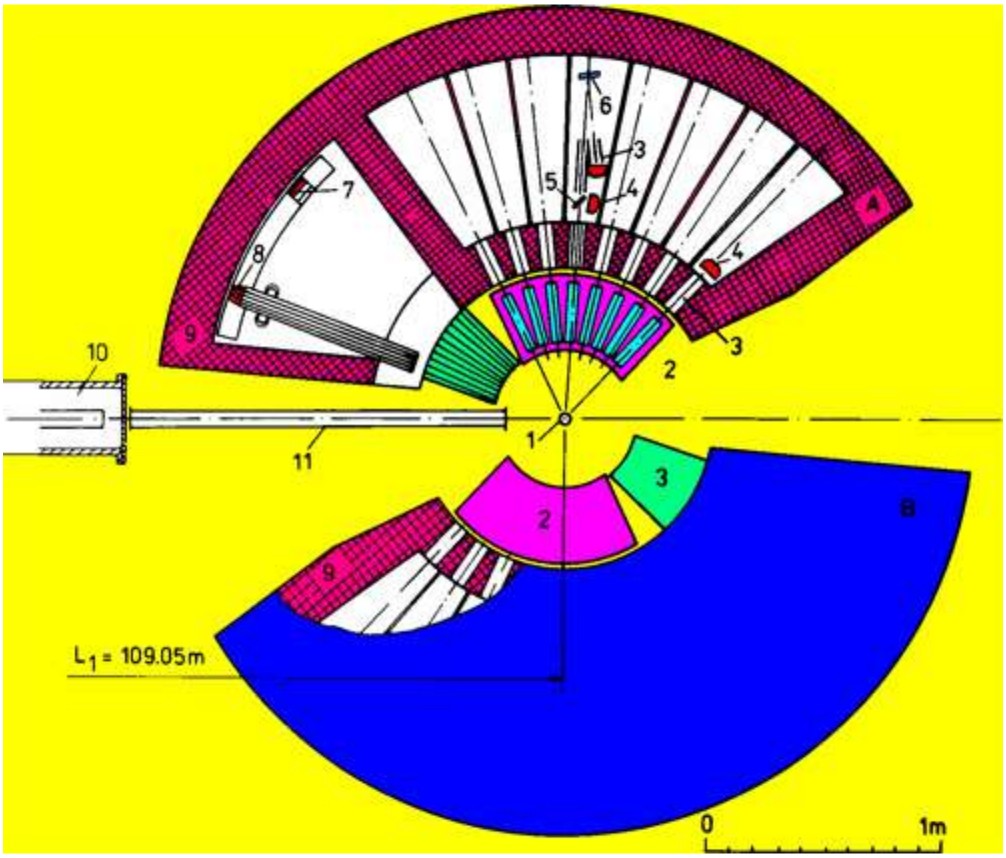
Apart from taking part at scientific research programs and modernization of the existing spectrometers of IBR-2M, the Polish scientists showing great interest in creating a new diffractometer DN-6, which will allow to significantly broaden the scope of structural investigation in conditions of extreme pressure up to record-breaking range of 0-50 GPa.



The scheme of future DN-6 spectrometer

Annual practical work organized together with the JINR University Center on the basis of FLNP and the IBR-2M reactor, opens to Polish students a lot of doors regarding learning the methods of neutron diffraction studies and their practical application for scientific problem solving. This encourages young Polish scientists to carry out neutron diffraction studies on the basis of the IBR-2M reactor.

Polish scientists has made a significant contribution to neutron scattering methods improvement, to performing neutron diffraction studies in the field of condensed matter physics, materials science, chemistry and interdisciplinary research fields. The inverse geometry spectrometer of inelastic scattering NERA-PR, created by the joint efforts of Polish and Russian scientists with support of the JINR member states, situated at the site of the IBR-2M reactor, is now active and successfully employed.



Th inverse geometry spectrometer of inelastic scattering NERA-PR of FLNP.

1 – sample; 2 - Be-filters; 3 – collimators; 4 - He3 detectors (INS and QNS); 5 - PG analysers (INS); 6 - single crystal analysers (QNS); 7 - detectors for high intensity diffraction; 8 - detectors for high resolution diffraction; 9 - spectrometer shielding; 10 - Ni-coated mirror neutron guide in a vacuum tube; 11 - vacuum neutron guide

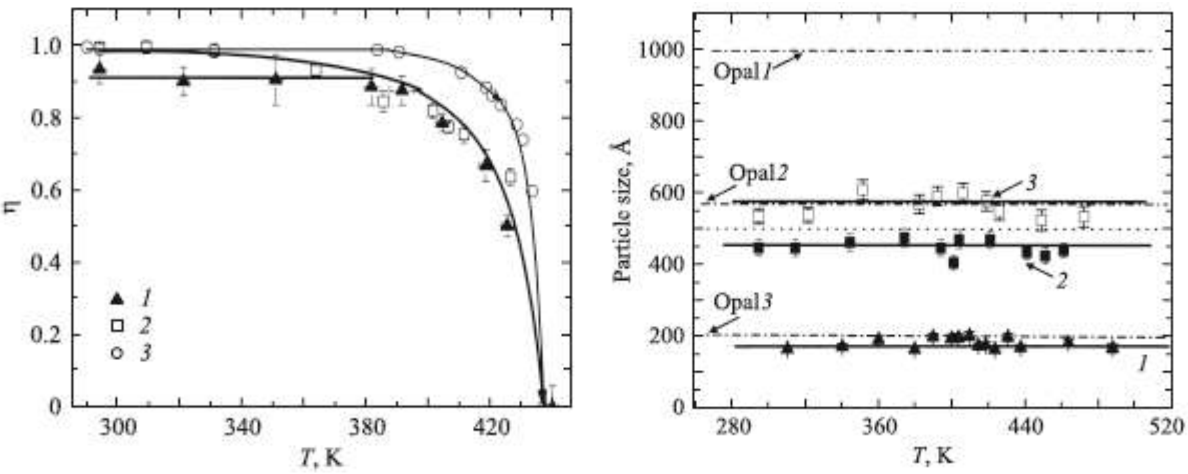
At present, in the **Department of Neutron Investigations of Condensed Matter** (DNICM) of FLNP there is a special group NERA-PR, predominantly populated by the Polish JINR staff members. They are Raewska Aldona (member of small-angle scattering group), Prof. Natkaniec Ireneusz (leader of the inelastic scattering group), Pawlukojc Andrzej, Nowak Dorota Marta, and Zalewski Slawomip (members of the group).

Within the framework of the JINR theme ***“Investigations of Nanosystems and Novel Materials by Neutron Scattering Methods”*** a close scientific cooperation with a range of Polish research groups from universities and research institutes of Warsaw, Poznan, Krakow, Wroclaw and Lublin takes place. The joint scientific framework is represented by the following subjects:

- Investigations of structural phase transformations, dynamics and physical properties of molecular crystal and pyridine-based organic ferroelectrics in a wide range of thermodynamic parameters (temperature, pressure) by means of neutron scattering and other complementary methods (diffraction, inelastic scattering), X-ray diffraction, Nuclear magnetic resonance (NMR) spectroscopy, Differential Thermal Analysis (DTA) and analysis of the inductive capacity.
- Investigation of molecular dynamics of polymers doped with fullerenes and nanocluster carbon materials.
- Quantum-chemical calculations of structure and dynamics of molecular crystal and complexes.
- Development of the IBR-2M reactor spectrometers complex and neutron diffraction methods.

According to the results of collaboration with Polish scientists at the DNICM taking place the past three years, there was published over 20 science papers and over 20 reports and test-bench were made and shown, respectively [1-21].

In particular the temperature dependences of the order parameter η(T) for sodium nitrite $NaNO_2$ embedded in porous glasses with average pore diameters of 320 and 20 nm, as well as in artificial opals, have been investigated in [4].



The temperature dependences of the order parameter η(T) (left) and nanclaser size (right) for $NaNO_2$ embedded in porous glasses with different average pore diameters of 320 and 20 nm. From [4].

It has been demonstrated that the dependence η(T) for sodium nitrite in the porous glass almost coincides with that for the bulk material, whereas this dependence for $NaNO_2$ in opals differs substantially from that observed in the bulk material and from those previously determined for sodium nitrite in porous glasses with average pore diameters of 3 and 7 nm. It has been revealed that the dependence of the order parameter for sodium nitrite in opals exhibits a temperature hysteresis (approximately equal to 8 K). The temperature dependence η(T) has been described using a simple model, which takes into account the nanopore diameter distribution existing in artificial opals.

Within the framework of fulfilment of the seven-year plan of strategic JINR development during 2010-2016 according to the direction “Condensed Matter Physics”, it is planned to maintain collaboration with Polish scientists in a way of investigations on the above-mentioned scientific fields, as well as the modernization of the IBR-2M spectrometers complex.

Beside the spectrometers the IBR-2M reactor dispose of radioanalytical complex equipped with the pneumatic transportation system REGATA and three hot cells for conducting **neutron activation analysis** (NAA) and radiation research. Nondestructive multielement instrumental neutron activation analysis was recognized as a primary analytical technique in 2007, as it allows one to get high-precision and high-sensitivity results.

Running REGATA (left) and chemical laboratory for conducting neutron activation analysis (right)

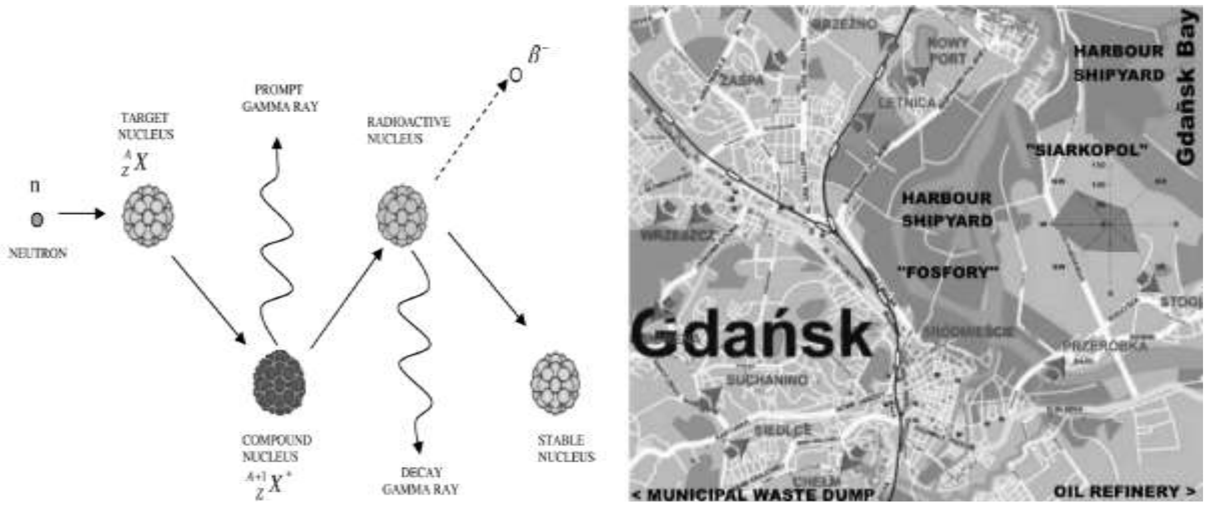
NAA is widely used in life sciences (ecological, geological, biological and medical investigations) and materials science (new materials: ultrapure, nano, etc.). A distinctive characteristic feature of irradiating channels of pneumatic transportation system REGATA is low temperature at the irradiation position (not higher than 60-70ºC as compared to 300-400 ºC of the heat reactors), which allows to analyze biological matrix without causing them any damage.

The fact that there are two irradiating channels – first with a cadmium shield for epithermal and fast neutrons irradiation, and the second – for a full neutron spectrum irradiation – makes it possible to optimize irradiation regimes for samples of various elemental chemical composition. Unique functional scope of neutron activation analysis of the IBR-2 (IBR-2M) reactor, high-qualified specialists of the NAA department, long work experience in ecological research at the world level within the framework of IAEA and EU projects make collaboration with the FLNP JINR NAA Department attractive to Polish specialists.

This department has always attracted attention of Polish scientists by its manifold scientific orientation. At their time there was working such noble scientists as Prof. A. Navrotsky, Prof. S. Sterlinsky, R. Lippert, E. Gatsek, V. Kantor, Z. Bobrovsky, L. Starostin and many others. Traditional bonds with the Institute of Chemistry and Radiology in Warsaw (Prof. R. Dybchinsky). Collaboration with the University n. a. Adam Mitskevich in Poznan (Prof. Z. Bloschiak), with the Technical University in Gdansk (Prof. Y. Namesnik and Prof. M. Bizyuk) is quite successful. They send their students for conducting practical work at our sites, as well as the Jagiellonian University in Krakov, University in Schechina and the Opol University of Technology do it.

Poland was the first JINR member state to support the work of the department with grants of the Authorized Polish Republic Representative as part of the Program of utilization of Polish financial contrinution for the intended purpose in JINR. Member of the Academy of Sciences A. Hrynckevich took a personal interest in biomonitoring of atmospheric pollution in Poland. These works are being carried out at the department since 1998 in collaboration with Polish staff members of the Institute of Botany in Krakov (Prof. Kristina Grodzinska, Prof. Barbara Godzik, Grazhina Zarek-Lukashevski and others) and are being translated to the European atmospheric pollution map, issued by the UNECE ICP Vegetation. Such attention of the authority has significantly contributed to biomonitoring popularization in Poland and involvement of undergraduate and postgraduate students of various Polish institutions [22-28].

With participation of Polish scientists in 2005 a large-scale international project of 5th UN Framework Program (program “Copernicus”) “Occupational monitoring for health and safety of people employed for the phosphorous fertilizer production in Russian, Poland, Romania, Denmark and Netherlands”, initiated by the FLNP JINR NAA Department, was successfully accomplished. Polish scientists collected samples at the manufacturing facility in Gdansk with the hands of the factory workers, postgraduate students and students of the Chemistry Department of the Technical University in Gdansk [22].



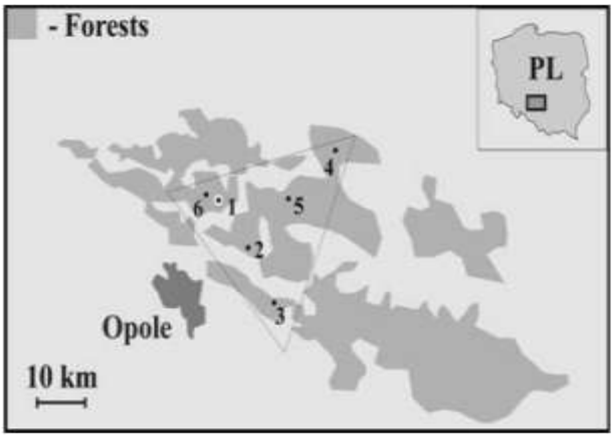
Schematic diagram illustrating the successions of events for a typical (n,γ) reaction (left). Sampling sites for biomonitoring of air pollution in Gdansk (right). From [22].

Analytical research was carried out at the FLNP JINR NAA Department in Dubna, while the results provided the ground for four diploma papers of Polish students and two PhD theses defended at the Technical University in Gdansk.

By invitation of Prof. R. Dybchinsky (the Institute of Chemistry and Radiology in Warsaw) the NAA Department participated in the international comparative check of new reference material designed in Warsaw, and got high results in the context of the analysis quality.

During 2005-2006 within the framework of two grants of Plenipotentiary Representative of Polish Republic, JINR collaborated with the Institute of Botany PAS and it led to productive cooperation with the Centre for Ecological Research PAS (Doc. Pietr Benkovsky) and the University of Warsaw (Prof. E. Bulska) on realization of the project "Evaluation of negative effects of poisonous agents on aquatic ecosystem and man, case study of Mariana lakes in Poland and the Rybinsk Reservoir in Central Russia with nuclear physics analysis methods".

Currently, within the framework of the sci-tech collaboration between the Russian Federation and the Republic of Poland (2008-2010) program (the Opol University of Technology, department of biotechnology and molecular biology, Prof. Maria Watslavek) the project ***"Contamination of woodlands of the south-western region of Poland with radionuclides and heavy metals"*** is fulfilled [23-28].



Tested area with sampling sites. Neighbouring localities:1-Kosowce; 2-Rzędów; 3-Staniszcze W.; 4-Olesno; 5-Szumirad; 6-Zagwiździe. Left From [23]. Location of the study area in Poland and sampling sites of moss (Pleurozium schreberi) in the Niepołomice Forest. From [24-26].

In 2010 these investigations have been supported by the collaboration between JINR and the Republic of Poland program. The continuation of these works is planned for the forthcoming year 2011. In summer of 2010 a collection of ecosamples has been gathered at the south region of Poland for the purpose of conducting the NAA at the IBR-2M reactor. Poland is planning to send a postgraduate student of the Opol University of Technology in the third quarter of 2011.

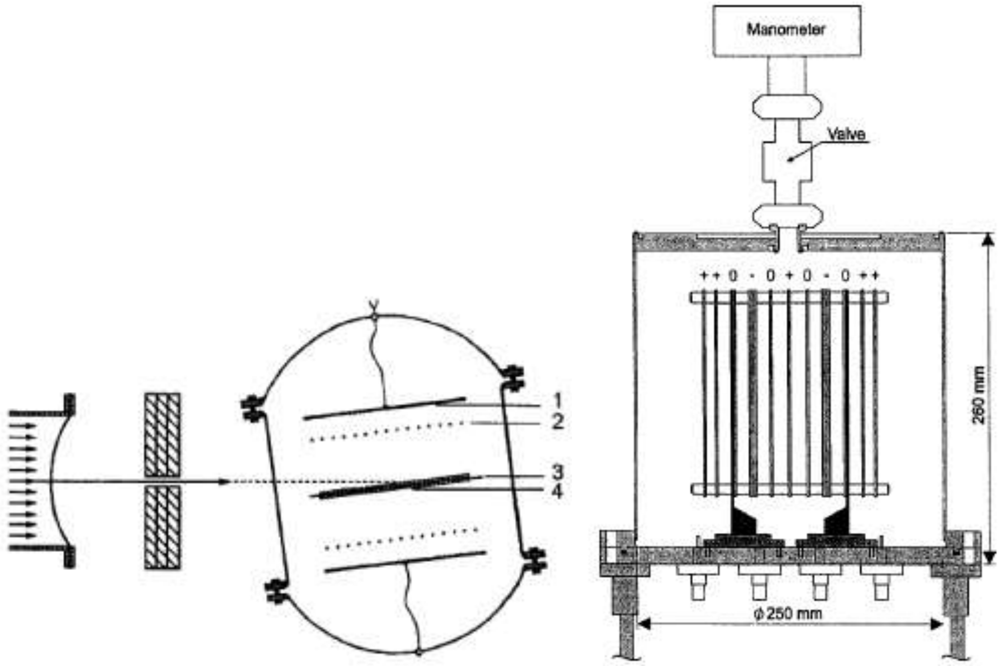
Apart from the IBR-2M reactor, the Frank Laboratory of Neutron Physics uses two instruments for neutron nuclear physics investigations – IREN facility and electrostatic generator EG-5.

The **IREN** apparatus (left, middle) and the **EG-5** electrostatic generator (right)

The IREN facility is an Intense REsonance Neutron source based on electron linac with a very narrow pulse width (~ 100 nsec) serving as an instrument for neutron physics experiments in the field of resolved resonance, requiring high energy resolution. EG-5 is a supplement to IREN, it provides neutrons with energy up to several MeV. EG-5 is an instrument of a high resolution of accelerating particles energy, used for the analysis of thin surface layers of solids.

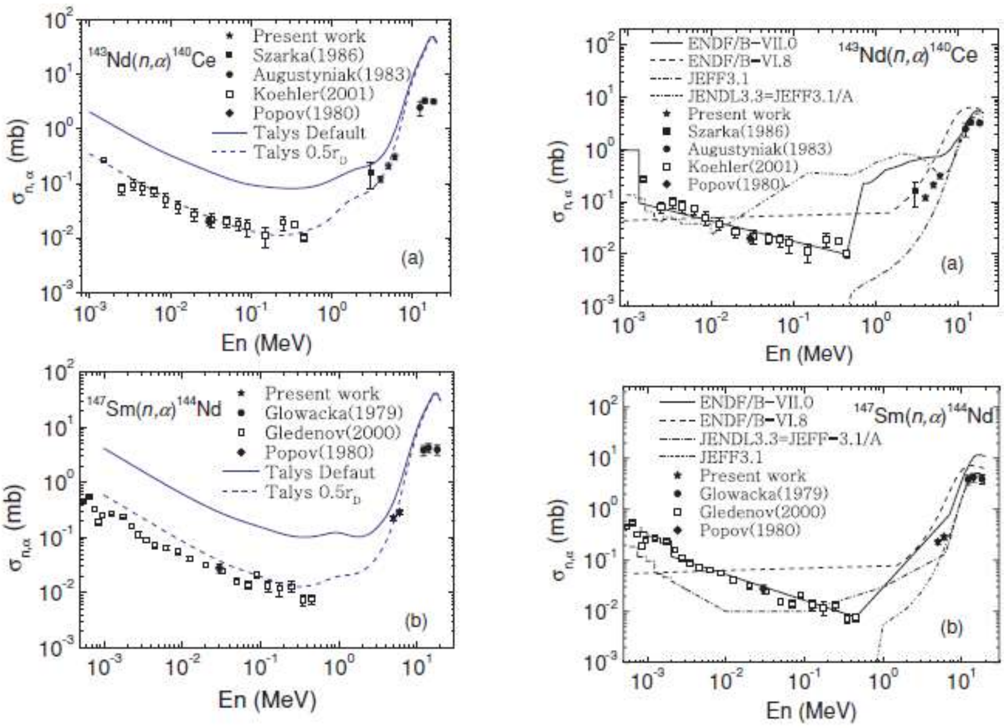
The FLNP Department of Nuclear Physics maintains long-lasting collaboration with Polish universities and research centres - particularly, with the Department of Nuclear Physics of the Lodz University and with the Institute of Physics of the Marie Curie-Sklodowska University. According to scientific results obtained through the joint research, Polish scientists have successfully defended around 10 master's and doctoral theses. Many times these works gained the first place in the best paper contests organized at FLNP and won runner-s-up prizes and, again, gained the first place in similar events at JINR. By virtue of this collaboration with JINR our Polish colleagues performed a lot of successful work at the FLNP JINR instruments (IBR-30, IBR-2, EG-5), as well as actively participated in joint measurement at nuclear facilities of other research centres of Russia. These opportunities are very important for Poland who does not possess any of the neutron sources of this level. At their turn, Poland contributes greatly into this collaboration by creating new detectors and improving their own facilities.

Currently, a close collaboration with Prof. Yu. Andjeevsky and Dr. P. Shalansky of the London University takes place. A productive collaboration in the context of fast neutron reactions research is in progress, the results constantly being published in the world's leading journals of physics. Moreover, these results will be used in the doctoral thesis of P. Shalansky. Poland has significantly contributed to creation of instruments required for work at IREN and EG-5 [29-41].



Scheme of the double parallel plate ionization chamber (left) where 1 − collector; 2 − grid; 3 − target backing; 4 – target. scheme of the four-part compensated ionization chamber (right). From [34].

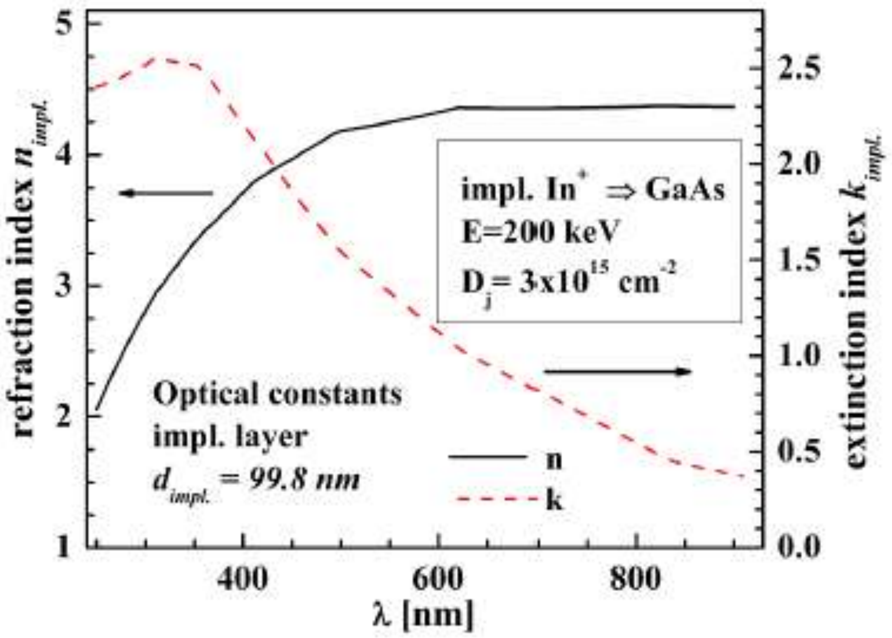
In particular in [38], cross sections and forward/backward ratios in the laboratory reference system were measured for the ^{143}Nd(n,α)^{140}Ce reaction at 4.0, 5.0, and 6.0 MeV and for the ^{147}Sm(n,α)^{144}Nd reaction at 5.0 and 6.0 MeV.



Results of paper [38] are compared with previous measurements, evaluations, and model calculations.

A twin-gridded ionization chamber and large-area back-to-back $^{143}Nd_2O_3$ samples and $^{147}Sm_2O_3$ samples were employed. Experiments were performed at the 4.5 MV Van de Graaff accelerator of Peking University, China. Fast neutrons were produced through the $^2H(d,n)^3He$ reaction by using a deuterium gas target. A small ^{238}U fission chamber was employed for absolute neutron flux determination, and a BF_3 long counter was used as the neutron flux monitor. Present experimental data are compared with previous measurements, evaluations, and model calculations.

In Lublin (IP MCSU) there is an implantator serving for modification of the surface layers of solids. In Dubna (JINR) analytical methods of nuclear physics at the ground of the accelerator EG-5 find application. They help in research related to the subsurface layers of solids [42-46]. These investigations were systematically financed by Plenipotentiary Representative of Poland in JINR. In particular the Influence of Ion Implantation on the Optical Parameters — Refraction and Extinction Coefficients of the Oxygen-Enriched Layers Covering GaAs Implanted with Indium Ions was studied in JINR-Polish collaboration in [44].



The spectra of refraction and extinction coefficients determined for GaAs layer implanted with indium [44].

As results of joint scientific work of Polish scientists and the scientific personnel of the FLNP Department of Nuclear Physics show, during the past three years there was published about 20 scientific papers and presented over 20 reports.

According to the 7-year plan of strategic development of JINR during 2010-2016 in the direction of “Neutron nuclear physics” it is planned to carry out collaborate research with Polish scientists within the framework of the above-listed fields.

Ricent publications of FLNP-Polish cooperation

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45. **Krzyzanowska H.**, Kobzev A.P., Zuk J., Kulik M. **"*Hydrogen and Oxygen Concentration Analysis of Porous Silicon*"**. Journal of non-crystalline solids. Vol. 354, issues 35-39, (2008) 4367 – 4374.
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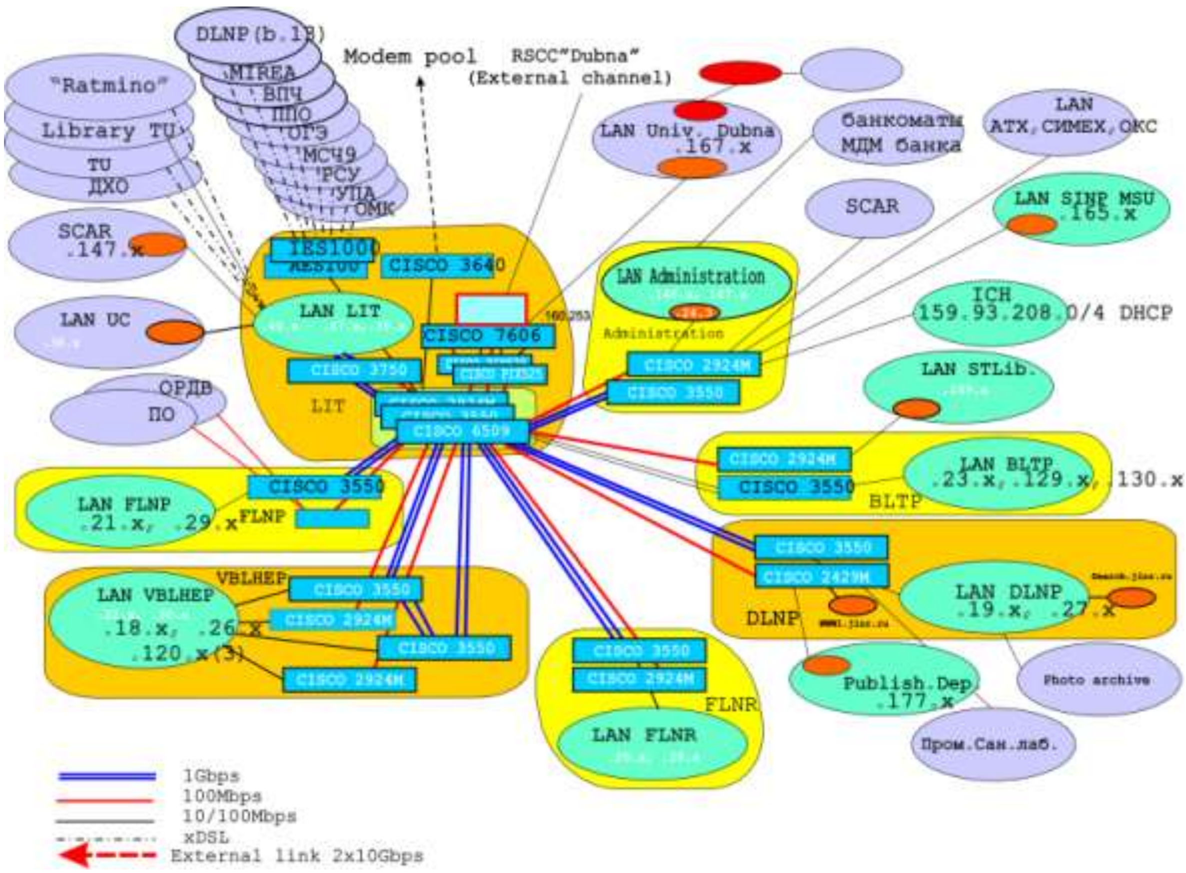
Collaboration of Laboratory of Information Technology with Republic of Poland

For more than ten years, the **Laboratory of Information Technology** (LIT) of JINR is actively involved in the study, use and development of advanced Grid technologies.

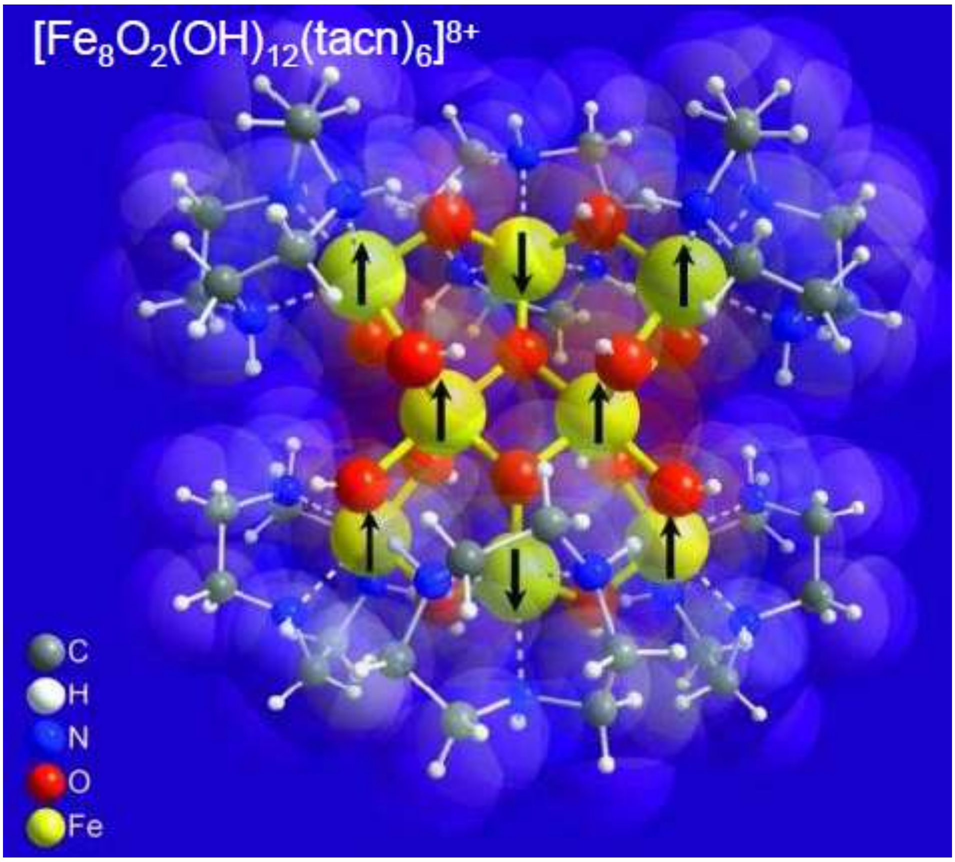
The most important result of this work was the creation of Grid-infrastructure in the JINR that provides the complete range of Grid services. Created JINR Grid site (T2_RU_JINR-LCG2) is fully integrated into the global (world-wide) WLCG/EGEE/EGI infrastructure. The resources of this site are successfully used in the global infrastructure, and on indicators of the reliability, the T2_RU_JINR-LCG2 site is ***one of the best*** Tier2 site in the WLCG/EGEE/EGI infrastructure.



Scheme of JINR Grid infrastructure

A great contribution is made by LIT staff members in testing and development of Grid middleware, the development of Grid-monitoring systems and organizing support for different virtual organizations. *The only specialized conference* in Russia devoted to Grid technologies and distributed computing is organized and traditionally held in JINR. In the field of Grid the JINR actively collaborates with many foreign and Russian research centers and special attention is paid to cooperation with the JINR Member States.

The fruitful Poland-JINR Grid-based cooperation is under active construction now. In particular, Prof. Grzegorz Musial (Faculty of Physics, Adam Mickiewicz University, Poznan) was an invited member of GRID2010 advisory commettee and gave plenary talk on the conference "Towards molecular spitronics: Numerical-Renormalization-Group method and distributed computing to study transport properties of single-molecule magnets new possibilities within SPINLAB project".

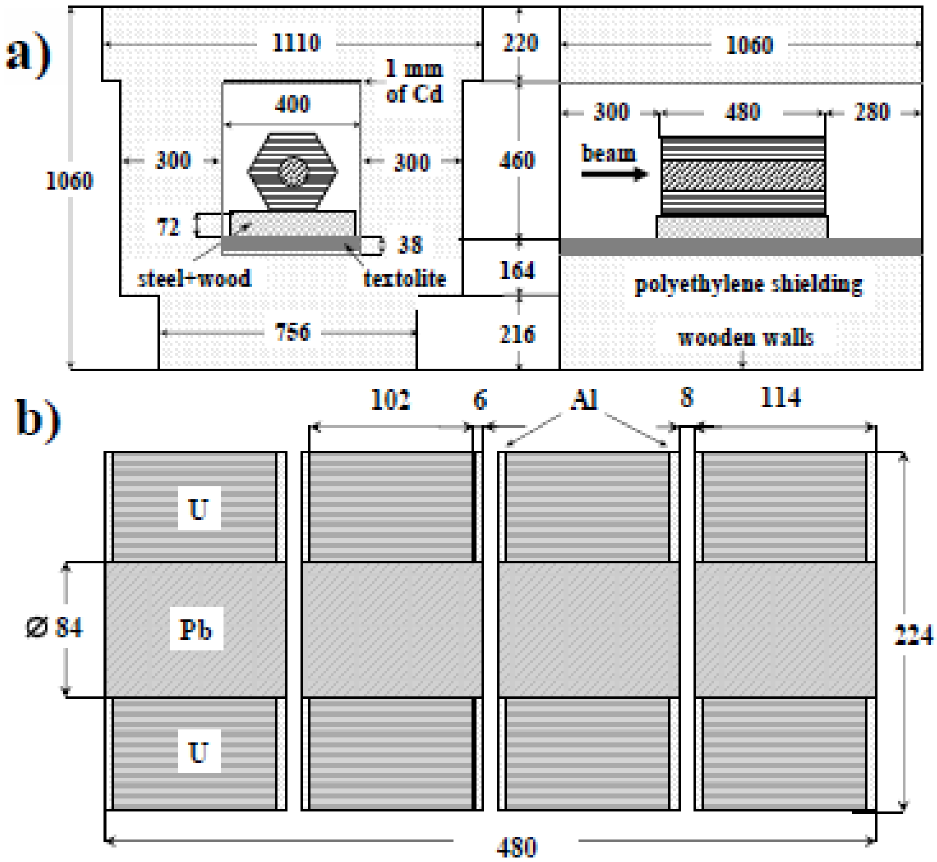


Example of Molecular spintronics. From Musial's talk.

This Fourth International Conference "Distributed Computing and Grid-technologies in Science and Education" was organized by the Laboratory of Information Technologies of the Joint Institute for Nuclear Research on 28 June-3 July, 2010 in Dubna.

In many research institutes all over the world are actively studied aspects of electronuclear energy production in the subcritical reactors. Feasibility of application of natural/depleted uranium or thorium without the use of U-235, as well as utilization of spent of fuel elements of atomic power plants is demonstrated based on analysis of results of known experiments, numerical and theoretical works [1].

The joint Polish-JINR investigations were performed within the framework of the scientific programme called “Investigations of physical aspect of electronuclear energy generation and atomic reactors radioactive waste transmutation using high energy beams of synchrophasotron/nuclotron JINR (Dubna)”- project “Energy plus Transmutation”. The scientific description of the project, including main ideas, history, former experiments’ description and results, uranium fission calorimeter description, experimental methodology used for neutron and proton field properties’ investigation (activation and Solid State Nuclear Track Detectors (SSNTD), nuclear emulsions, He-3 detectors etc.), can be found in publications of the “Energy plus Transmutation” collaboration [2-7]. The geometry the U/Pb assembly is presented in the work [2-7].

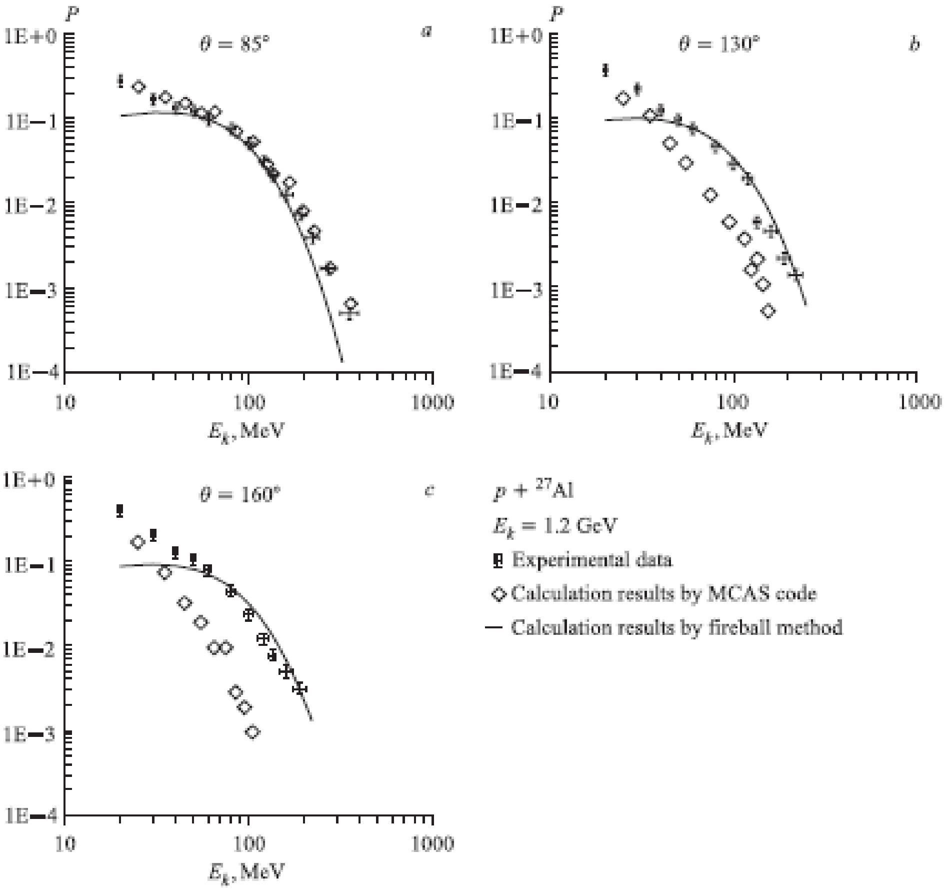


The layout of the “Energy plus Transmutation” setup: a) the front cross-section and the side cross section, b) the side cross-section of the target-blanket only [2-7].

In 2010 the calculations results of U/Pb assembly using 4 GeV deuteron beam and a concept of the Thermal Breeder Reactor [TBR] base on thorium fuel were performed by LIT-Polish collaboration [8-9].

There is continuation of the simulation works on the subject at LIT under leadership of Prof. A.Polanski, former deputy director of the LIT (during 2000-2003). The following results were obtrained during last 5 years.

Cascade Evaporation Model and Quantum Molecular Dynamic (QMD) model for the description of the spallation reaction was development at LIT [10]. The experimental data on energy and multiplicity distributions of protons and momentum spectra of deuterons emitted in the reactions of pions and protons of energy ranging from 2.5 to 200 GeV with several nuclei are compared to the calculations based upon two different model approaches: CASCADE code and the tube-fireball (TF) model [11]. The results of this confrontation are discussed within the framework of the intranuclear interaction mechanism assumed.

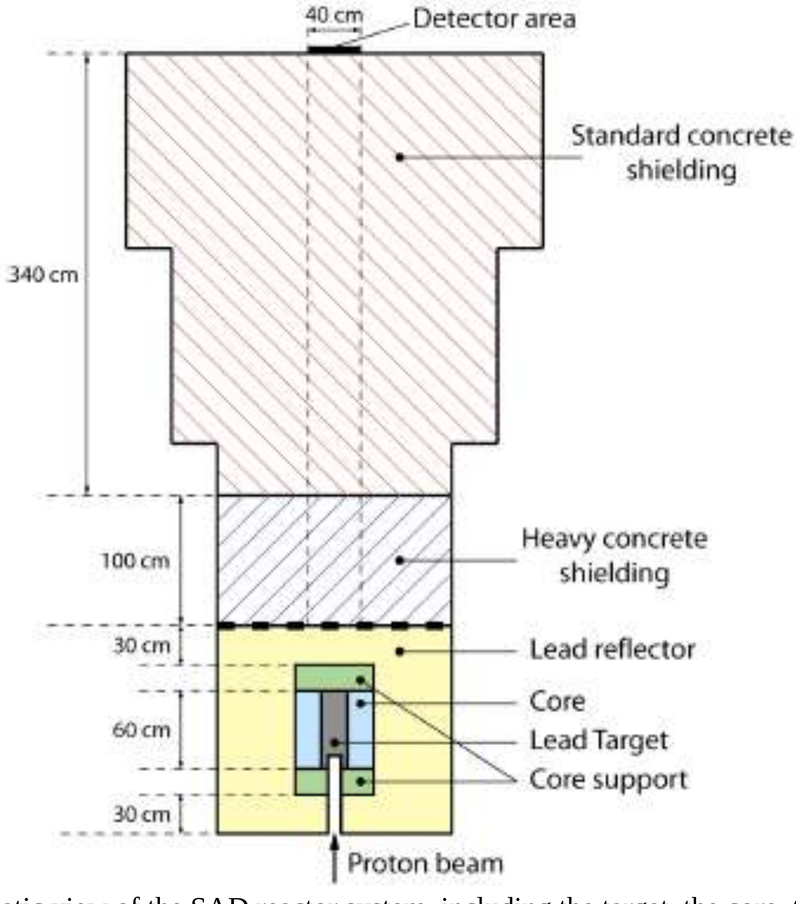


Energy distributions of neutrons emitted in the reaction p+^{27}Al (1.2 GeV) at the angles 85 (a), 130 (b) and 160◦ (c). P, E_k are the probability and the kinetic energy, respectively. From [11].

Designing of an accelerator driven subcritical assembly needs a thorough evaluation of build-up of long-lived radioactivity and changes in elemental composition in target materials. The spectrum of particles and residual nuclide mass and charge distributions in reactions of protons and neutrons with heavy targets (^{238}U, ^{208}Pb, ^{207}Pb and ^{206}Pb) has been calculated at JINR using the QMD+GEM model [12]. Study of polonium production in bismuth foils placed in lead target was carried out in [13]. Proton-induced production of residual nuclei $^{206-210}$Po in ^{209}Bi foils placed in lead target irradiated by 660 MeV protons was calculated. A comparison with calculated spatial distribution of polonium production using CASCADE and MCNPX code and experimental results has been performed.

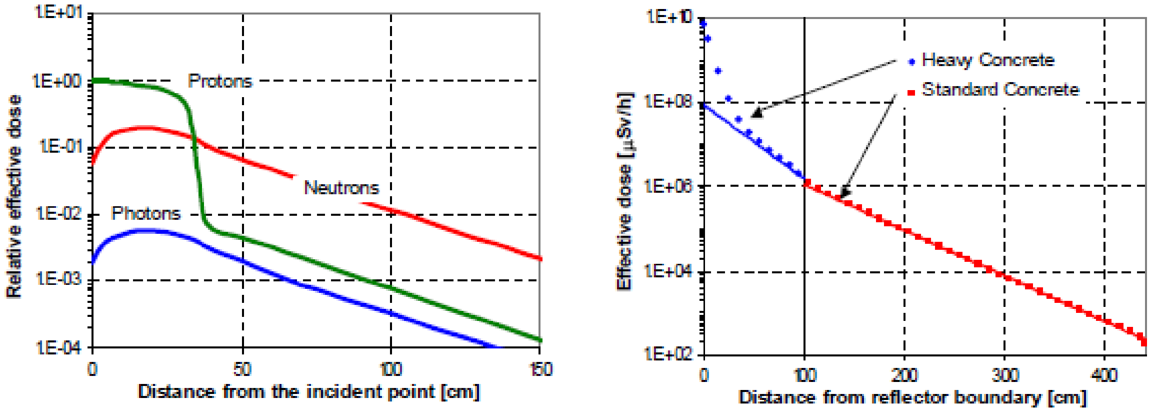
Experimental results of measurement long-lived radioactivity in target materials are presented in [14]. Two types of detectors were irradiated inside and/or on the surface of a cylindrical Pb targets irradiated with 660 MeV protons: activation detectors made of typical target materials Pb, Bi, and track detectors with heavy metal radiators Bi, Pb, Au, W, Ta. Activities of several radionuclides in Pb and Bi samples were determined. In the track detectors density of tracks and their size distributions were measured. Their spatial distributions were then compared with respective values obtained in the calculations made with the use of CASCADE, FLUKA and MCNPX code.

Results of Monte Carlo modeling of an Experimental Accelerator Driven System (ADS), which employs a subcritical assembly and a 660 MeV proton accelerator operating at the DLNP in Dubna were given in [15,16]. The mix of oxides PuO2 + UO2 MOX fuel designed for the reactor will be adopted for the core of the assembly. The design of the experimental Subcritical Assembly in Dubna (SAD) is based on the core with a nominal unit capacity of 30 kW (thermal). This corresponds to the multiplication coefficient Kerr = 0.95 and the accelerator beam power of 1 kW. A subcritical assembly has been modeled by CASCADE and MCNPX code for different options of the target and fuel elements.



Schematic view of the SAD reactor system, including the target, the core, the lead reflector and the upper part of the biological shield-ing. The shielding consists of a 100 cm thick section of heavy concrete plus 340 cm of standard concrete. The effective dose was calculated at the detector area at the upper surface of the biological shielding. From [17]

The radiation fields and the effective dose at the SAD have been studied with the Monte Carlo code MCNPX [17,18]. By separating the radiation fields into a spallation-induced and a fission-induced part, it was shown that the protons and neutrons with energy higher than 10 MeV, originating exclusively from the proton-induced spallation reactions in the target, contribute for the entire part of the radiation fields and the effective dose at the top of the shielding. Consequently, the effective dose above the SAD reactor system is merely dependent on the proton beam properties and not on the reactivity of the core.



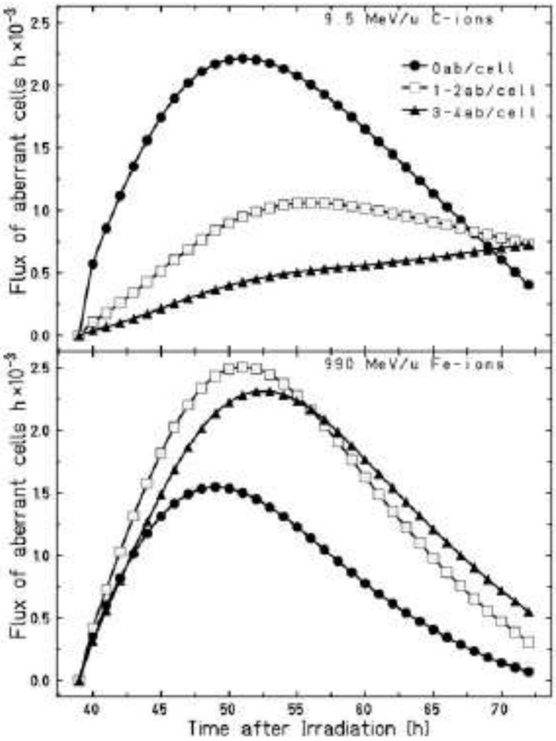
Attenuation of the effective dose in heavy concrete for parallel beams of 500 MeV protons. The different curves represent the separate contributions to the effective dose from protons, neutrons and photons (left). Total effective dose induced by the particles leaking out from the SAD reactor system as a function of the distance from the reflector-shielding boundary. Exponential curves have been fitted to the MCNPX-calculated values; one in the heavy concrete and one in the standard concrete. (right) From [17].

The essence of the work [19] was to show the comparison of fluxes of secondary particles emitted from subcritical assemblies being irradiated with proton beams. These assemblies, at present under investigation SAD, with keff = 0,95-0.98 and the “Energy plus Transmutation” with keff = 0.24. Monte Carlo modeling is used to forecast production of secondary proton and neutron fluxes in different subcritical assemblies under irradiation with protons in the energy range from 660 MeV up to 2.0 GeV. Neutron and proton spectra emitted from the surface of these assemblies are calculated using a version of the codes CASCADE and MCNPX code. The data obtained and methods developed were used to calculate parameters of isotope transmutation in various nuclear reactions.

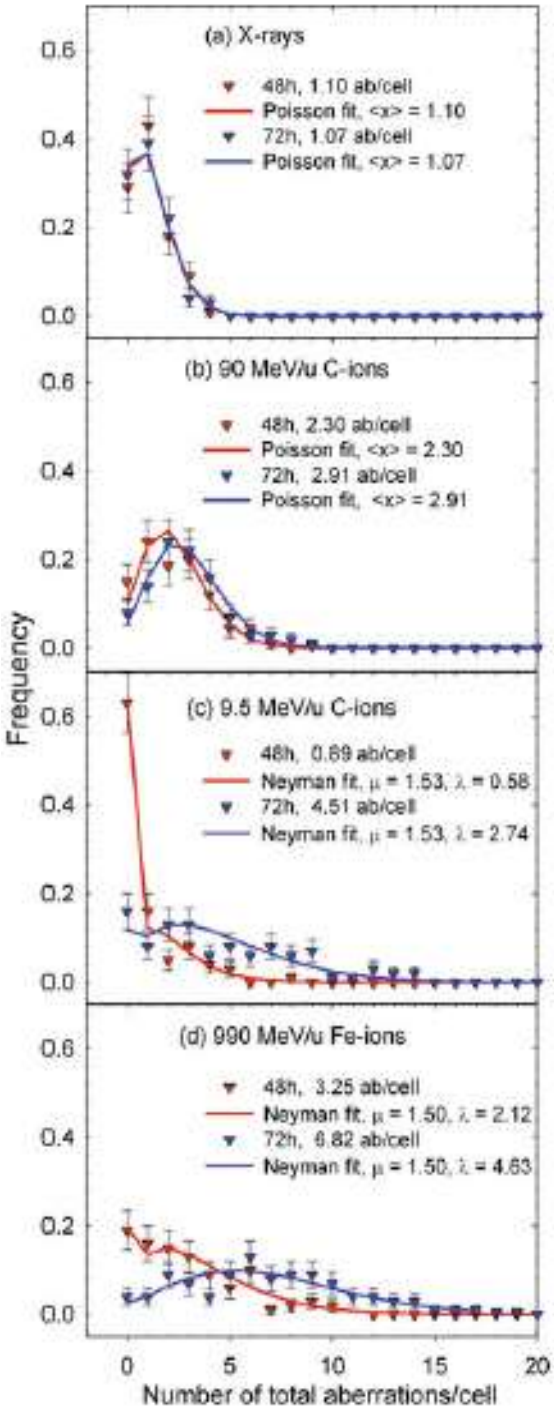
Further LIT-based cooperation with Polish specialists is on the biological project “**Modeling of chromosome location in the human cell nucleus and radiation induced chromosome aberrations”.** This Project is operated within the Foundation for Polish Science International Ph.D. Projects Programme co-financed by the European Regional Development Fund covering, under the agreement MPD/2009/6, the Jagiellonian University International Ph.D. Studies in Physics of Complex Systems. The goal of the project for 2011-2013 is better understanding of interactions between radiation tracks and biological targets. To this end it is necessary to know chromosome territories.

In the present joint study it was demonstrated nonuniformity effects of a local dose deposition for different ion track structures. The Monte Carlo simulations of chromosome aberrations distributions in relation to time after exposure to X-rays, Fe-ions and C-ions with assumption of various linear energy transfer (LET) was carried out at JINR [20].

The numerical simulations clearly demonstrate the impact of the track structure on the formation of chromosome aberrations. But it is not enough for understanding the kinetics of the particle-inducted radiation damage (especially lethal one) in biological materials at various stages of its hierarchic organization. Quantitative knowledge about chromosome aberrations in the cell nucleus provides only approximative dose after accidents [21,22] but it says nothing about the types of damages and types of the involved chromosomes.



Flux of undamaged and aberrant lymphocytes through mitosis after exposure to similar doses, i.e. 2 Gy of 9.5 MeV/u C-ions (upper panel) and 2.3 Gy of 990 MeV/u Fe-ions (lower panel). The data clearly indicate that there is a selective delay of heavily damaged cells (left).



Distributions of chromosome aberrations induced by (a) 2 Gy of X-rays, (b) 2 Gy of 90 MeV/u Cions, (c) 2 Gy of 9.5 MeV/u C-ions or (d) 2.3 Gy of 990 MeV/u Fe-ions. The relative frequency of first cycle metaphases carrying a distinct number of aberrations is plotted. Vertical bars along frequency values represent statistical errors by assuming Poisson statistics. The solid line represents the best fit to the experimental data by a Poisson distribution (a and b) or a compound Poisson (Neyman) distribution (c and d). Fixation time, average number of aberrations per cell and the fit parameters are displayed in each panel (right). From [20].

Therefore, one was not able to predict well the late effects of the radiation exposure. Accordingly, in the next step the cooperation is going to develop new model by including various models of the track structure and the nuclear architecture. In the model it will be assumed the chromosome complexes of aberrations which suggest chromosome clusters. Simulated data will be compared with experimental results obtained by the biophysic group in GSI. Due to special interest in estimation of radiation-risks in space exploration (long term cosmic human aircraft missions) and in cancer ion-therapy, the project meets direct requirements of application in medicine, radiobiology and space research.

Ricent publications of LIT-Polish cooperation

1. J.Adam, A.Baldin, M. Kadykov, V.Pronskikh, S.Tyutyunnikov, **A.Wojciechowski** et al., ***"Study of Deep Subcritical Electronuclear Systems and Feasibility of their application for Energy Production and Radioactive Waste Transmutation"***, Preprint JINR, E1-2010-61,2010.
2. M.I.Krivopustov, M.Bielewicz, M.Szuta, **Z.Strugalski, A.Wojciechowski** et al., ***"Experiments with a large uranium blanket within the installation Energy-plus Transmutation" exposed to 1.5 GeV protons"***, Kerntechnik 68 (2003) 48.
3. M.I.Krivopustov, A.V.Pavliouk, **A.Wojciechowski** et al, ***„About the first experiment on investigation transmutation I-129, Np-237, Pu-238 and Pu-239 at deuteron beam nuclotron JINR (Dubna) in field neutrons generatedin ^{nat}U/Pb-assembly "Energy plus transmutation" setup by energy 2.52 GeV"***, JINR – Preprint E1-2007-7, Dubna.
4. M.Bielewicz, S.Kilim, **E.Strugalska, A.Wojciechowski,** et al, ***"Experiments of high energy neutron spectrum investigation on U/Pb – assembly using 1.60 and 2.52GeV deuteron beam from JINR nuclotron (Dubna)"***, XIX Baldin Seminar, Dubna, 29.09 – 4.10.2008.
5. S.Kilim, **A.Wojciechowski,** M.Szuta, M.Bielewicz, **E.Strugalska**, et al. ***"Determination of high energy spallation neutron spectrum on U/Pb-assembly "Energy plus Transmutation" irradiated with 1.6 and 2.52 GeV deutron beam from Nuclotron accelerator"***, NATO Advanced Research Workshop "Safe Nuclear Energy", BITP, Kiev., Yalta, Ukraine Yalta, Crimea, Ukraine, September 27 - October 2, 2008.
6. M.I.Krvopustov, **A.Wojciechowski** et.al., ***"First results studing the transmuta-tion of 129I, 237Np, 238Pu, 239Pu in the irradiation of an extended natU/Pb-asembly with 2.52GeV deuterons"***. Journal of Radioanalytical and Nuclear Chemistry Vol.279,No.2 (2009), 567-584.
7. M. Bielewicz, S. Kilim, E. Strugalska-Gola, M. Szuta, **A. Wojciechowski, A. Polanski,** I. Adam, M. Kadykov, V. Pronskikh, V. Wagner, A. Krasa, M. Majerle, **"Measurements Relevant to High Energy Neutron Spectrum by Application Ytrium Detectors in the U/Pb-assembly using 4 GeV Deuteron Beam from JINR Nuclotron (Dubna)"**, XX Baldin Seminar, Dubna, 3-9 November, 2010.
8. **A.Wojciechowski, M. Szuta**, ***"Monte Carlo Methodology Calculations for the contribution to the analysis of thorium based fuel application in the accelerated driven systems (ADS)",*** IAEA Technical Meeting on "Low Enriched Uranium (LEU) Fuel Utilization in Accelerator Driven Sub-Critical Assemblies", 22 – 26 February 2010, Mumbai, India.

9. **M.Szuta, A.Wojciechowski**, ***"Once through Thorium based fuel cycle analysis of Accelerator Driven System for energy production and radioactive waste transmutation – impact on economy improvement"***, XX Baldin Seminar, Dubna, 3-9 November, 2010.
10. **A. Polanski**, ***"Development of Methods for Simulation of Electronuclear Processes"***, in Progress in High Energy Physics and Nuclear Safety, NATO Science for Peace and Security Series B: Physics and Biophysics, V.1, 2009, p. 319.
11. **A.Polanski , B.Slowinski, A.Wojciechowski**, ***"Evolution of Intranuclear Collision at Intermediate Energies"***, Physics of Elementary Particles and Atomic Nuclei, Letters, 4, 3(139), 417-427, 2007.
12. **A. Polański**, S. Petrochenkov, V. Uzhinsky ***"Developmen of a quantum molecular dynamic model (QMD) to describe fisson and fragment production"***, Radiation Protection Dosimetry, 116(1-4), 582-584, 2005.
13. **A Polański**, S.Petrochenkov, **W.Pohorecki**. ***"Proton-induced polonium production in massive lead-bismuth target irradiated by 660 MeV protons"***, Nucl. Instr. Meth. A, 562, 2, 764-766, 2007.
14. **W. Pohorecki, T.Horwacik, J. Janczyszyn, S.Taczanowski, V.P.Bamblevski**, S.A.Gustov, I.V.Mirokhin, A.G.Molokanov, **A.Polanski**, ***"Spatial distributions of residuals produced inside a spallation target."*** Radiation Protection Dosimetry, 115(1-4), 630-633, 2005.
15. **A.Polański,** S.Petrochenkov, V.Shvetsov, **W.Gudowski,** P.Seltborg, ***"Power upgrade of the subcritical assembly in Dubna (SAD) to 100 kW"*** Nucl. Instr. Meth. A, 562, 2, 879-882, 2007.
16. **W. Gudowski**, V. Shvecov, **A. Polanski**, C. Broeders, ***"The Subcritical Assembly in Dubna (SAD). Part II: Research program for ADS-demo experiment"***. Nucl. Instr. Meth. A, 562, 887, 2006.
17. P. Seltborg, **A. Polanski**, S. Petrochenkov, A. Lopatkin, **W.Gudowski**, V. Shvetsov. *"**Radiation shielding of high energy neutrons in SAD"***, Nuclear Instruments and Methods in Physics Research, A:, 550, 313-328, 2005.
18. P. Seltborg, A. Lopatkin, **W. Gudowski**, V. Shvetsov, **A. Polański**, ***"Investigation of radiation fields outside the Subcritical Assembly in Dubna"***, Radiation Protection Dosimetry, 116(1-4), 449-453, 2005.
19. **A. A. Polanski**, A. N. Sosnin, "***Monte Carlo Modeling of Secondary Neutron and Proton Fluxes from the Surface of Subcritical Assemblies Under Irradiation with High Energy Proton Beams"***, Transport Theory and Statistical Physics, 37, 5/7, 576 - 588, 2008.
20. **J.Deperas-Standylo**, R.Lee, A.Ayriyan, E.Nasonova, S.Ritter, E.Gudowska-Nowak, ***"Time-course of aberrations and their distribution: impact of LET and track structure",*** Eur. Phys. J. D V.60, N. 1, 93 - 99, 2010.
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22. J.Morand, **J.Deperas-Standylo**, W.Urbanik, R.Moss, S.Hachem, W.Sauerwein, A.Wojcik, Radiat. Prot. Dosimetry 2008; 128:437–443.

Cooperation between the Laboratory of Radiation Biology and the Poland Republic

Since 2004, the Laboratory of Radiation Biology (LRB) has been closely collaborating with Polish researchers (M. Deperas-Kaminska and Prof. A. Wojcik of the Institute of Biology, Jan Kochanowski University, Kielce).

The work is focused on studying individual radiosensitivity and biological dosimetry. The urgency of this research is determined by the worldwide practical interest in the problem of radiation dosimetry concerning possible emergencies related with the large-scale radiation disasters, which has grown in the past years. The results of the audit of laboratories working in biological dosimetry conducted by the International Health Organization (IHO) show a high degree of the readiness of some research centers to do the biodosimetric monitoring of small groups of casualties. It was found, however, that their capacity would not be sufficient for large-scale disasters. In December 2007, the IHO held consultation meetings in Geneva, Switzerland, and proposed that a global biodosimetry network (BioDoseNet) be created. Cooperation with Polish scientists in this field is thus promising in terms of the involvement of more Polish and Russian research centers in BioDoseNet functioning.

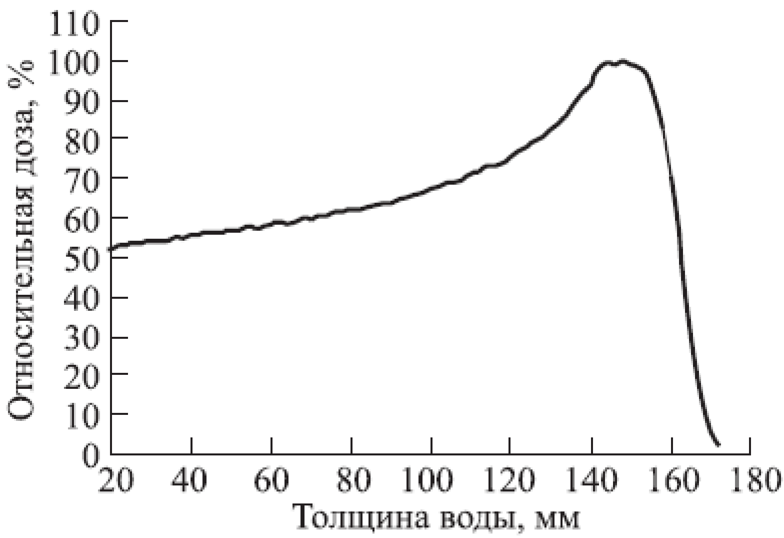
The establishment and improvement of the biodosimetry standards of the International Commission on Radiological Protection (ICRP) is an important aspect of the cooperation between JINR and Polish research centers. The topicality of this cooperation is caused by the necessity of regular review and correction of the ICRP biodosimetry standards due to the development of new research techniques.

Within this range of topics, a series of joint experiments were performed to study individual variations of the DNA damage distribution in chromosomes 2, 8, and 14 of human peripheral blood lymphocytes depending on the linear energy transfer (LET) of radiations. It was the first research in this field to be done *in vitro* at high LET of radiations (^{11}B, ^{17}Li, ^{20}Ne), which is of great practical importance for the development of new methods of biodosimetry. The results of the experiments show that differences between donors can cause a biodosimetric error in the evaluation of the absorbed dose. Moreover, the ratio between the centric rings and dicentrics in chromosome 2 can be a fixed point for estimating the dose at high LET.

It is planned to expand joint research on biodosimetry by broadening the spectrum of the used radiations with different LET and studying the effect of temperature factors on the yield of chromosome aberrations during irradiation *in vitro*.

The results of joint work are regularly reported to international conferences and published in refereed journals and periodicals. Candidate's thesis in this field is going to be defended in 2011 by M. Deperas-Kaminska [1-9].

In particular during Polish-JINR cooperation, the physical parameters of therapeutic proton beam delivered from the JINR Phasotron are investigated and described. The study of chromosomal damages in the cells on the model of human blood lymphocytes after irradiation with the initial 170 MeV proton beam at the entrance of an object and in the Bragg peak region has been performed, which corresponds to the irradiation of surrounding tissues along the beam path and tumour tissues. High efficiency of the Bragg peak protons has been shown. RBE value was ~ 1.25 within the dose interval of 1-4 Gy, while protons at the entrance did not differ from γ-radiation.



Dose distribution of therapeuftic proton beam with extended Bregg peak [2].

Since the therapeutic proton beam dose to a tumour is formed by patient irradiation from several directions (up to 7), the level of cytogenetical damages of cells in surrounding tissues along the initial proton beam path is decreased by an order. So, about 80% of tumour cells will obtain the damages after irradiation by a dose of 3 Gy, but in surrounding healthy tissues it will not exceed 10%. The data conˇrm high efˇciency of proton beams for radiotherapy [1,2].

Publications of the LRB JINR, carried out together with Polish scientists

1. R.D. Govorun, **M. Deperas-Kaminska,** E.M. Zaytseva, G.V. Mytsin, A.G. Molokanov. ***"Estimation of the therapeutic proton beam effect on human cells based on cytogenetic disorders in peripheral blood lymphocytes".*** Proceedings of the All-Russian conference "Radiobiological Principles of Radiation Therapy," 19–20 April 2005, Moscow, p. 40 (in Russian).

2. R. D. Govorun, **M. Deperas-Kaminska,** E. M. Zaitseva, E. A. Krasavin, G. V. Mitsyn, A. G. Molokanov, ***"The Study of Chromosomal Damages in Human Cells on Irradiation with the Therapeutic Proton Beam of the Joint Institute for Nuclear Research's Phasotron (rus)"***, PEPAN Letters, 2006, v 3, 1, pp. 92-100.
3. **M. Deperas-Kaminska**, E. A. Krasavin, **A. Wojcik**. ***"Investigation of chromosome aberrations distribution in 2, 8 and 14 painted chromosomes after in vitro carbon ions irradiation"***. 4th International Workshop on Space Radiation Reseach and 17th Annual NASA Space Radiation Health Investigators' Workshop. Moscow – St. Petersburg, June 5-9, 2006. Dubna, 2006. P. 27-28.
4. **M. Deperas-Kaminska, A. Wojcik,** E. Zaytseva. ***"The application of heavy ion beams in biodosimetric investigation"***. VI-th International conference "Ion implantation and other applications of ions and electrons" Ion 2006. Kazimierz Dolny, Poland, June 26-29, 2006.
5. **M. Deperas-Kaminska,** E.Zaytseva, **J Deperas-Standylo**, E. A. Krasavin, **A. Wojcik**. ***"Variable sensitivity of chromosomes 2, 8 and 14 in human peripheral blood lymphocytes exposed to heavy ions"***. The 36th meeting of the European Radiation Research Society, Tours, France. 09.2008.
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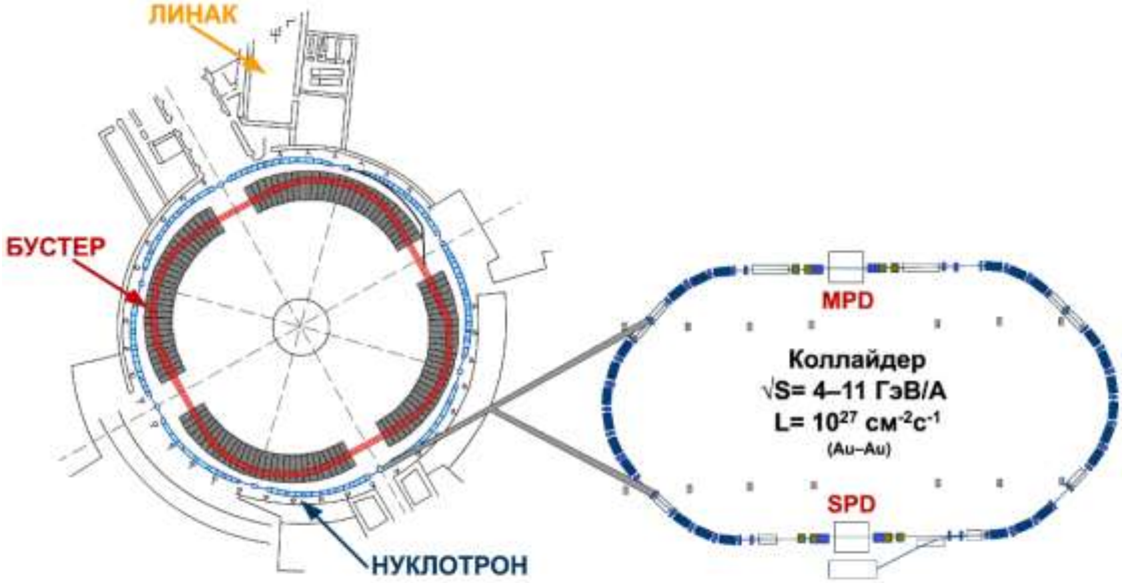
Collaboration of Veksler and Baldin Laboratory of High Energy Physics with the Republic of Poland

In 2010–2016 in full accordance with the Long-Term plan of JINR scientific development, the Veksler and Baldin Laboratory of High Energy Physics (VBLHEP) will preserve its main directions of research in **high-energy heavy-ion** physics and **modern particle physics** which, in particular, include investigations of the nucleon spin structure, tests of the Standard Model, search for new physics and the study of CP violation.

The research in high-energy heavy-ion physics at JINR will be carried out at the VBLHEP accelerator complex **Nuclotron-M** and further at **NICA** collider facility, the construction of which is the primary objective of this Laboratory. At this complex, within the MPD project, an experimental study of the properties of hot and dense hadronic matter and search for the so-called "mixed phase" of such matter (i.e. a mixture of quark-gluon and hadron states) as well as for a possible phase transition will be performed at the energy of colliding particles up to $\sqrt{s_{NN}}$ =11 GeV.

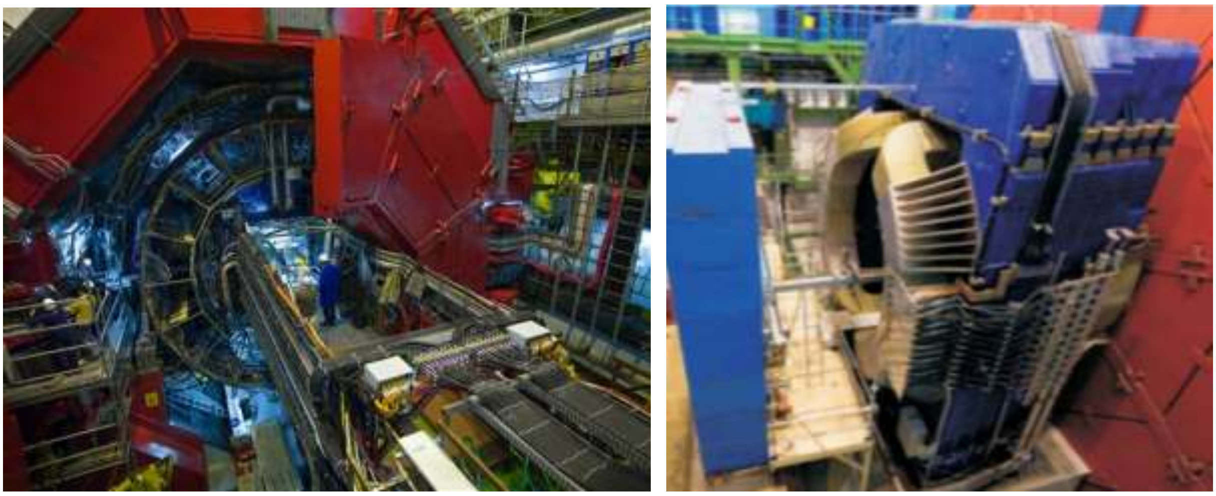
Nuclotron-M of VFLHEP of JINR

For the all JINR member-states the Nuclotron-M/NICA facility can serve as an advanced scientific-technological base, being universal superconductive facility built on modern technological basis, where unique program in fundamental and applied research can be realaized. The collision energy interval chosen for the facility and its corresponding instrumental infrastructure are optimal for research of matter in its transitions to most unexpected forms. This allows one to reach better understanding of the fundamental laws of nature, its symmetries and properties as in the evolution in time as at the very moment of creation of Universe. Unique possibilities offered by NICA are complementary to the existing world mega-scaled facilities including the LHC.



Scheme of the NICA complex of VBLHEP

The level of involvement of VBLHEP groups in research on high-energy heavy-ion physics at other world's accelerator laboratories will be defined by the progress of activities on the NICA/MPD project and the emerging opportunities for work at the Nuclotron-M/NICA accelerator complex. At the same time, VBLHEP scientists will participate in the study of the properties of nuclear matter in states with extremely high density and temperature, in the search for manifestations of quark deconfinement and possible phase transitions within joint research on heavy-ion physics in the experiments **STAR** at the RHIC collider (BNL), **NA61** (SPS) and **ALICE** (LHC) by investigating the production of various hadrons including light vector mesons and heavy quarkonia as well as in measurements of direct photon and dilepton yields.



Elements of ALICE setup at LHC

The study of the nucleon spin structure will be carried out by JINR scientists at the VBLHEP accelerator complex and at CERN and BNL. In general, the physics of spin has long-standing history at VBLHEP and scientists from Republic of Poland have significantly contributed to this branch of particle physics. At present, series of experiments are planned to be conducted with the extracted polarized beams of the Nuclotron-M, particularly, using a **movable polarized target.** These investigations are associated with preparations for implementing the spin program of the NICA project and are aimed at creating effective polarimetry as well as at developing technology for polarized targets and polarized particle sources.

The ultimate goal of the NICA/MPD project is to construct a collider (based on the Nuclotron-M accelerator) that will allow carrying out investigations with colliding beams of high-intensity ions at an average luminosity of $L=10^{27}$ cm^{-2} s^{-1} for Au^{+79} within the energy region $\sqrt{s_{NN}}$ = 4–11 GeV, as well as with polarized proton ($\sqrt{s_{NN}}$ up to 20 GeV) and deuteron ($\sqrt{s_{NN}}$ up to 12 GeV) beams with longitudinal and transverse polarization and with extracted ion beams as well as polarized proton and deuteron beams.

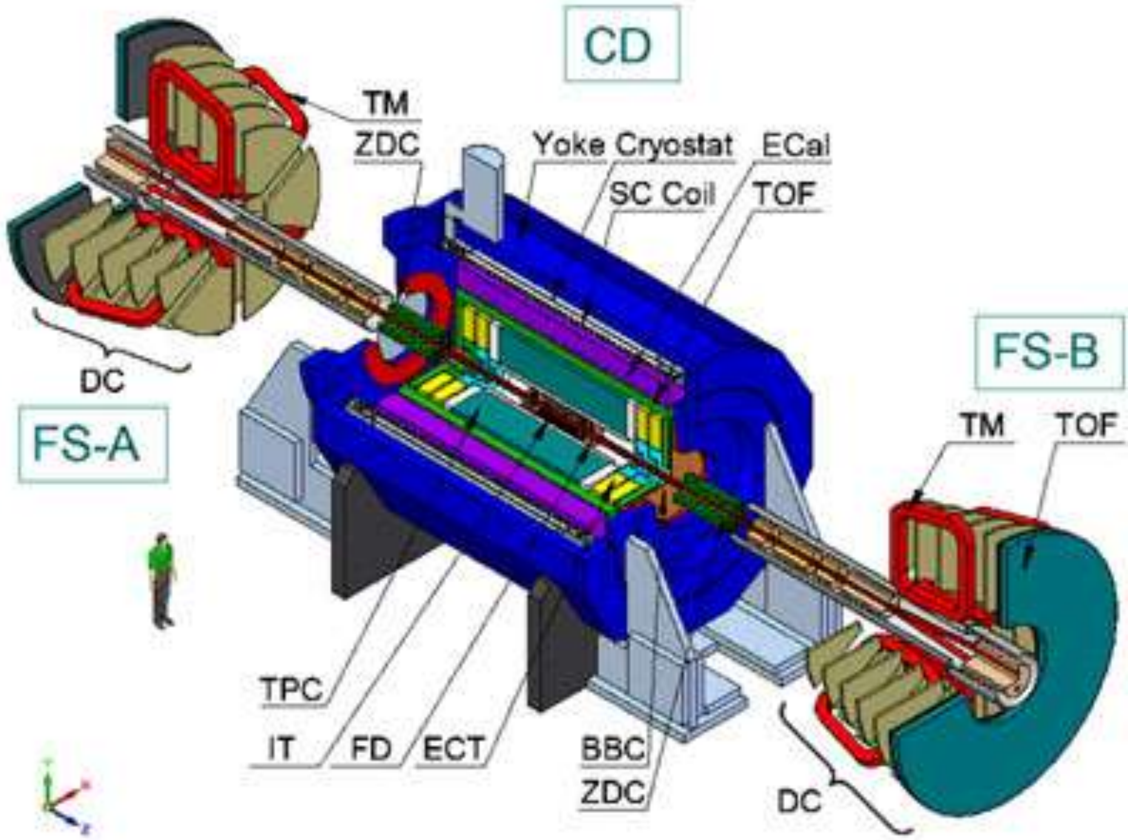
This requires creating a source of highly charged heavy ions, constructing a linear injector accelerator, designing and building a booster synchrotron, developing and constructing two superconducting storage rings, integrating the developed systems and the existing accelerator Nuclotron-M into a collider providing at least two beam intersection points. It is planned to complete the Nuclotron-M project in 2011. The physical start-up of the NICA facility is planned for 2015.

To use effectively the NICA collider opportunities, it is necessary to construct adequate detector set-ups at JINR. Such experimental instruments will be detectors MPD and SPD at VBLHEP.

The goal of the MPD project is experimental studies of strong interactions in hot and dense hadronic matter and a search for a possible formation of the so-called “mixed phase” of such matter. The design concept of the MPD set-up envisages placing the central complex of detecting equipment in the solenoid magnetic field as well as two forward-backward detectors. Under the MPD project, the DLNP is planning to take responsibility for the construction of a compact high-performance electromagnetic calorimeter (EMC).

The **SPD** facility is being developed at VBLHEP for realization of the second part of the scientific program for the NICA collider concerning investigations of the interactions of colliding light-ion beams and polarized proton and deuteron beams. This will allow setting up spin physics experiments to continue the JINR research program in this area at a brand new level.

The successful achievement of the goal, set before VBLHEP, for the construction of the NICA accelerator complex and MPD and SPD detectors requires concentration of essential resources and optimization/minimization of financing for another projects carried out in the Laboratory within the existing JINR obligations.



The scheme of the mixed-phase detector MPD setup

During the past 4 years, after approval by the JINR PPC of the NICA program, running of the Nuclotron for physics research was very limited, whereas acceleration of polarized deuteron was stopped at all. The last was motivated by the decision to design and construct the new high intensity polarized proton and deuteron source. Work on the new ion source manufacturing and tests should be completed in 2012. Modernization of the Nuclotron (project "Nuclotron-M") was completed in main parts by the fall 2010. Completion of the commissioning is expected in 2011. Thus, the Nuclotron running with polarized beams is scheduled for 2012 and after that.

Experiments with Nuclotron-M beams extracted to fixed targets are essential part of the high-energy heavy-ion physics and spin physics at JINR. These experiments will be carried out as during the NICA collider stage as after start of its operation complementing moderate energy part of the NICA/MPD research program. The energy region covered by fixed target experiments at VBLHEP overlaps and extends further the GSI and FAIR (at SIS-100 stage) energy regions as well what gives a good ground for cooperation between JINR and FAIR.

Besides fundamental studies, it is planned to perform innovative projects in radio-biology, nuclear waste transmutation, nano-technology and other directions at the Nuclotron-M and NICA facility. Realization of the NICA-project will push forward development of new technologies in industry of the JINR member-countries.

Apart from taking part at scientific research programs and in the Nuclotron-M and NICA project, scientists from Poland participate in education process at JINR.

Annual practical work organized together with the JINR University Center on the basis of VBLHEP opens to Polish students a lot of doors regarding learning methods of experimental and applied investigations as well as modern data analysis tools. Participation of the students in works on realization of the Nuclotron-M/NICA/MPD project and in experiments with fixed targets at extracted Nuclotron beam gives good basis for their practical work on preparation diplom, magister and PhD Theses.

Collaborative works within Nuclotron-M project is aimed first of all to modernization of the Nuclotron. Contribution of specialists from the Republic of Poland and high-technology industry to realization of this project is significant, in particular to the modernization of cryogenic systems of the Nuclotron. In 2004 contract N 08626319/011351-74 was finished with IAE (Swerk) on R&D and production of a module for system of beam diagnostic in Nuclotron. This module was tested at a test-bench and in the Nuclotron run at the end of 2004.

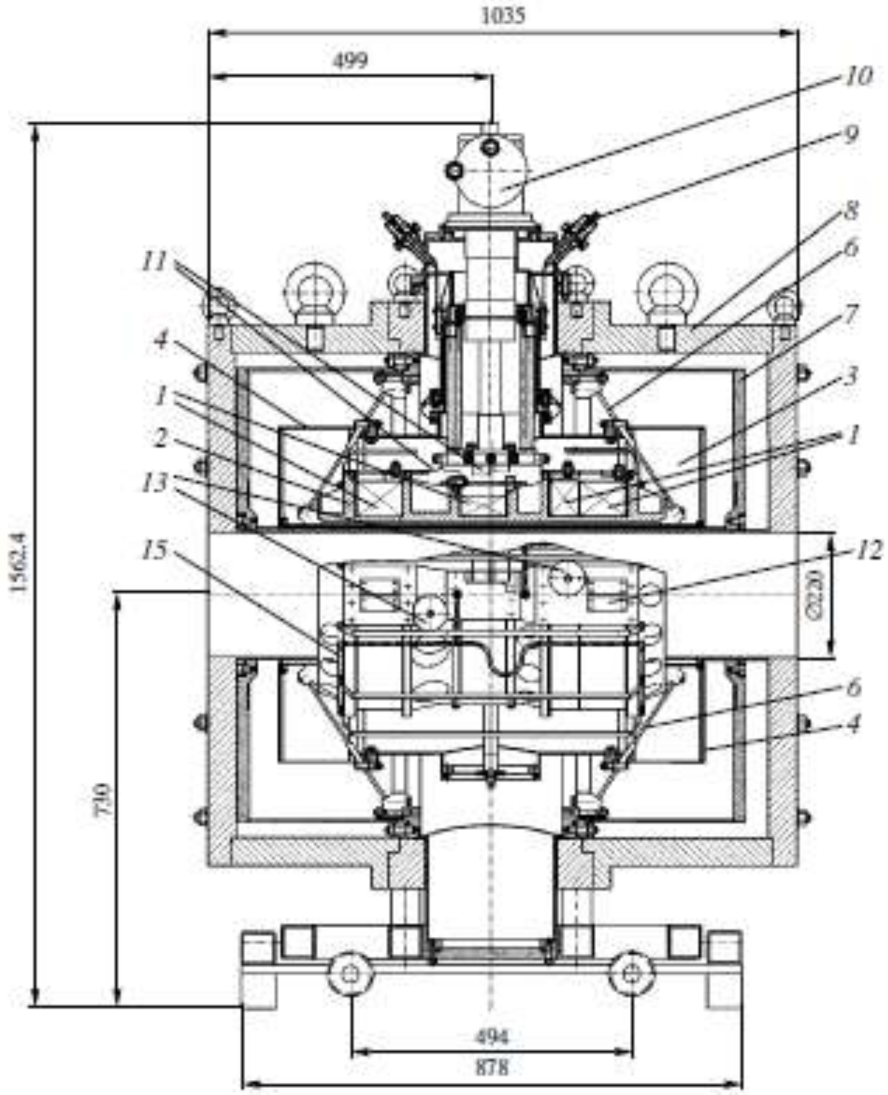
Today there is a strong VBLHEP-Polish cooperation on Research-and-Development (R&D) works within cryogenic technologies (group of H. Malinowski). First of all it is development and production of new superconductive systems based on classic as well as on the **high-temperature superconductors** (HTSCs) with use of cryo-cooling technology for cooling of those systems.

Technology of production of these systems is almost independent on goals for which they are being produced. Main parts of the superconducting systems are very similar to those used in the superconducting magnets operating in Dubna and to the energy accumulators, superconducting transformators and superconducting separators developped in Poland. For cryogenics the VBLHEP is unique Laboratory where use of superconductors comes full way from a project stage up to the mass production and exploitation.

Collaboration with Polish specialists in the cryogenics is aimed at use of superconducting technologies in nuclear physics and in the other industry branches (such as chemistry, for example) in Poland as well in Russia. Up to now the following works were completed in VBLHEP of JINR.

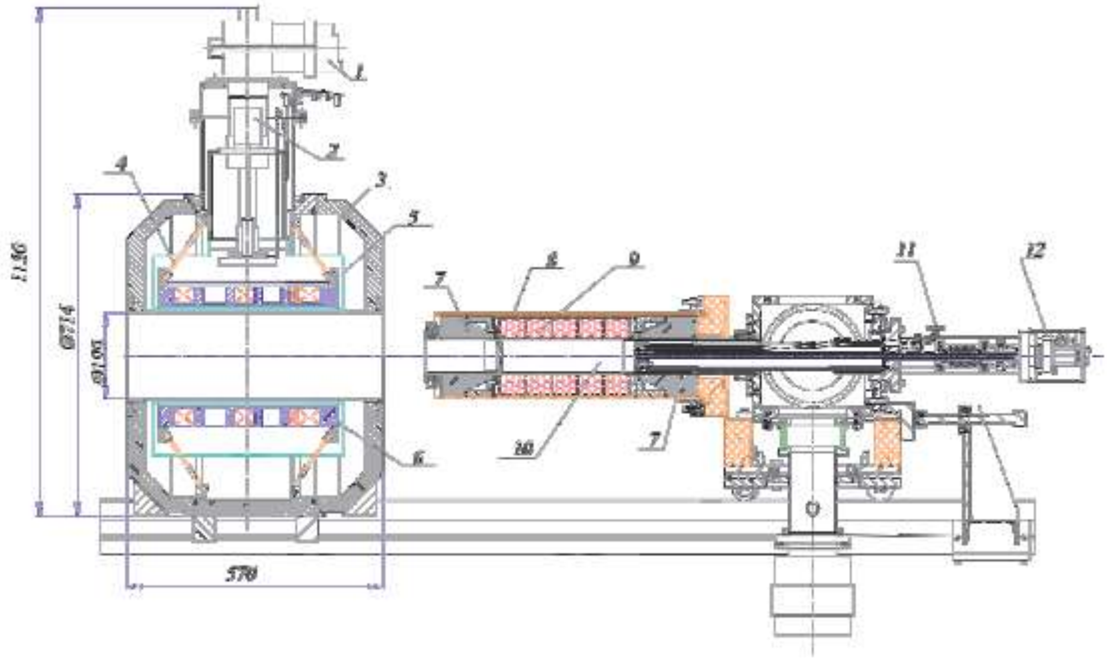
Cryo-cooler system for cooling of the **superconductive magnet system** (SCMS) of the ion source DECRIS was developped with use of experience in cryo-coolers usage at IEl Warsawa. This system works successfully during several years. Technology of production of such ion sources became exemplary for other supercoducting systems.

A series of superconducting modules were designed for ths afore-mentioned system, in particular the HTSC current-transfer lines for superconducting magnets with current up to 150A. Without such current-transfer lines exploitation of similar cryo-cooled magnets is impossible. High stability of magnetic field in SCMS and their reliability can be provided with use of superconductive switches. An R&D research on technology of production of such switches was performed.



The general view of the magnet assembly (in longitudinal section): 1—superconducting solenoids; 2—framework of solenoids; 3—thermal shield; 4—multilayer vacuum-shield insulation; 5 —reflecting aluminum shield; 6—support for the cold masses; 7 —vacuum enclosure; 8—magnetic screen; 9—lead-in wires; 10 —cryocooler; 11 —heat conductors; 12 —“cold” diodes; 13 —voltage-dropping resistors; 14 —turbomolecular pump; 15—nitrogen heat exchanger. From [1].

Reliability of cryo-cooled superconductive systems can be garanteed by new methods of quench-protection. This includes elements called ”cold diodes”. Such protection system was designed, developped and works successfully on several magnets produced in VBLHEP. Exploitation of any SCMS needs information about temperature of its elements. Choice and calibration of the low-temperature termometers are performed at the Laboratory using attested and certified test-bench [1,2].



A cross sectional view of the DECRIS-SC2: 1 - cryocooler head; 2- current leads; 3 - vacuum vessel; 4 - support of the cold mass; 5 - heat screen; 6 - framework with coils; 7 - iron plugs; 8 - plastic insulator; 9 - hexapole; 10 - plasma chamber; 11 - u.h.f. injection; 12- biased electrode remote drive. From [2].

In further continuation of above-mentioned crogenic research the following works are under way in VBLHEP. First of all they include design, development and production of the magnetic system for the ion source KRION. The cryo-cooled SCMS of this source must provige magnetic field up to 6 T which must be very homogeneous. Several prototypes are nowadays being tested.

View into KRION setup

Further R&D works of new superconductive materials for current-transfer lines for Nuclotron are in progress. They are aimed to replacement of existing copper conductors in some current-transfer lines (with currents up to 200 A) by HTSC conductors what promises save up to 20% of liquid helium necessary for cooling of all the current-transfer lines of the Nuclotron. It is planned in 2011 to perform test-bench study of a prototype of the current-transfer line with standard magnet. After relevant test-bench studies the mass-production of sich lines is planned in Electrotechnical Institute (IEl) of Warsaw in Poland.

It is known that the strong magnetic fields in chromatography opened new qualitative possibilities of this process and a new direction of “magneto-chromatography” was created. Polish scientists from UMCS, using strong magnetic fields, in particular, at SCMS in VBLHEP, have obtained important results which can form a basis for a new usage of the chromatography for analysis of complicated chemical materials [3-7].

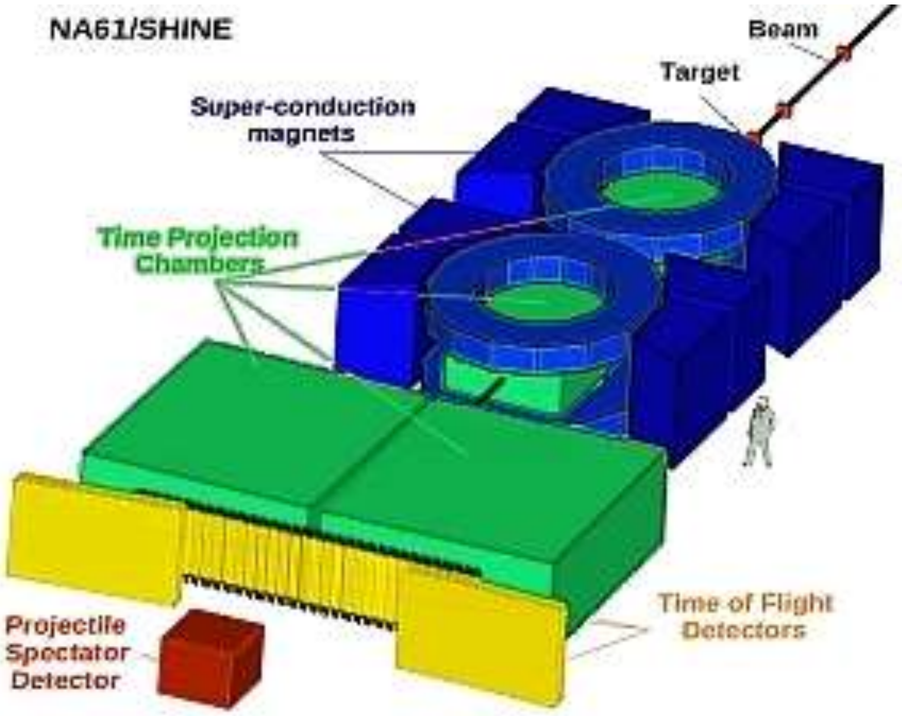
New prospects for other applied joint R&D in VBLHEP are under investigation. Negotiations about use of superconductive magnetic systems for separation or enrichment of various industrial materials (separation of coal from sulphur, enrichment of various ores etc.) are in progress with Skochinsky Institute of mining (Russia), IEl and GIG (Poland), Academy of Science in Ukraine. It is planned to continue R&D on current-transfer lines for high currents (up to few thousands A) for Nuclotron and on current restrictors for superconducting transformators (in Poland). Research in magneto-chromatography with use of a magnet based on HTSC conductors will be continued.

In course of the collaborative work within this topic 5 diploma theses were completed by Polish students and 2 diploma theses by Russian students. One PhD thesis was completed by PhD-student from UMCS (Lublin) with use of data obtained in magnetochromographical exeriments performed at VBLHEP.

Collaboration of JINR with Polish specialists in the **Relativistic heavy ion physics** has long-standing traditions in VBLHEP. In the last years it is going mostly within the experiment **FAZA** (see above in DLNP) at Nuclotron with participation of academician A.Budzanowski, Drs. W.Karcz, I. Skwirczynska, B.Czech (from H.Niewodniczanski Institute of Nuclear Physics, Cracow) and within experiments NA49 and NA61/Shine at CERN.

The experiment NA61/SHINE studies hadron production in hadron-nucleus and nucleus-nucleus collisions at the CERN SPS. The NA61 detector is an upgrade of NA49. Detector NA61 is a large acceptance hadron spectometer with excellent capabilities for momentum, charge and mass measurements. The experimental facility consists of Time Projection Chambers, Time of Flight and Projectile Spectator Detectors.

The Physics goals of the experiment NA61/SHINE include search for the critical point of strongly interacting matter; detailed study of the onset of deconfinement, and hadron production reference measurements for neutrino (T2K) and cosmic-ray (Pierre Auger Observatory, KASCADE-Grande and KASCADE) experiments. The study of high transverse momentum phenomena in proton-nucleus and proton-proton interactions is another subject of this experiment [12-19].



The experimental NA61 facility consists of Time Projection Chambers, Time of Flight and Projectile Spectator Detectors.

Furthermore the leader of the NA49 experiment Prof. M. Gazdzicki is one of the prominent experts, who are participating in formulation of the NICA/MPD physical program. The other Polish physicists – Prof. B.Słowiński, Prof. M.Stępiński (Lodz) and Prof. S.Mrowczynski, take part in this physics as well. This work is concentrated mostly in the Division for physics at extracted beams of Nuclotron-M (Department for heavy ion physics of VBLHEP).

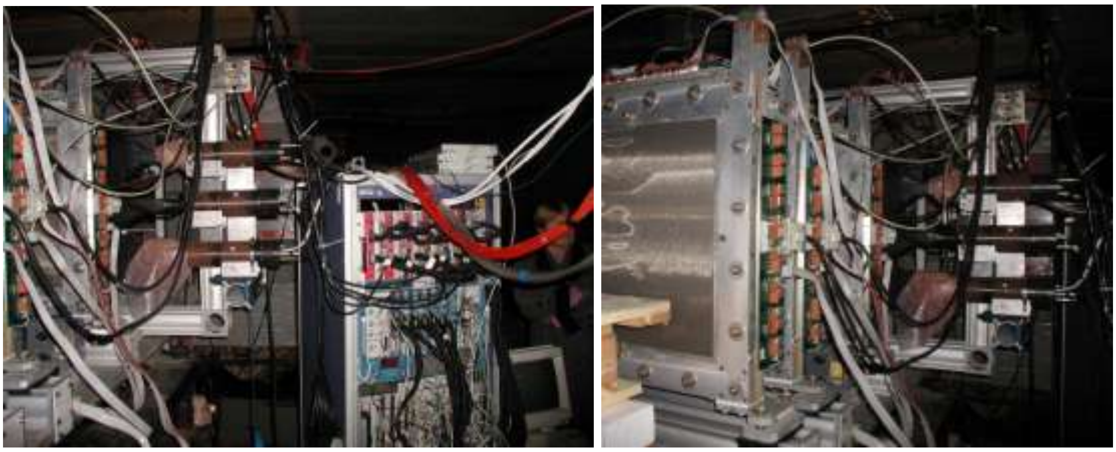
In the last year it was opened joined research and educational program ***"Towards the extreme baryon densities"*** with responsible persons Prof. J. Pluta from Faculty of Physics of WTU, Warsaw, and Prof. R.Lednicky from JINR. The scientific part of this program includes three directions of cooperation.

In particular there is one which directly related to the physics program of the NICA/MPD project. It includes computer simulation of particle registration in the selected elements of the MPD detector; implementation of SHIELD generator in ROOT geometry manager, tracking in the TPC for MPD, reconstruction of high multiplicity events for NICA/MPD. It includes also an analysis of registration properties of the MPD detection system by computer simulations: study of multigap Resistive Plane Chambers for time-of-flight system; modeling of the selected parts of NICA accelerating system: setting of linear accelerator, particle dynamics in the accelerator ring, stochastic cooling system, new source of polarized ions etc.

The reaction plane reconstruction, analysis of flows, charge azimuthal asymmetries and polarizations; analysis of femtoscopy correlations of non-identical particles; study of multifragmentation in heavy ion collisions all are the subjects of the program.

Polish specialists are actively participating in the JINR topic ***"Study of Polarization Phenomena and Spin Effects at the JINR Nuclotron-M Facility".*** The research work in this direction is concentrated mostly in the Division for physics at extracted beams of Nuclotron-M (Department for spin physics and few nucleon system problems). Participation of the specialists from the Republic of Poland in theoretical and experimental studies of polarization phenomena and spin effects within the JINR topical plan is traditional, effective and important. But at the present time it is limited to only 3 persons from SINS (Otwock-Swierk) under the leadership by T. Siemiarczuk. Research program of the topic includes investigation of the following problems**:**

- Methodical support of the experiments at polarized beams of the Nuclotron-M and NICA facilities, including development of polarimetry systems.
- Measurement of analyzing power for the reaction p + CH_2 at polarized proton momentum up to 7.5 GeV/c at the setup ALPOM-2.



ALPOM-2 setup at VBLHEP

- Measurement of tensor analyzing power and spin correlation in $d \longrightarrow p$ reaction in the deuteron core area with the use of polarized ^{3}He target and polarized deuteron beam of the Nuclotron-M. Study of 2N- and 3N-correlations in deuteron-proton elastic scattering and deuteron break-up reactions at the Nuclotron internal target.
- Works on modernization of Saclay-Argonne-JINR polarized proton target (setup PPT). The measurements of set of the *np* spin observables at 0^{o} - $\Delta\sigma_T(np)$ (the total *np* cross section differences), using transverse (T) polarized targets and the unique quasi-monochromatic relativistic 1.2-3.6 GeV polarized neutron beams of the Nuclotron-M. Determination of the forward scattering *NN* amplitudes over this energy region. Comparison of the obtained data with QCD motivated model calculations.
- Study of charge-exchange processes in *dp*--interactions at the setup STRELA.
- Development of theoretical models for description of the simplest nuclear systems taking into account relativistic effects, meson and quark-gluon components of the systems. Theoretical analysis of experimental data obtained at Nuclotron-M.
- The study of the properties of strongly interacting matter utilizing polarization phenomena in hadron-nucleon and lepton-nucleon interactions, and in the decay of polarized radioactive atomic nuclei.

- Study of highly excited nuclear matter and collective effects in nuclear media.

Based on the above mentioned results the main plans for farther development are the following. A new project will be presended for development of methodical base and instruments for experiments at light ion polarized beams of the JINR accelerator facility in 2012-2016 taking into account the NICA project realization, including development of polarimetery systems. Setups to exposition at the Nuclotron-M polarized beams will be prepared. Participation will be continued in the joint scientific programs and experiments, design and test of the new detectors and electronics for the use at COSY (Julich), SPS (CERN), RHIC (BNL), TJNAF (Newport News), FAIR (GSI) in accordance with the approved collaborative agreements. Development will be continued of the methods to calculation of the amplitudes and polarization characteristics of deuteron fragmentation and deuteron elastic scattering on protons and nuclei taking into account final state interaction and relativistic effects.

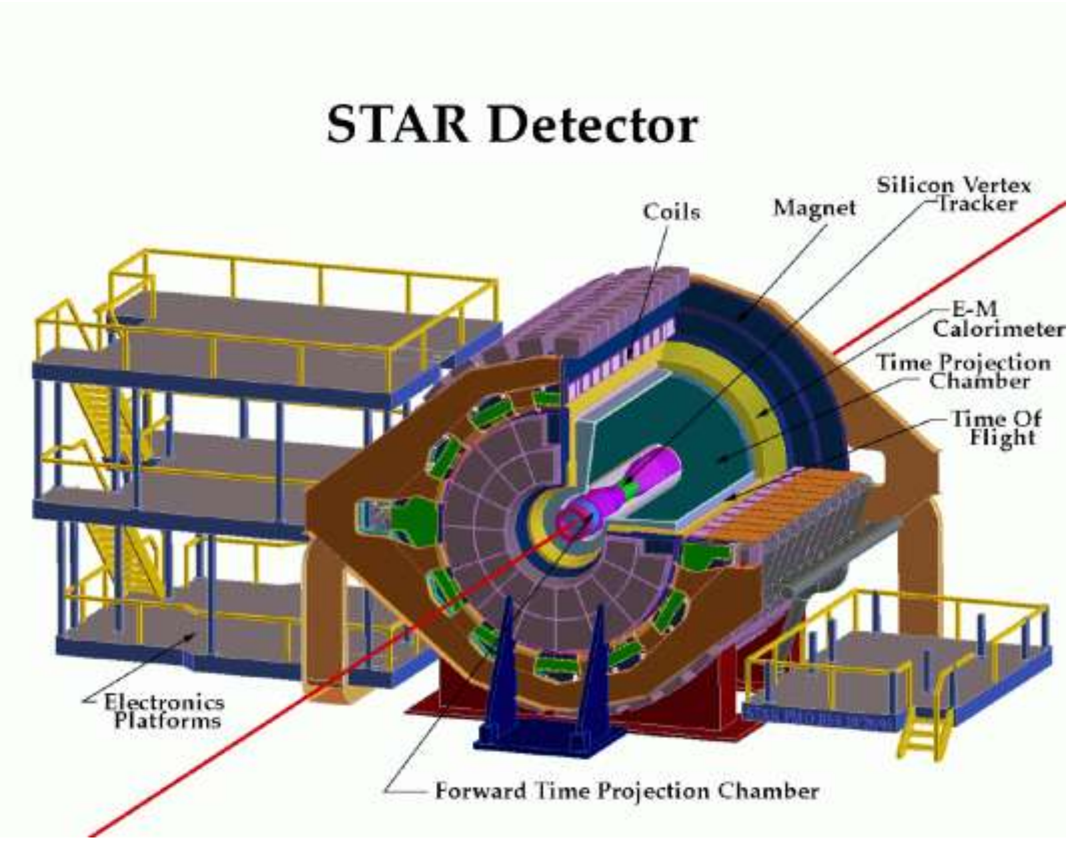
The VBLHEP expects more intensive involvement of young Polish physicists and engineers into investigation of spin physics problems in near future (since 2012), when the modernization of the Nuclotron facility will be completed and the accelerator running time for physics data taking will be increase substantially. The future interest is connected with the NICA collider facility construction at JINR.

Collaborative **analysis of data from external facilities** is performed with Polish scientists in the Division for physics of high energy heavy ions of VBLHEP. The analysis is mainly of data from the **STAR (S**olenoid **T**racker **A**t **R**HIC collider**)** detector working at heavy ion collider **RHIC** (Brookhaven National Laboratory's **R**elativistic **H**eavy **I**on **C**ollider**)**.

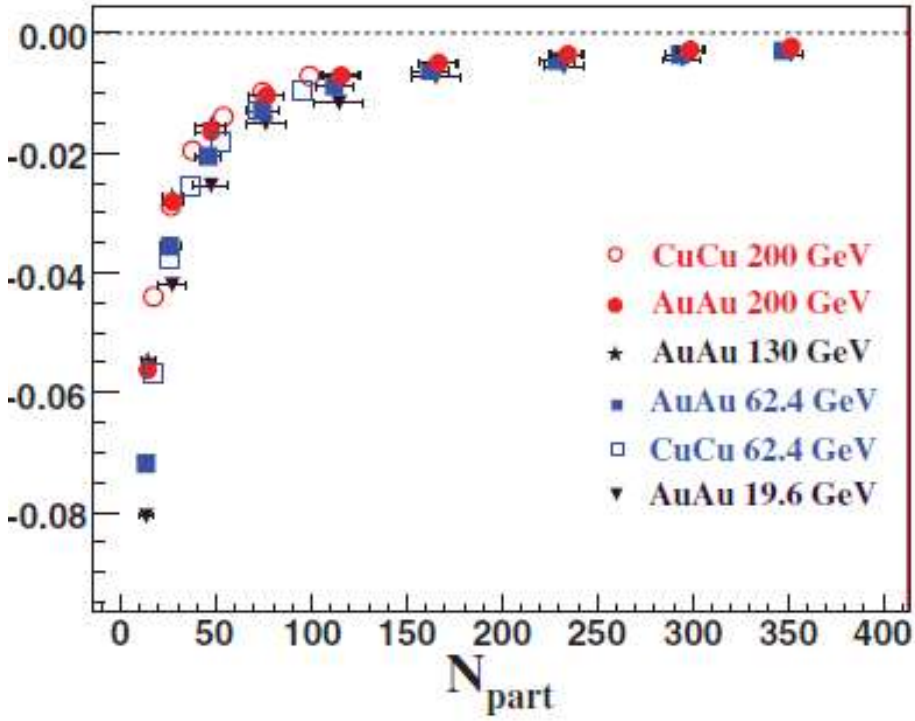
The primary physics task of STAR is to study the formation and characteristics of the quark-gluon plasma (QGP), a state of matter believed to exist at sufficiently high energy densities. Detecting and understanding the QGP allows us to understand better the universe in the moments after the Big Bang, where the symmetries (and lack of symmetries) of our surroundings were put into motion.

Unlike other physics experiments where a theoretical idea can be tested directly by a single measurement, STAR must make use of a variety of simultaneous studies in order to draw strong conclusions about the QGP. This is due both to the complexity of the system formed in the high-energy nuclear collision and the unexplored landscape of the physics we study. STAR therefore consists of several types of detectors, each specializing in detecting certain types of particles or characterizing their motion. These detectors work together in an advanced data acquisition and subsequent physics analysis that allows final statements to be made about the collision [20].

Strong VBLHEP collaboration with physicists from WTU Warsaw under leadership of Prof. J. Pluta is doing analysis of correlations of two identical and non-identical particles. The goal of this study is to estimate sizes and dynamics of sources emitting such particles in proton-proton and nucleus-nucleus collisions at energies from few GeV/nucleon up to 200 GeV/nucleon [21-29].



Theoretical basis of such studies was founded by VBLHEP physicists G.I.Kopylov, M.I.Podgoretsky, R.Lednicky and others.



Dynamical net charge fluctuations of particles produced within pseudorapidity $|\eta| < 0.5$, as function of the number of participating nucleons. From [22].

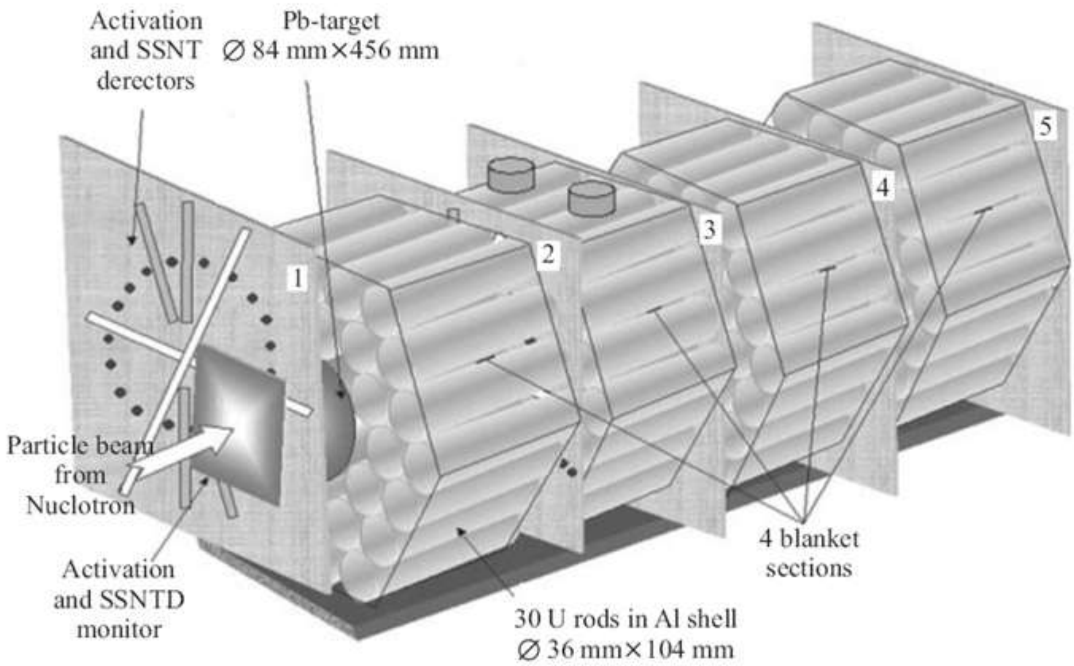
In particular, the measurements of net charge fluctuations in Au + Au collisions at $\sqrt{s_{NN}}$ = 19.6, 62.4, 130, and 200 GeV, Cu + Cu collisions at $\sqrt{s_{NN}}$ = 62.4 and 200 GeV, and p + p collisions at $\sqrt{s}$ = 200 GeV were obtained in [22] using the dynamical net charge fluctuations measure. It was observed that the dynamical fluctuations are nonzero at all energies and exhibit a modest dependence on beam energy. Weak system size dependence is also observed. The collision centrality dependence was examined of the net charge fluctuations and it was found that dynamical net charge fluctuations violate $1/N_{ch}$ scaling but display approximate $1/N_{part}$ scaling. The azimuthal and rapidity dependence of the net charge correlation strength was studied and strong dependence on the azimuthal angular range was observed.

Common Polish-JINR works in application of fundamental results for technologies

Apart from collaboration in superconductivity applications, which is carried out within Nuclotron-M/NICA project as was outlined above, another strong collaboration is working on the border between **fundamental and applied physics.**

This collaboration, called “**Energy and Transmutation**” (E+T), carries out research within the JINR topic **“Investigation of deeply subcritical electro-nuclear systems and feasibility of their application for energy production and radioactive waste transmutation” [31,32]**.

The collaborating with JINR group from the Republic of Poland includes M.Shuta, E.Strugalska-Gola, S.Kilim, M.Bielevicz, A.Wojeciechowski. All of them are from IAE (Swerk).



Layout of VBLHEP assembly for investigation of highly under-critical atomic reactors (alternative nuclear technology) and transmutation of nuclear plant waste.

The Polish group is interested in investigation of neutron characteristics of the assemblies «lead target plus uranium blanket» (the installation «Energy plus Transmutation»), «uranium target plus lead moderator» (the installation «Quinta»), «lead target plus graphite moderator» (the installation «GAMMA-3») and “extended natural uranium target with/without graphite moderator” («EZHIK») under protons and deuterons irradiation by Nuclotron beams with energy from 0.6 up to 6.0 GeV.

Their main goal is verification of the method of spallation neutron spectrum determination with yttrium activation samples. Another goal of this collaboration is information on neutron energy spectra and their spatial distribution as well as investigation of opportunities for nuclear energy production and simultaneous transmutation of radioactive wastes on the basis of semi-infinite targets from natural uranium and thorium.

Cooperation of VBLHEP and Poland in education goes within the above-mentioned program ***“Towards the extreme baryon densities”***. Under the program using opportunities offered during annual practical work, organized together with the JINR University Center, exchange of students from Faculty of Physics of WTU in Warsaw is foreseen under supervision of Profs. Jan Pluta and Wiktor Peryt. The list of topics for diploma, magister and PhD Theses which can be prepared during the student’s practical work in VBLHEP was agreed and is available from UNC web-cite.

It was established the agreement with Prof. J. Pluta from Polish side and Prof. Yu. Panebratsev from the JINR side about collaborating work on development of educational computerized tools and interactive programs on high energy physics for Polish and Russian educational institutions.

Recent publications of VBLHEP-Polish collboraton

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5. **I. Malinowska, B. Marczewska**, **„*Zastosowanie metod spektroskopowych w analizach TLC. – Nauka i Przemysł – metody spektroskopowe w praktyce – nowe wyzwania i***

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3. Education of Polish specialists and students in Dubna

JINR's international character, its scientific schools, and its basic research facilities make up the grounds for its successful research activity. But JINR's development as a really international organization should also be based on the continuous inflow of the gifted youth from JINR Member States. It is exactly the task of the **JINR University Centre** (the UC) to make for this inflow. The main fields of the UC's activity include organization and conduction at the Institute's level of international actions like ***student practices and schools***; organization of visits to JINR for students, postgraduates, and secondary school pupils of JINR Member States; attracting to JINR graduate students from its Member States and other countries for doing diploma work and organization of their studies.


At the JINR University Centre laboratories (left) and lectures (right)

The International Student Practices have been organized every year since 2004 on the initiative of the UC, Moscow Engineering Physics Institute, Moscow Institute of Physics and Technology, a number of Polish universities, and the Czech Technical University in Prague. The practices are intended for graduate students of the JINR Member States and the countries that have government-level agreements with JINR. The practices are held in the summer during the student holidays.

The practices are two or three-week long. They are held so that the students would get the fullest possible information on the research performed at JINR, would perform short student research work at JINR's basic facilities; get acquainted with JINR's scientists and find for themselves their prospective scientific supervisors (those students who would like to come to JINR later for longer time to perform their diploma work or enter the JINR postgraduate studies); attend lectures by leading scientists on current issues of physics. Dr. W. Chmielowski is the Poland Republic contact person responsible for the student-related activities.

The BLTP has very good traditions of organizing International workshops and schools in Dubna. The DIAS-TH project (Dubna International Advanced Schools of Theoretical Physics) is a sort of specialized superstructure under BLTP which organizes and controls all educational programs for students, postgraduates, and young scientists. It functions continuously and the standard schools (about 3-4 in a year) are organized coherently. Other educational programs in Dubna, such as the JINR University Center (mainly addressed to students preparing to work in experimental groups) are correlated with DIAS-TH (common programs on modern theoretical physics, workshops for students and young scientists, etc.). In a bit more details the main goals of DIAS-TH project are the following:

- Training courses for students, graduates, and young scientists in the Member-States and other countries (according to special agreements and grants);
- Looking for and supporting gifted young theorists in the JINR Member-States; creating databases of students and young researchers;
- Organization of schools of different scales in Dubna and coordination with similar schools in Russia Germany, and other European countries;
- Support of the JINR experimental programs by organizing lecture courses and review lectures on new trends in modern physics;
- Cooperation with the University Center in training students and postgraduates as well as in organizing schools for students;
- Cooperation with existing training programs in mathematics and physics for gifted schoolchildren (there are at present two such high - level programs acting in Dubna);
- Coordination of the research - training programs with workshops and conferences at JINR;
- Coordination with the schools and workshops supported by European community, UNESCO-ROSTE and other organizations;
- Publication of lectures and discussions in different forms, in particular, with the use of modern electronic equipment, etc.

During 2008-2010 about 20 young scientists and PhD students from Poland took part in the Dubna International Advanced Schools of Theoretical Physics Schools organized within the project **DIAS-TH** in JINR by leading scientists of Bogoliubov Laboratory of Theoretical Physics.

Some most important positions of the **Programmes for Students and Postgraduates from the Republic of Poland at the JINR in 2008–2010 are the following.**

In 2008. Eight master theses were written at FLNP and FLNR during the year by students from University of Opole.

Twenty-two university students from Lublin took part in the first targeted professional practical work “Radiological protection and nuclear safety” organized at JINR on 10–18 February.

Teachers and students (a total of 15) of secondary schools from Poznan, Leszno, Olsztyn, Swinoujscie, Tarnowskie Gory, Sulecin, and Busko-Zdroj visited JINR over the period 18–30 June.

Twenty-four students and postgraduates from universities of Warsaw, Krakow, Wrocław, Poznan, Opole, and Szczecin participated in the International Students’ Practical Work for students and postgraduates from Poland in the fields of research carried out at JINR, which was organized by the JINR University Centre on 10–28 September.

2008. Dubna, 11–17 February. Polish students attending the courses «Nuclear Safety and Radiation Protection» on an excursion at the Veksler and Baldin Laboratory of High Energy Physics

Photos from Practice in JINR Fields of Research for Polish Students in September 2008

Six students from University of Opole took part in the scientific excursion "Basic facilities and major lines of research at JINR" held on 4–11 October.

A review seminar for school and university students and postgraduates who visited Dubna in 2008 was held at Adam Mickewicz University in Poznan on 18–19 October. There were 50 participants from Poland and Dubna, among them staff members and executives of the university and the General Consul of the Russian Federation in Poznan.

A total of 75 Polish students, postgraduates, teachers and school students visited Dubna in 2008. The expenditures for these events within the Bogolyubov–Infeld programme amounted to 48 800 USD.

In 2009. During this year university students from Poznan, Rzeszów, and Toruń prepared five master theses, and D.Nowak (FLNP) defended the candidate of sciences thesis.

Nine university students from Lublin took part in the second targeted professional practical work "Radiological protection and nuclear safety" organized at JINR on 22 February–1 March 2009.

Four teachers and ten students of nine Polish schools came on a scientific excursion to JINR over the period 22 June–2 July.

Twenty-one students and postgraduates from the universities of Warsaw, Krakow, Wrocław, Poznan, Szczecin, and Zielona Góra took part in the International Summer Practical Work for Students and Postgraduates.

Participation of 24 students and postgraduates from ten Polish institutes in the V International Summer School "Nuclear physics methods and accelerators in biology and medicine" held at Bratislava University on 6–15 July was supported by the Bogolyubov–Infeld programme. The proceedings of the School were published by the American Institute of Physics. Among the lecturers at the School were Polish scientists A. Dobzek? Анджей Добек and M. Kruzhinski? Михал Кужински from Adam Mickewicz University (Poznan).

In October, the participants in the educational programmes at JINR met at the traditional final seminar in Poznan. In 2009, a total of 73 Polish students, postgraduates, teachers and school students took part in various educational programmes organized by JINR and supported by the Bogolyubov–Infeld programme. The total expenditures within the program amounted to 59 526 USD.

In 2010. Nineteen university students from Lublin took part in the third targeted professional practical work "Radiological protection and nuclear safety" organized at JINR on 11–20 April.

Ten students from the AGH–UST Student Scientific Society group on physics visited JINR on 17–25 May. They listened to four talks by Polish scientists and two talks by Russian scientists and went on an excursion to Moscow, Sergiev Posad, and Mednoe.

In June, 16 Polish students and teachers came to Dubna for one day from Dmitrov, where they participated in the scientific visit to the Dmitrov Professional College.

Three teachers and four students from four Polish schools came on a scientific excursion to JINR on 19–29 June.

Twenty-one students and postgraduates from the universities of Warsaw, Lodz, Krakow, Wrocław, Poznan, Toruń, Warsaw and Wrocław Universities of Technology participated in the International Summer Practical Work for Students and Postgraduates.

In October, the participants in the educational programmes at JINR met at the traditional final seminar in Poznan.

On 21–22 November, deans of faculties of physics of Polish higher education institutions and directors of physics research institutes met at the regular session of their Forum in Poznan. The officials of the Bogolyubov–Infeld programme delivered a report on cooperation of JINR with Polish research centres and universities in the field of education. The Forum highly appreciated the effectiveness of the Programme and proposed that new forms of cooperation should be developed (e.g., targeted scientific practical work for Polish university graduates to familiarize them with various directions in the research carried out at JINR).

In 2010, a total of 78 Polish students, postgraduates, teachers and school students took part in various educational programmes organized by JINR within the Bogolyubov–Infeld programme. The total expenditures within the program amounted to 547 308 USD.

JINR University Centre, February. Students of the Marie Curie-Sklodowska University (Lublin, Poland) at a practice class

Czech Prof. I. Ulehla has once said: ***“The Joint Institute has helped educate many of our specialists not only in nuclear physics or high- and low-energy physics themselves but also in areas of mathematics, chemistry, and technology related to theoretical and experimental problems in nuclear physics.”***

Today we can undoubtedly conclude that this very important process still under well developing way at JINR.

4. Closing remarks and Future

Nowadays the internal development of the modern science, in particular, the high-energy particle and nuclear physics as well as modern condensed matter and biological physics, strongly forces scientists from different countries to join their efforts in the fields.

Therefore the fields of the science inevitably acquire the international character. It is this character over the 55 years has been the main feature of the JINR. The character has allowed JINR to survive and to bypass all obstacles of the “wrong” years of the last decades. Today JINR has ambitious 7-year plan for future development and the full budget to successfully fulfill it.

The Republic of Poland is one of the oldest JINR Member-state and simultaneously one of the most important scientific JINR partner. It is right place to repeat the important message that JINR-Polish connections are very tight. Since the very beginning the Polish scientists strongly contributed in genuine development of JINR. It is impossible to overestimate the contributions of famous Polish physisits L.Infeld, H.Niewodniczanski and A.Soltan, Marian Danysz, A. Hrynkiewicz, A.Budzanowski, J. Bartke, Mieczyslaw Sowinski and many others, who held high posts of JINR ruling bodies.

Many Polish physicists have started their scientific careers and have gained great experience at JINR. Today they have continued fruitful collaboration with their Dubna colleagues and share their experience in many Polish universities and institutes. Furthermore there is a group of new generation of Polish scientific leaders who were educated and matured at JINR. These people determine further development of many important scientific directions in the Republic of Poland and in JINR.

One of the main goals of the JINR is to educate, to mature national specialties for JINR Member-states. Republic of Poland is between the leaders in this process. It is enough to note, that at least during the last 3 years more than **220** Polish students have passed Students’ Summer Practice at JINR. Some of them have already defended their diploma thesis on the JINR-based research. The other decided to work further at JINR for their PhD thesis. During the last several years some young Polish scientists have appeared as JINR staff-members at DLNP, FLNP, BLTP, the other young Polish scientists work on very tight basis with their JINR colleagues. The number of Polish staff-members at JINR today has reached 21 persons in 2010 (5th position between all 18 JINR member-states).

The reason is clear – the JINR-Polish collaboration in general runs on the right track of development in the most perspective and most important scientific directions of the fundamental and applied physics. The booklet has clear demonstrated the point.

Finally, one can see that the history of nuclear physics developments, the people relations and interests, the science preferences and ideas, the education priorities and ambitious future plans are intrinsically very common for polish scientists and the other JINR Member-state scientists and specialists. We all have already gained very good experience in the field, we do the same exiting work, and the best way is to do it further together.