NCBJ HIGHLIGHTS 2021 2022

NATIONAL CENTRE FOR NUCLEAR RESEARCH
ŚWIERK

Polish Scientific Institution

GENERAL INFORMATION

NCBJ since 2011 (IBJ since 1955)

GENERAL INFORMATION

The National Centre for Nuclear Research is a Polish research institute that is a state legal entity. It is supervised by the Minister of Climate and Environment and subsidized by the Ministry of Education and Science.

Postal address:

Narodowe Centrum
Badań Jądrowych
ul. Andrzeja Sołtana 7
05-400 Otwock, Świerk
Poland

Warsaw site:

Pasteura 7
02-093 Warszawa

Warsaw IDEA site:

Wołodyjowskiego 83
02-724 Warszawa

Secretary's Office

phone: +48 22 27 31 001
fax: +48 22 77 93 481
e-mail: ncbj@ncbj.gov.pl

Spokesman

phone: +48 512 583 695
e-mail: rzecznik@ncbj.gov.pl

Spokesman, Nuclear Power

phone: +48 22 27 31 305
e-mail: andrzej.strupczewski@ncbj.gov.pl

A WORD FROM THE DIRECTOR

The years 2021 and 2022 were a very busy period. After the very difficult "lockdown" period caused by the COVID-19 coronavirus pandemic, which mainly affected NCBJ's commercial activities, in 2021 and 2022 the Institute's financial situation became more stable.

In order to maintain the continuous operation of the Institute during the COVID-19 period, ensure the safe operation of the reactor and nuclear installations, and minimize the risk of contamination, it was necessary to introduce new solutions both in terms of work organization and communication.

These new solutions, especially in the field of IT, will stay with us for longer and are now partially adopted as standard procedures at NCBJ.

Despite the new risks related to the Russian invasion of Ukraine and inflation, the dynamics of NCBJ's development did not slacken. In the years 2021-2022, NCBJ continued three large infrastructure projects: POLFEL – the Polish Free Electron Laser, CERAD – the Center for Design and Synthesis of Molecularly Targeted Radiopharmaceuticals and CENTRIX – an Industrial Radiography Laboratory.

The recruitment process for the NOMATEN Centre of Excellence for New Materials (established as a separate department at NCBJ in 2020, funded by a TEAMING European grant and a Polish Foundation for Science, FNP, grant) was finally completed.

The research staff at NCBJ developed dynamically. In the years 2021-2022, 9 doctorates and 2 habilitations were awarded, and 2 members of staff received the title of professor from the President of the Republic of Poland. We were also pleased with the high number of new and ongoing projects.

In the years 2019-2020, the Institute carried out the GOSPOSTRATEG project, under which preparatory work was carried out in the field of the technology of high-temperature gas-cooled reactors (HTGR). A new contract for the implementation of HTGR design work for a demonstrator of this technology – a small HTGR reactor in Świerk – was signed in May 2021 between MEiN and NCBJ. The project, worth PLN 60 million, is now under implementation in cooperation with Japan. This project opens the possibility of building a new, fourth generation reactor at NCBJ in the coming years and greatly expands the scope of NCBJ's competences in the fields of physics and nuclear reactor design. It will also allow us to equip the materials laboratories necessary for testing elements of nuclear technologies, including those supporting the Polish Nuclear Power Program.

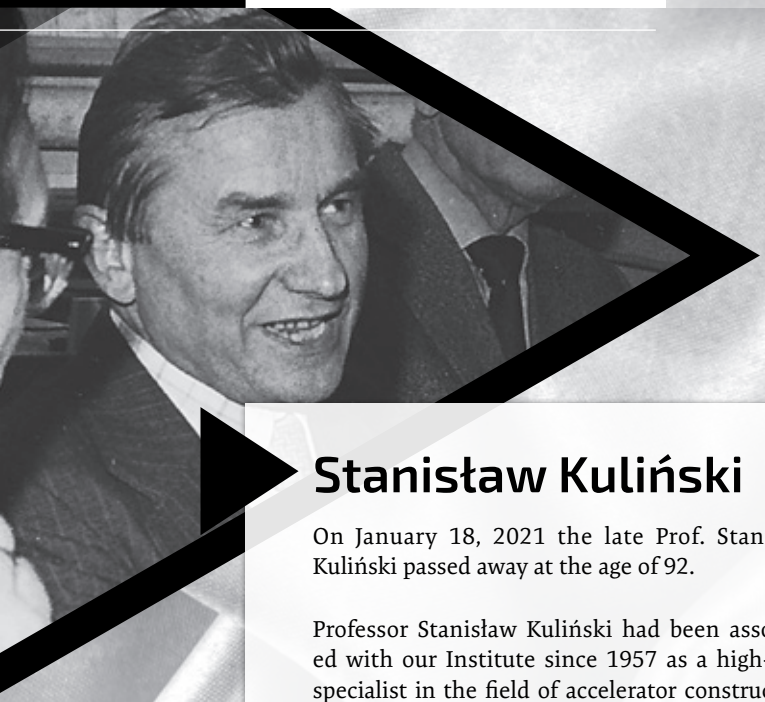
The Accelerator Division of NCBJ, HITEC, obtained a very prestigious award in 2022 – "Teraz Polska" (Now Poland) together with our industrial partner the PiD company for a specialized radiographic accelerator system dedicated to border inspection and installed at the Polish-Bielorussian border in Kuźnica Białostocka. The system is used for cargo train inspections.

In September 2022 the MARIA reactor was stopped due to preparations for the planned modernization of its electric systems. This is a part of big modernization program of the MARIA reactor, accepted by the Polish government with dedicated funding (around PLN 100 million for 7 years) which will allow MARIA to operate safely for at least the next 15 years.

I am sure that NCBJ will continue to develop dynamically in the coming years and will maintain the highest level of basic and applied research as well as competences in the field of very demanding nuclear technologies.

Krzysztof Kurek

Director of NCBJ

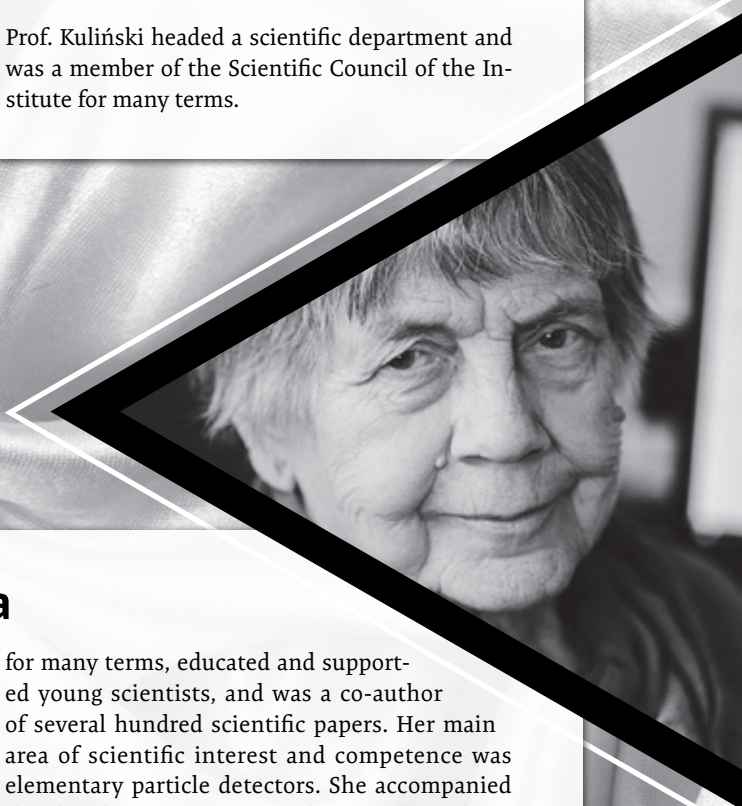


Stanisław Kuliński

On January 18, 2021 the late Prof. Stanisław Kuliński passed away at the age of 92.

Professor Stanisław Kuliński had been associated with our Institute since 1957 as a high-class specialist in the field of accelerator construction. Among other things, he actively participated in the construction of the 10 MeV linear proton accelerator in Świerk, took part in the work on the U-200P isochronous cyclotron, and implemented 4 and 10 MeV accelerating structures for dozens of linear electron accelerators. Thanks to his professional and organizational successes, three linear electron accelerators (LNF, Irvin Elettronica), a high-power electron gun (Elettra Triest) and a special microwave generator for ultra-fast diagnostics of beams in the nanosecond range (LNF Frascati) were created in Świerk at the request of Italian institutions.

Prof. Kuliński headed a scientific department and was a member of the Scientific Council of the Institute for many terms.



Maria “Hula” Szeptycka

On January 23, 2022 the late Prof. Maria “Hula” Szeptycka passed away at the age of 85.

Professor Maria Szeptycka was associated with our institute for almost 60 years. She was an active participant in research groups conducting experiments in high-energy physics, especially at CERN and JINR-Dubna, headed a research department, sat on the Institute's Scientific Council for many terms, educated and supported young scientists, and was a co-author of several hundred scientific papers. Her main area of scientific interest and competence was elementary particle detectors. She accompanied the development of these devices throughout her scientific career, used them for analysis and shared her broad and in-depth knowledge of them with generations of colleagues.

Ludwik Dobrzyński

Small doses of radiation appreciated!

On January 10, 2022 the late Prof. Ludwik Dobrzyński passed away at the age of 85.

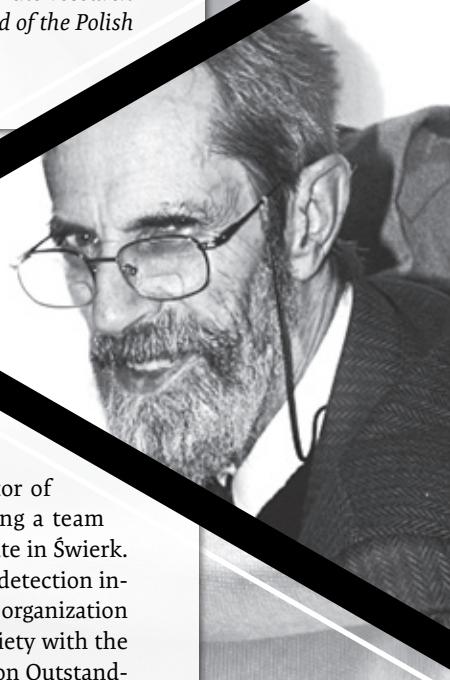
Most of Professor Dobrzyński's scientific life was related to our Institute: he began his scientific career here in 1963, here he built our competences in the field of nuclear methods in solid state physics, here he was active in Solidarity, for which he paid the price, and finally he created here an educational center unique on the European scale familiarizing young people and teachers with difficult issues related to nuclear energy and radiation.

Professor Dobrzyński worked very intensively in Poland and on the international arena to rationalize the approach to the threats related to ionizing radiation and nuclear energy. He was an advocate of taking into account both in law and in practice knowledge of radiation hormesis. From 2002 he was a member of the Polish delegation to the meetings of UNSCEAR (United Nations Scientific Committee on the Effects of Nuclear Radiation), and from 2009 its vice-chairman.

Professor Dobrzyński was the author of about 300 scientific papers, supervisor of doctoral theses, and a member of scientific committees and organizations. He popularized knowledge willingly and with enthusiasm, organizing competitions, events, giving numerous interviews, and recording lectures.

Small doses of radiation appreciated!

When the body first receives a small dose of ionizing radiation, and after some time a second, much larger dose, the risk of negative effects will be lower than if it received only the latter. The phenomenon, known as the Raper-Yonezawa effect, was successfully described by scientists from the National Centre for Nuclear Research in a paper co-authored by Professor Ludwik Dobrzyński. In 2022 the research was honored with the prestigious award of the Polish Radiation Research Society.



Marek Moszyński

On December 27, 2022 the late Prof. Marek Moszyński passed away at the age of 84.

Professor Marek Moszyński was a world authority in the field of research into the detection and spectroscopy of ionizing radiation, in particular in research on scintillator materials. He was the co-inventor of the world's first PET tomograph using information on the time of flight of gamma annihilation quanta and the discoverer of the fast component of the light pulse of barium fluoride - an inorganic scintillator used for decades to detect light signals with nanosecond time resolution.

In recent years, he was actively working on the characterization of new photodetectors and on the practical use of scintillation techniques. He was a master and educator of two generations of scientists, creating a team unique on a global scale at the institute in Świerk. His contributions to the scintillation detection industry were recognized by the global organization IEEE Nuclear and Plasma Science Society with the Glenn Knoll Radiation Instrumentation Outstanding Achievement Award.

CONTENT

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CANIS wins the TERAZ POLSKA competition

The system for non-invasive inspection of large-size goods, CANIS, a joint project between PID Polska and the Nuclear Apparatus Department of NCBJ, was this year's winner of the Teraz Polska emblem in the innovation category. The heart of the device was created at Świerk, i.e. the accelerator, the source of the gamma ray scanning beam.

This solution is unique on a global scale as it allows for efficient and simultaneous scanning of goods of various densities. Constructed and built in the NCBJ Nuclear Equipment Division (HITEC), a dual-energy accelerator dedicated to the MultiControl CANIS system enables smooth real-time beam energy changes over the full energy range, i.e. from 2 MeV to 9 MeV. Thanks to this, it is possible to scan loads of different densities such as: polyurethane foam, plastics or polymer composites, which are characterized by low density, as well as objects of high density, such as: non-ferrous metals, steel or blocks of special reinforced concrete. The solution enables the control of the load in a non-invasive, quick and precise way. Border control services – and others – now have an invaluable tool to detect undeclared goods, contraband, weapons and works of art. MultiControl CANIS enables the inspection of cargo, railway wagons and large-size vehicles. CANIS is currently the main product of MultiControl.

The accelerator beam, changing energy with a frequency of up to 1000 Hz, allows the smallest detail in the analyzed image to be captured. High image quality is also a solution based on precise scintillators and linear detectors. The entire system was individually tailored to the customer's needs. Acceleration of image interpretation through pre-processing or control of the radiation source through the user panel using the auto-calibration process and beam angle adjustment are just some of the solutions used in the system.

When designing the system the creators were assisted by the Polish customs service, making use of submitted comments and trying to find solutions best suited to real needs. The MultiControl CANIS system has been operating since 2019 at the railway border crossing at the external border of the European Union in Kuźnica Białostocka. During this time it has repeatedly proved its usefulness by detecting, for example, attempts to smuggle cigarettes.

High position of NCBJ in the Nature Index ranking

NCBJ was classified in fifth place in Poland in the Physical Sciences category of the Nature Index ranking for the period October 1, 2021 – September 30, 2022. The ranking is based on research papers published in the period analyzed: a point is assigned if one or more of the authors of a research article are from the institution concerned. Only the most influential scientific journals are taken into account in the calculations.

Top 2% ranking

Stanford University, together with the publishing house Elsevier and SciTech Strategies, has created a ranking of the top 2% of scientists in the world. It contains about 194 000 names, including 1000 from Polish scientific institutions. Among these are the following professors employed at NCBJ: Andrzej Deloff, Jerzy Kowalski-Glikman, Andrzej Królak, Stanisław Mrówczyński, Leszek Roszkowski and Grzegorz Wilk. The list also includes the late Professors Adam Sobiczewski and Marek Moszyński. The "Top 2%" ranking uses a complex methodology, including 6 basic indicators. The most important are the number of citations and the Hirsch index. Scientific activity in various fields within a research team is also considered to be a major asset.

The ranking also presents the top 2% scientists of the past year. Among these are seven NCBJ employees: Grzegorz Wilk, Guillaume Beuf, Stefanos Papanicolau, Andrzej Królak, Stanisław Mrówczyński, Leszek Roszkowski and Marek Moszyński.

Eighth place in Poland among universities in the CWUR ranking

The World University Ranking 2021-2022 places NCBJ among the top 4.5% of 19,788 universities worldwide, in eighth position in Poland, even though we conduct only higher degree studies. The rankings are unique:

- Objective indicators are used for all four key pillars underlying the ranking methodology (quality of education, employment of graduates, faculty quality, and research results) excluding the surveys and university data submitted.
- There is an equal emphasis on the learning and research environment.

The position was determined primarily by NCBJ's high scientific results, which gave 40% of the points in the ranking.

NCBJ is one of the best companies in Mazovia

The europejskafirma.pl portal announced its list of Great Modernizers 2020 of the Mazowieckie Voivodeship. NCBJ was honored with this title as one of 652 entities with the highest scores among over 85 thousand Polish entrepreneurs. The analysis covered financial data and company values.

It is worth noting that only four scientific institutions were classified in the top 100 winners, including NCBJ in 71st place. Only the University of Warsaw and Warsaw University of Technology were ranked higher.

Science and Technology Park Świerk has been accredited by the Mazovian Business Environment Institution (IOB)

IOBs support entrepreneurs, in particular micro, small and medium-sized enterprises, in contacts between science and business. They deal with consulting and researching the company's needs. They offer assistance in applying for programs (related to, among others, technology transfer) on a national and international scale. Science and Technology Park Świerk has been accredited for two years.

Dr. Sebastian Trojanowski has won the 2022 Polityka Science Award

Dr. Trojanowski is an employee of the Theoretical Physics Division (as well as the Astronomical Center of the Polish Academy of Sciences). The prestigious Scientific Awards of “Polityka” - one of the largest opinion-forming weeklies in Poland - are awarded by the cooperating chapters: "professional" and "citizen". The latter consists of outstanding personalities in public life. The achievements of Dr. Trojanowski include the co-design of a new experiment at the LHC, FASER, which will search for dark matter particles. It will be located in the unused LHC service tunnel 480 m downstream of the proton-proton interaction point of the ATLAS experiment. The FASER detector will be sensitive to new particles if they decay in its volume.

Dr. William Pearson has received a scholarship for outstanding young scientists

Dr William James Pearson from the NCBJ Astrophysics Division received one of the 2022 scholarships from the Minister of Education and Science for outstanding young scientists demonstrating significant achievements in scientific activity. Dr. Pearson’s work was focused on the formation and evolution of galaxies using modern machine learning methods. He has improved the XID+ tool that deblends far-infrared objects and he was the first person to conduct a study using galaxy mergers identified with deep learning. Dr. Pearson is one of three young scholars awarded in the astronomy category.

Minister's scholarship for Dr. Paweł Sznajder

Dr. Paweł Sznajder from the NCBJ Theoretical Physics Division received a three-year scholarship from the Minister of Education and Science for outstanding young scientists demonstrating significant achievements in scientific activity in 2021. Dr. Sznajder is interested in the phenomenology of GPDs. This applies in particular to the development of methods for global analysis of experimental data. Due to the complexity of this issue, the analyses published by Dr. Sznajder are some of the few of this type and are characterized by high innovation due to the numerical methods used, such as neural networks, genetic algorithms and error propagation methods based on the so-called data replication. One of the key elements of these studies is the reduction of model uncertainties, which often make it impossible reliably to assess the properties of the nucleon's structure.

Award for gravitational essay

Professor Jerzy Kowalski-Glikman from the NCBJ Division of Theoretical Physics, together with three co-authors, won the 2022 second prize for Essays on Gravity. The competition has been organized since 1949 by the Gravity Research Foundation. The winning paper is entitled "Infrared Quantum Gravity Phenomenology". The authors focus their discussion around the concept of quantum gravity, including the concept of quantum space-time, which appears in metastring theory. This theory makes it possible to describe the evolution of a cosmological universe in which the dual degrees of freedom of strings decouple as the universe ages. Importantly, such an implementation of quantum gravity allows the inclusion of a fundamental length scale without introducing Lorentz symmetry violation at the fundamental level. In conclusion, the authors point out that the mechanism they describe may represent a completely new source of dark matter/energy.

Prof. Michał Kowal member of the Scientific Council of GANIL

Prof. Michał Kowal, Head of the NCBJ Theoretical Physics Division, joined the Scientific Council of the French research center GANIL (French: Grand Accélérateur National d'Ions Lourds – Large National Heavy Ion Accelerator). The GANIL Scientific Council meets annually to review the condition of the accelerators and current and future instrumentation. The board make recommendations to the GANIL management on priorities.
Scientists from NCBJ take part in the work at GANIL, mainly by developing theories and predictions for the experiments conducted there.

Prof. Wojciech Wiślicki represents Poland on the Advisory Board of the CERN Quantum Technology Initiative

Prof. Wojciech Wiślicki, Director of the Complex Systems Research Department at NCBJ, was nominated by the representatives of the CERN Council as a member of the CERN QTI (Quantum Technology Initiative) Advisory Board. Prof. Wiślicki, as one of the 22 members of the Council composed of experts in the field of quantum technologies, will, together with the Program Management Team, build and conduct both national and international activities and cooperation in the field of quantum technologies.
Together with the development of the use of quantum effects in computing technologies, research institutes are launching projects to implement such technologies in their research activities and, in the future, in infrastructure. This leads to the development of quantum technologies, and may also improve research processes.

Prof. Marek Rabiński as the new President of the Polish Nuclear Society

On April 17, 2021 Dr. hab. Marek Rabiński from the National Centre for Nuclear Research was appointed President of the Polish Nuclear Society (PTN).
During the 15th PTN Congress, the newly appointed President in his speech drew attention to the need to present the opinions of the atomist community when decisions are made related to the Polish nuclear energy program, the need to present cooperation in this field with other associations and social environments, and the need to intensify the activities of the rising generation of nuclear power engineers.

The achievements of Prof. Sławomir Wycech appreciated at a special session

At ECT, Trento, a working session was held at the end of May devoted to the interaction of "strange particles" with atomic nuclei, K-meson atoms, hypernuclei and the role of strange particles in the structure and size of neutron stars.
The organizers devoted one day of the session to lectures on the scientific achievements of Professor Sławomir Wycech from the NCBJ Theoretical Physics Division.
The results of research conducted by Professor Wycech, concerning the understanding of K-meson atoms, the search for baronium (proton and antiproton bound states), the search for eta-meson nuclei, the study of the surface of atomic nuclei and understanding the nature of the interaction of the K meson and proton, were reported.

NCBJ's annual recognition of outstanding scientific and organizational achievements

2021

Scientific achievements

- Katarzyna Małek for a collection of publications summarizing the HELP (Herschel Extragalactic Legacy Project) project, in which she led a working group on the determination of the physical properties of galaxies.
- Jacek Rzadkiewicz and Karol Kozioł for a series of publications in the field of atomic physics on the depopulation of nuclear isomer states and the development of multiconfiguration Dirac-Fock computational methods for exotic atomic systems.
- Karol Kowal for numerical reliability analyses for the fusion neutron source and the high-temperature nuclear reactor.
- Małgorzata Frelek-Kozak for a series of scientific articles on the study of the mechanical properties of radiation-damaged alloys.

Research and technical achievements

- A team led by Marek Migdal (Marek Migdal, Maciej Lipka, Piotr Mazerewicz, Anna Talarowska, Grzegorz Wojtania, and Antoni Zawadka) for the design, construction, and commissioning of a high-temperature probe in the MARIA reactor.
- M. Maurin, I. Cieszykowska, and W. Wojdowska for the preparation of production facilities for the production of investigational medicinal products (IMPs) and the extension of the GIF permit for the production of investigational medicinal products in the form of sterile lyophilizates and small-volume liquids in accordance with GMP requirements.

Organizational achievements

- Agnieszka Boettcher for leadership of a complex project on the technical, legal, and organizational foundations for the construction of a prototype high-temperature reactor at NCBJ.

2022

Scientific achievements

- Urszula Karczmarczyk, for her publishing activity and motivating the POLATOM team to disseminate the results of research.
- Renata Ratajczak, for a series of papers devoted to the study of defects in complex semiconductors.
- Łukasz Janiak and his team (Łukasz Janiak, Michał Gierlik, Sławomir Wronka, Rafał Prokopowicz, Gaweł Madejowski, Jacek Rzadkiewicz), for the measurement of the half-life of the isomer state of 184Re.
- Special award for young researcher - Kamil Skwarczyński, for his contribution to the analysis of neutrino oscillations in the T2K experiment.

Research and technical achievements

- Jan Klimaszewski and his team (Krzysztof Kacperski, Jan Klimaszewski, Tymoteusz Kosiński, Andrzej Łubian, Józef Bogowicz, Natalia Kozak, Michał Matusiak, Sławomir Wronka, Tomasz Zakrzewski), for the ISWOT backscattered photon imaging system.
- Team of Tomasz Pliszczyński, Adam Dudziński, and Grzegorz Zagórski, for the development and production of an air aerosol sampling station.

Popularization achievements

- Team award - Konrad Klimaszewski, Wojciech Krzemień (DBP), Magdalena Kośla, Agnieszka Ślązak-Gwizdała (DP), Lech Raczyński, for the organization of the International Workshop on Machine Learning and Quantum Computing Applications in Medicine and Physics in Warsaw, September 13-16, 2022.

Awards of the Director of the NCBJ Fundamental Research Department

2021

Scientific achievements

- Varvara Batozskaya for the analysis of CP symmetry breaking in Bs0 decays based on data from proton-proton collisions in the LHCb experiment.
- Marek Biesiada for proposing a new method of dark matter viscosity testing, the use of quasars in the standard candles method, and studying the velocity distribution of early-type galaxies using gravitational lensing.
- Michał Kowal and Janusz Skalski for preparing tabulated data on over 1300 superheavy nuclei.

Popularization activities

- Katarzyna Małek for numerous articles on modern astronomy in the Delta monthly.

2022

Scientific achievements

- Michał Bluj for his crucial contribution to the first measurement of the CP structure of the Yukawa tau-Higgs boson coupling.
- A team composed of Paweł Ziń and Maciej Pylak for a series of works on the properties of quantum droplets - self-bound Bose-Einstein condensates.
- Michael Romano for his series of works on star formation indexes of galaxies with redshifts up to z ~ 6, in particular, for the development of an original method for determining the content of ionized carbon [CII] in the interstellar medium.

Popularization achievements

- Miguel Figueira for a series of popular articles published in the Delta magazine, focusing on astrophysics, particularly on the mechanisms of star formation.
- Jerzy Kowalski-Glikman for his popularization of physical sciences through a series of columns published on the Pulsar portal, and for his involvement in creating the portal.

Calculations indicate a hitherto unconsidered way of producing superheavy elements

The results obtained by a team of researchers with the participation of NCBJ scientists show that the probability of fusion of a new nucleus does not decrease as rapidly with the increase of the excitation energy as previously assumed.

The heaviest nuclei are formed by the collision and fusion of nuclei of lighter elements. A complex excited system is formed, in which repulsive electromagnetic interactions and strong interactions, capable of opposing the former, compete with each other. There is a chance that after getting rid of excess energy, a system forming a stable nucleus will remain, or at least one that will live long enough to be observed and and allow determination of some of its physical properties. The new results show that the probability of fusion of a new nucleus does not decrease as rapidly with the increase in the excitation energy as was previously assumed. The calculations show that scenarios in which the expected nucleus is formed after the emission of 6, 7 or even more neutrons are still worth considering and should be taken into account by experimenters.

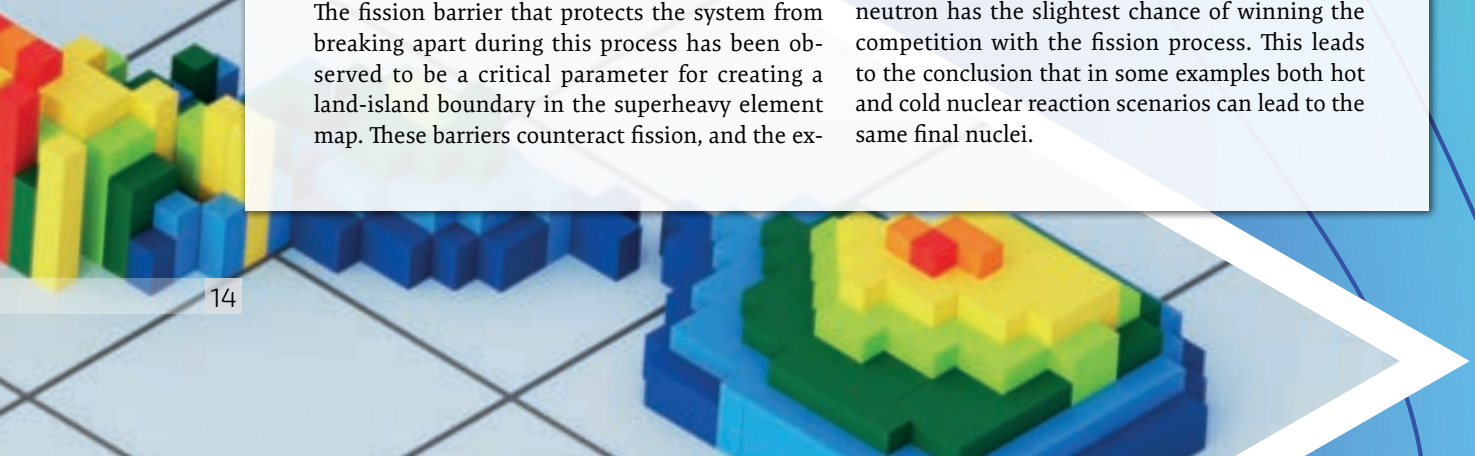
Preventing the synthesis of superheavy elements

The "cold synthesis" process can be divided into three stages. In the first stage, the projectile nucleus must approach the target nucleus sufficiently closely to overcome the charge repulsion barrier. The next stage is the fusion of the two nuclei and the formation of an excited complex nucleus. The last step is to get rid of excess energy and move to the end state. NCBJ and Warsaw University scientists argue that the intermediate stage of the reaction is responsible for a dramatic decrease in the cross-sectional area. The key importance for understanding the behavior of the fusion probability is to include in the model used the angular momentum that the system acquires during the reaction. The proposed reaction model can reproduce the observed values of cross sections for the production of nuclei of the heaviest elements.

Superheavy nuclei: between land and island

The synthesis of superheavy elements takes place as a result of heavy ion collisions. The resulting superheavy nucleus can be either strongly excited (hot) or slightly excited (cold).

The fission barrier that protects the system from breaking apart during this process has been observed to be a critical parameter for creating a land-island boundary in the superheavy element map. These barriers counteract fission, and the excess energy of the excited nuclear system resulting from the collision of the projectile and the target is removed by the emission of one, two or more neutrons. However, in the land-island border area, these barriers are extremely low, and there no neutron has the slightest chance of winning the competition with the fission process. This leads to the conclusion that in some examples both hot and cold nuclear reaction scenarios can lead to the same final nuclei.



A new theoretical description of the forced release of energy from nuclear isomeric states

The process of forced release of energy from the 93mMo isomer under ion-atom interaction conditions, taking into account the Compton profiles of target electrons, has been described. Previous theoretical approaches describing the processes of energy release from isomers under ion-atom interaction conditions were based on recombination models treating target electrons as quasi-free. Taking into account the bonding of electrons in the target atoms, new probability values for the NEEC process were obtained. The obtained result changes our perception of the nature of the process from quasi-discrete (resonant) to continuous as a function of projectile energy. The new theoretical approach, although it only slightly shifts the upper theoretical limit for the total probability of the NEEC process for the 93mMo isomer (compared to the experimental value), shows the importance of including the Compton profile in the theoretical description, in particular for the L shell of the 93mMo ion, for which the probability of energy release increases by several orders of magnitude compared to the values obtained in recombinant models.

New, most accurate lifetime measurements of the ^{184m}Re isomer

A scientific team from the Nuclear Equipment and Techniques Department of NCBJ together with experts from the US Army Research Laboratory conducted a new, successful experimental test for the production of rhenium isomers using the neutron flux of the MARIA reactor. Metallic samples of natural rhenium were subjected to a stream of thermal neutrons in the central channels of the reactor for almost a week. The researchers then conducted a series of spectroscopic measurements at a dedicated stand. By combining several passes in rhenium, 8 lines of γ reference isotopes and two different detectors, over 200 independent values of the rhenium-184m lifetime were finally obtained, on the basis of which a new reference value was determined.

The new result, 177.25 ± 0.07 days, is two orders of magnitude more accurate than the previous one (168 ± 9 days). The research was carried out as part of a project financed by the US Department of Defense and the Ministry of Education and Science.

Metal ions are also important in the plasma of fusion reactors (Assistant research highlighted)

In addition to hydrogen and helium, the plasma of fusion reactors contains a certain amount of metal atoms used in their construction, e.g. tungsten. Due to the high temperature in the plasma, metal atoms lose some of their electrons and go into excited states. Atomic spectroscopy of these metal ions gives a unique opportunity to learn about the properties of plasma structures and atomic processes leading to their formation.

The rich spectroscopic structure of multiply ionized tungsten atoms is the result of the possibility of ions occurring in many atomic states, often lying close to each other, between which various radiation transitions (including the so-called forbidden transitions) can occur. The analysis of the complex structure of energy levels of tungsten ions requires the use of precise theoretical tools. Using these tools, authors from NCBJ described the spectroscopic structure of eightfold ionized tungsten atoms, determining the energy of over 27,000 atomic levels and the intensities of over 300 million transitions between them. The result is an important step in the development of X-ray diagnostics of plasma structures in fusion reactors.

Photon races under the magnifying glass of gravity

An international team of authors investigated the possibility of Lorentz invariance violation (LIV) by analyzing time delays observed in two gamma-ray burst (GRB) candidates that had been gravitationally lensed. Using data from the Hubble Space Telescope and the Chandra X-ray Observatory, the researchers were able to measure the time delays between the arrival of photons of different energies from the GRB candidates. They found no evidence of LIV, which suggests that the fundamental symmetries of spacetime remain intact at very high energies. The study provides important constraints on theories that predict LIV and may guide future efforts to develop a theory of quantum gravity. The results also demonstrate the power of gravitational lensing as a tool for testing fundamental physics.

Artificial intelligence will track down gravity lenses

Gravitational lensing is an important phenomenon in astrophysics that provides a unique opportunity to study the properties of the universe. However, identifying strong gravitational lenses is a challenging task that requires careful analysis of large data sets of astronomical images. A team of physicists has developed a new method for identifying strong gravitational lenses using a machine learning technique called self-attention. The self-attention method involves training a neural network to recognize the unique features of strong gravitational lensing events in astronomical images. To test the effectiveness of the method, the researchers used a data set of simulated astronomical images and compared the performance of the self-attention method with other machine learning algorithms commonly used for identifying gravitational lenses. The results showed that the self-attention method outperformed the other algorithms in identifying strong gravitational lenses, achieving a higher accuracy and lower false positive rate. The researchers also applied the self-attention method to real astronomical images and identified several new strong gravitational lenses that had not been previously detected. The study highlights the potential of machine learning techniques in accelerating the discovery of strong gravitational lenses and advancing our understanding of the universe.

How heavy can a graviton be?

The mass of the graviton, a hypothetical particle associated with the force of gravity, remains an elusive concept in modern physics. A group of researchers utilized X-ray telescope data from the XMM-Newton Cluster Outskirts Project (X-COP) to measure the graviton mass. The team analyzed 13 galaxy clusters and utilized X-ray observations to estimate the graviton mass by comparing theoretical predictions with observed data. The methodology used involved estimating the cluster mass and size, which were then used to calculate the gravitational force. By comparing this force with the theoretical predictions of different models, the team was able to estimate the graviton mass. Their results provide a lower bound on the graviton mass, which is consistent with current upper limits from other experiments. The study's findings offer new insights into the fundamental nature of gravity and may have implications for the development of new theories of gravity and the search for dark matter.

Gravitational waves allow us to test the General Theory of Relativity

Scientists have successfully tested Einstein's theory of general relativity using data from the LIGO and Virgo detectors. The researchers analyzed data from the first detection of gravitational waves, which occurred in 2015, and compared it to theoretical predictions of the general theory of relativity. Nine different methods were used to verify the consistency of Einstein's theory with the observational data. No discrepancies were found. The results provide strong confirmation of the theory, which predicted the existence of gravitational waves over a century ago. The study also demonstrated the precision of LIGO and Virgo in detecting gravitational waves and the potential for gravitational wave astronomy in advancing our understanding of the universe. The researchers hope to use future gravitational wave detections further to test and refine Einstein's general theory of relativity and potentially uncover new insights into the nature of gravity and the universe. NCBJ scientists are part of the Polgraw group participating in this research.

Gravitational signals could help measure the viscosity of dark matter in the future

A new method for measuring the viscosity of dark matter has been proposed by analyzing time delays in strongly lensed gravitational waves. Scientists simulate the lensing of gravitational waves by a massive object and study the effect of the viscosity of dark matter on the time delays. They show that the viscosity of dark matter can be inferred from the time delays, and that the measurements could be used to distinguish between different models of dark matter. The proposed method offers a new way to study the properties of dark matter and may help to address some of the long-standing questions about the nature of this elusive substance.

Credit:Gabriel Pérez Díaz, SMM (IAC).

Influence of gravitational darkening on the spectrum of rotating objects

NCBJ scientists have investigated the impact of gravitational darkening on the spectral properties of rapidly rotating neutron stars. Gravitational darkening refers to the effect of gravity on the distribution of temperature and luminosity across the surface of a star. The researchers used a model of a rapidly rotating neutron star to simulate the effects of gravitational darkening on the spectrum of emitted radiation. They found that the presence of gravitational darkening can have a significant impact on the spectral properties of neutron stars, particularly for stars with high rotation rates. The results provide new insights into the behavior of neutron stars and have implications for the interpretation of observational data from neutron star systems. The findings could also help to refine our understanding of the fundamental physics of gravity and astrophysical processes in extreme environments.

The history of quasar HE 0435-5304 – distance matters!

Results have been presented of an observational study of an ultraluminous infrared galaxy (ULIRG) known as HE 0435−5304, which is a gravitational lens system with four images of the background quasar QSO 0435−530. Researchers used high-resolution near-infrared spectroscopy to investigate the active galactic nucleus (AGN) in this ULIRG and found that it has a complex, multi-component emission line spectrum with distinct velocity components. The study also revealed evidence of outflows in the AGN, possibly driven by the radiation pressure from the accretion disk. The authors used a combination of techniques, including diagnostic diagrams and modeling of the line profile shapes, to classify the AGN in HE 0435−5304 as a Seyfert 2 type, which indicates an obscured AGN with a narrow-line region. The results suggest that the AGN in this ULIRG is likely powered by accretion onto a supermassive black hole, and the complex emission line spectrum indicates that the AGN is embedded in a complex environment with varying densities and ionization states.

Searching for the gravitationally lensed glow of gamma-ray bursts

This work presents a study that searches for gravitationally lensed gamma-ray bursts (GRBs) using their afterglows. The method involves using the high angular resolution of radio observations to identify potential lensed systems and then verifying them through follow-up observations. The study uses a sample of 45 long-duration GRBs detected by the Swift satellite and searches for counterparts in radio observations made by the Very Large Array. The authors identify two candidate lensed systems and perform follow-up observations with the Gemini South telescope to confirm their gravitational lensing nature. The analysis of the lensing models allows the authors to estimate the masses of the lensing galaxies and the dark matter halos. Additionally, the study uses the properties of the lensing galaxies to infer their star formation rates and finds that they are consistent with those of other star-forming galaxies. The study concludes that afterglow observations in the radio band can be a powerful tool for identifying gravitationally lensed GRBs, which can provide valuable insights into the properties of the lensing galaxies and dark matter halos.

Credit: ESA, Hubble, NASA.

Credit: Todd Mason, Mason Productions Inc. LSST Corporation

How do you weigh galaxies for the greatest sky surveys?

This work presents a method for estimating the physical properties of main-sequence galaxies at $z<2.5$ in preparation for data from the Large Synoptic Survey Telescope (LSST). The researchers used a combination of broadband photometry and spectroscopic data from the SDSS-IV/MaNGA survey to calibrate a set of empirical relations between galaxy colors and physical properties such as stellar mass, star formation rate, and metallicity. They applied these relations to a sample of $z<2.5$ main-sequence galaxies from the COSMOS survey to estimate their physical properties. The results show that the method produces robust estimates of galaxy physical properties with uncertainties comparable to those from direct spectroscopic measurements. The method is expected to be useful for characterizing large samples of galaxies in upcoming surveys.

A new method of determining distances in the universe uses quasars

A study was conducted to calibrate the Hubble diagram at higher redshifts using a model-independent approach that involved the use of quasars. Researchers analyzed a sample of quasars that had been previously observed with multi-epoch spectroscopy, allowing for the measurement of their time-variable emission line profiles. Using a novel technique, the researchers were able to measure the cosmological redshift and the time dilation of the quasar spectra, providing a distance indicator that is independent of any cosmological model. This distance indicator was then used to calibrate the Hubble diagram at higher redshifts and constrain the cosmological parameters. The results of the study suggest that the Hubble constant is consistent with previous measurements, while the matter density and dark energy density are found to be slightly lower and higher, respectively, than current concordance cosmological model predictions. The model-independent approach used in this study provides a valuable tool for future studies of cosmology, as it does not rely on any assumptions about the underlying cosmological model.

HELP – a modern standardized catalog of extra-galactic objects

An international team of researchers has provided scientists and enthusiasts with the most complete catalog of extragalactic objects to date, covering an area of over 3% of the of the sky's full solid angle and containing 170 million sources. The modeling of their energy spectra was the responsibility of the NCBJ Astrophysics Department. The Herschel Extragalactic Legacy Project (HELP) is a large-scale, multi-wavelength survey of the extragalactic sky that was conducted to study the formation and evolution of galaxies. HELP combines data from a range of telescopes and surveys, including Herschel, Spitzer, and ground-based observations, to produce a comprehensive view of the extragalactic sky in the infrared, optical, and ultraviolet wavelengths.

Credit: HELP Project.

Radio images of the young universe

The LOFAR Two Meter Sky Survey (LoTSS) has published the results of a wide-field radio survey of the northern sky using the Low Frequency Array (LOFAR) telescope. The survey covers over 10,000 deg2 of sky and was conducted at frequencies between 120 and 168 MHz, providing a unique view of the low-frequency radio sky. The survey has produced a catalog of over 300,000 radio sources, including many new sources not previously detected at higher frequencies. The catalog includes a wide range of source types, from nearby galaxies to distant quasars, and provides a valuable resource for studies of galaxy evolution, cosmology, and the intergalactic medium. The methodology used in LoTSS involves combining data from multiple LOFAR observations and using advanced data processing techniques to produce a high-quality radio map of the sky. The sources in the catalog were identified using a combination of visual inspection and machine learning algorithms, and their physical properties were estimated using multi-wavelength data from other surveys.

Giant hidden black hole discovered in the early universe

This research involved the use of multi-wavelength imaging and spectroscopic observations, using ground-based telescopes and space-based observatories. The methods employed allowed for the identification of a black hole only 1.4 billion years after the Big Bang, which was found to be approximately 10,000 times more massive than the Sun and hidden behind thick gas and dust. The study provides insight into the early stages of black hole formation and the growth of supermassive black holes in the early Universe. The findings have implications for our understanding of the formation and evolution of galaxies and the role of black holes in galaxy evolution.

A starry sky made of more than 25,000 supermassive black holes

The LOFAR LBA Sky Survey has conducted a low-frequency survey of the sky. The survey included the observation of radio sources at frequencies from 120-168 MHz and covered an area of approximately 4240 square degrees. The data obtained were processed using a custom pipeline that allowed for the detection and characterization of radio sources, including their positions, flux densities, and spectral properties. The largest and sharpest map of the sky at ultra-low radio frequencies has been obtained. It reveals more than 25,000 active supermassive black holes in distant galaxies. The survey represents a significant advance in our understanding of the low-frequency radio sky and has the potential to provide insight into a wide range of astrophysical phenomena, including galaxy clusters, radio galaxies, and pulsars.

Credit: LoLSS

Sudden death in the universe - the agony of a massive dusty galaxy as seen by its blue companion

This study focused on the multiwavelength dissection of a massive heavily dust-obscured galaxy and its blue companion at z~2. Adonis is less dusty and is not bright in the longer wavelengths of infrared bands, and together with Astarte, it forms an interesting system of opposites, which can reveal a lot about their evolution and may possibly answer the puzzle of how these massive galaxies managed to become more massive than their local environments in a very short timescale. The research involved the use of a range of imaging and spectroscopic data, including infrared, X-ray, and optical observations, as well as high-resolution simulations. The methods employed allowed for characterization of the heavily obscured galaxy and its companion, including their masses, star formation rates, and morphologies. One important conclusion of the study was that the ultramassive Astarte, which is more massive than our old and mature Milky Way, is dying; Astarte is turning its hydrogen into stars by inertia from its past when it was once a starburst too, like its neighboring Adonis.

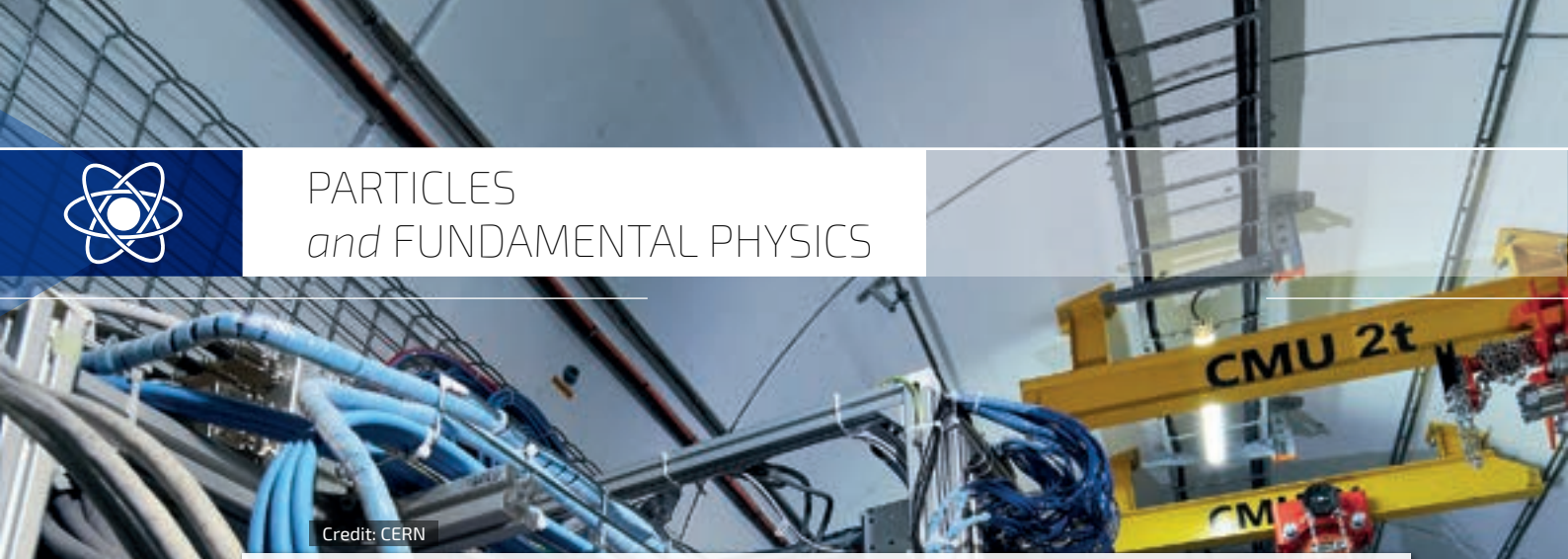
Knocking on the Dust Giants' gates

This study focused on the evolution of the dust-to-stellar mass ratio in distant dusty galaxies. The research involved the use of a sample of galaxies at redshifts of 2-6, selected from the Herschel-ATLAS and ALMA surveys. The methods employed allowed for the measurement of the dust and stellar masses of the galaxies, as well as their star formation rates and metallicities. The study revealed a significant increase in the dust-to-stellar mass ratio with redshift, indicating that galaxies were much more dusty in the early Universe. The findings suggest that dusty galaxies may have played a significant role in the evolution of galaxies and the build-up of stellar mass in the early Universe. The study provides new insights into the formation and evolution of galaxies and the processes that govern their growth and development over cosmic time.

SONATA BIS Grant: DINGLE - Dust IN Galaxies

This project, prepared by Dr. Ambra Nanni from the NCBJ Astrophysics Division, aims to model dust formation around mass-losing stars and in the interstellar medium of galaxies, and to develop a reliable description of light absorption and re-emission from dust grains. It involves the use of multiwavelength observations, including optical, infrared, and radio data. The project's methodology allows for the measurement of dust mass and temperature and the identification of dust features. The project's findings should contribute to our understanding of the physical properties of galaxies and the role of dust in their evolution.

Credit: COBE satelite



Credit: CERN

Neutrino research program at the LHC

NCBJ scientists contribute to the preparation and conducting of experiments within the LHC research program on neutrino physics. One such project is the ForwArd Search ExpeRiment (FASER), which is designed to search for new particles that may be produced in collisions at the LHC. FASER consists of detectors placed in a tunnel located about 500 meters from the collision point of the LHC. Another project is the Short Neutrino Detector (SND@LHC), which aims to study the properties of neutrinos and their interactions with matter. SND@LHC will be located near the CMS experiment at the LHC and will use a new technology to detect neutrinos. The project is expected to provide important insights into the nature of neutrinos, which may help explain the mysteries of the universe.

The authors of the FASER detector concept proposed a new direction for LHC research, which includes the measurement of high-energy neutrinos and the search for traces of new physics along the proton beam collision axis. Initial plans to build a new underground laboratory at CERN assume that it could accommodate more experiments along the axis of the collision beam. Among the experiments proposed for the new laboratory is the FASER 2 detector, which would significantly expand the discovery potential of the current detector. The authors propose a new detector called FLArE (Forward Liquid Argon Experiment), which would use liquid argon projection chamber technology directly to observe light dark matter particles. The detector would be a new tool to search directly for dark matter particles by studying their interactions at very high energies and in a laboratory-controlled flux of such particles. The idea for the FLArE detector was included in the initial engineering plans for the new laboratory and experimental discussions, including future neutrino research at the LHC.

KEK, UTokyo and NCBJ Sign MoU to Promote Hyper-Kamiokande Project

The National Centre for Nuclear Research (NCBJ) and the University of Tokyo's Institute for Cosmic Ray Research (ICRR) have signed a Memorandum of Understanding (MoU) to promote the Hyper-Kamiokande project, a next-generation neutrino observatory in Japan. The Hyper-Kamiokande project aims to study the behavior of neutrinos, which are fundamental particles that are difficult to detect but play a crucial role in our understanding of the universe. The MoU will facilitate collaboration between the two organizations in areas such as detector design and construction, data analysis, and training of personnel. The Hyper-Kamiokande project is expected to have a significant impact on the field of particle physics and astrophysics, since it will provide researchers with a more detailed understanding of the properties of neutrinos and their role in the universe. The project is expected to be completed in the mid-2020s, and will involve more than 1,000 scientists from around the world. The signing of the MoU represents a significant milestone in the development of the Hyper-Kamiokande project and highlights the importance of international collaboration in advancing scientific research.

Credit: Kamioka Observatory, ICRR, The University of Tokyo

Catching neutrinos in the Large Hadron Collider

Scientists from NCBJ Poland are among the international researchers using the Large Hadron Collider (LHC) to study neutrinos, elusive particles that play a crucial role in our understanding of the universe. The NCBJ scientists are involved in the LHCb experiment, which is designed to study b-quarks, but can also be used to study neutrinos indirectly. When a neutrino collides with a particle in the LHC, it produces a shower of other particles. The LHCb can detect these particles and use them to reconstruct the properties of the neutrino that caused the collision. The LHCb is not as sensitive to neutrinos as other detectors, but it is still an important tool for studying these elusive particles. In particular, it can be used to study the properties of neutrinos and to search for new particles that interact with them. The study of neutrinos is a rapidly evolving field, and researchers are constantly developing new techniques to study these particles. The NCBJ scientists contribute to the design and operation of the LHCb detector, as well as the analysis of data from the experiment.

Can dark matter help solve the problem of how fast the universe is expanding?

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Credit: CERN, Ordan, Julien Marius

Quantum drops - exotic, but better and better understood

Physicists from Warsaw institutions have published a series of papers describing the behavior of quantum droplets that can form in Bose-Einstein condensates. A Bose-Einstein condensate is formed when a dilute bosonic gas is cooled to an ultralow temperature, and the atoms of the gas occupy the same quantum state, exhibiting the same quantum properties. One of the distinctive properties of the Bose-Einstein condensate is that it has a vanishing viscosity, i.e. superfluidity. Quantum droplets are formed under special conditions of the Bose-Einstein condensate in which the interatomic forces lead to both attractive and repulsive interactions. Theoretical studies by the team led to a better understanding of the properties of quantum droplets. They explained that quantum droplets can be visualized as well-localized cloudlets, with sizes measured in micrometers, which behave like a strange gas that does not fill the entire vessel in which it is located. The team hopes their research will contribute to the further development of the study of quantum droplets, which have a great potential for practical applications in quantum computing and other fields.

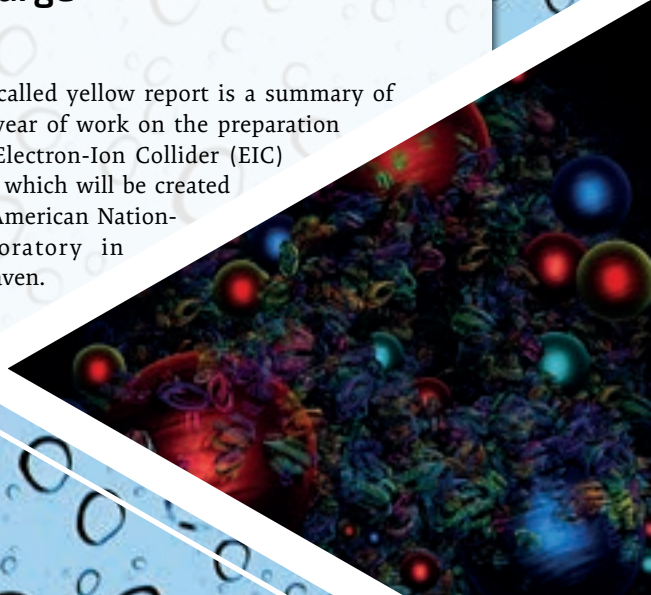
Antiprotons will help to study unstable nuclei

The PUMA experiment, which aims to study the surfaces of a series of atomic nuclei that do not exist permanently in nature, has been approved for implementation at CERN. The goal of the project is to create antiprotonic atoms, in which one of the electrons is replaced by an antiproton, and the nucleus of the atom is unstable. In the reaction, the antiproton will annihilate with the nucleus's nucleons, particularly the neutrons on the outer nuclear shell, producing several mesons that will be registered by the detectors. The identification of the resulting products and the analysis of their kinematic parameters will allow for the study of neutron halos in unstable nuclei and the evaluation of correlations between neutrons on the surfaces of the studied nuclei. The key measurements of the experiment will be analyzed at the NCBJ Theoretical Physics Division. The experiment is technically challenging, involving the production and deceleration of antiprotons in the ELENA device, followed by the trapping of the prepared particle in a magnetic trap and transportation to another device called ISOLDE, which produces unstable nuclei.

The detailed assumptions of a new large research device are created

In 2021, a yellow report was published on a new Electron-Ion Collider (EIC) to be built in the US. The report was created by scientists from over 150 institutions around the world, including NCBJ. It formulates expectations regarding the research carried out at the future device and indicates ways to create the best design for this purpose.

The so-called yellow report is a summary of over a year of work on the preparation of the Electron-Ion Collider (EIC) project, which will be created at the American National Laboratory in Brookhaven.



Credit: CERN »

Nucleon Tomography - Awaiting New Experiments (Assistant research highlighted)

Dr. Paweł Sznajder, one of the 12 assistant professors at NCBJ whose work was rewarded in 2021, is interested in the interior of nucleons such as protons, neutrons, and similar particles. The Generalized Parton Distributions (GPDs) of nucleons are related to the tensor of energy-momentum, which can help solve the spin puzzle and determine mechanical properties such as pressure distributions inside the nucleon. The author is developing a theoretical description of the processes used to measure GPD distributions while modeling these distributions based on experimental data. The program involves classical modeling methods as well as machine learning techniques such as neural networks and genetic algorithms. The work has led to the development of a tomographic image of the nucleon and criticism of previous attempts to determine its mechanical properties.

One of Dr. Sznajder's roles in the research program is the development of the PARTONS platform, which facilitates knowledge and experience exchange between theoretical and experimental researchers studying GPDs. This project is crucial for current and future experiments that determine GPDs, particularly for the upcoming Electron-Ion Collider (EIC) project in the United States.

SONATA BIS: beyond the Standard Model

There exist phenomena that are not predicted in the Standard Model framework so that developing a theory "beyond" the Standard Model and a sound strategy for its detection have become crucial endeavors. The energy scale of the new theory is unknown. It could be the extremely high energy of quantum gravity, which is well-motivated but very difficult to explore experimentally. Much closer to the energies we can probe, however, we sense the presence of particles possibly responsible for some signals which recently appeared in the LHCb detector, and many theorists believe that just before our eyes may stretch a world of invisible, feebly interactive light particles, which could be at the origin of dark matter. The goal of the project of Prof. Enrico Sessolo, winner of a SONATA-BIS grant from the National Science Center, is to draw a link between these different energy scales using new techniques in quantum field theory, like the idea of asymptotic safety, and a systematic treatment of empirical data. By combining a variety of multi-scale inputs, Prof. Sessolo aims to derive unique predictions that can be tested in current and future experiments.

SONATA BIS: The search for precision in nonlinear high-energy QCD

Dr. Guillaume Clement Beuf from the Theoretical Physics Division is one of the NCBJ scientists who received grants in the 10th edition of the NCN SONATA BIS competition. His project focuses on the theory regime which can be studied by high-energy particle collisions without wide-angle scattering or heavy particle production.

The strong nuclear force is responsible for the binding of quarks and gluons into protons and neutrons, and is well understood by the theory of Quantum Chromodynamics (QCD). QCD can make precise predictions for particle collisions involving large angle scattering or the production of heavy particles, but becomes challenging in the low energy regime. A third regime of QCD exists that can be probed by high-energy particle collisions without large angle scattering or heavy particle production; it is called gluon saturation. However, existing theoretical QCD predictions lack precision, making it difficult to find gluon saturation effects in experimental data. The aim of this new project is to improve the theory of gluon saturation by including corrections of various types, in order to obtain precise predictions for high-energy processes at CERN and at the future Electron-Ion Collider in the USA.

Credit: Brice, Maximilien: CERN

Radioisotope Centre POLATOM

With over 60 years of experience the Radioisotope Centre POLATOM is a world-renowned supplier of high-quality radiopharmaceuticals and diagnostic kits for nuclear medicine, and an important producer of radiochemical products for customers all over the world. POLATOM is the main Polish producer of radiopharmaceuticals and other radioactive products reaching over 2000 customers in more than 80 countries.

The current POLATOM portfolio includes:

- a wide range of scintigraphic ^{99m}Tc labeling kits for organ examination and cancer diagnosis,
- preparations of Iodine-131 for the diagnosis and treatment of thyroid diseases,
- preparations for palliative treatment of bone metastases,
- ^{99}Mo / ^{99m}Tc radionuclide generators,
- precursors for the preparation of therapeutic radiopharmaceuticals,
- a wide range of preparations for clinical studies and medical research and development,
- sealed radiation sources,
- radioactive standard solutions and sources,
- radiochemical reagents,
- a wide range of special radioactive preparations tailored to users' needs,
- accessories and services for nuclear medicine units:
  - » calibration and servicing of dose calibrators,
  - » installation and maintenance of isotope equipment,
  - » trans-shipment and transport of radioactive materials.

POLATOM's activities in all areas meet European and international standards within the scope of the quality assurance system.

The Radioisotope Centre POLATOM holds the PN-EN ISO 9001:2015-10 Quality System Certificate and implemented WSK (Internal Compliance Program) for trade in dual-use goods, as well as a Certificate confirming compliance with Good Manufacturing Practice (GMP) requirements. Its Radioactivity Standards Laboratory maintains a management system compliant with the international standard PN-EN ISO/IEC 17025:2018-02. The RSL's technical competence – as a calibration laboratory – is confirmed by the accreditation certificate AP 120 granted by the Polish Center for Accreditation.

NCBJ becomes one of the partners of the European medical radionuclide program PRISMAP

NCBJ is participating in the European program PRISMAP, which aims to produce new medical isotopes for diagnostic and therapeutic purposes. PRISMAP will bring together leading research institutions in Europe working on new radiopharmaceuticals to advance the field. The network will include facilities where radioisotopes are produced, installations for separating and purifying radioisotopes, and research facilities where new drugs are designed. NCBJ, with its experience in producing and researching radionuclides, will be one of the elements of the communication network for users of new radionuclides for diagnostics and therapy created within the project. Its involvement will include making radioisotopes available, as well as its experience in radioisotope labeling methods, analytical qualitative research and preclinical studies. NCBJ will collaborate in the working group to develop quality requirements for new radionuclides and radiopharmaceuticals. The project is expected to improve healthcare and ultimately improve the lives of citizens.

POLATOM delivers radiopharmaceuticals to patients in a more secure way thanks to the status of a Known Consignor

POLATOM has obtained a certificate as a Known Consignor, a proof of recognition of internal safety procedures that ensure the safe and fast delivery of their products to patients worldwide by air. The Known Consignor status exempts loads from security checks, ensuring the integrity of the shipment during each stage of transport, but internal security procedures must comply with civil aviation security standards. POLATOM adjusted its infrastructure and internal procedures to meet the requirements for obtaining the status, including appointing a person responsible for air cargo security, creating a security program, and conducting employee training and background checks. The achievement highlights the professionalism of the manufacturer and opens up new paths of cooperation. The radiopharmaceuticals produced by POLATOM are used by over one hundred thousand patients annually in 80 countries on 6 continents, and the Known Consignor status ensures the fastest and safest possible transport for therapy and diagnostics.

New perspectives in the treatment of difficult-to-diagnose neoplasms

A group of experts in the field of nuclear medicine and radiopharmaceuticals, including scientists from the Radioisotope Centre POLATOM, summarized their experience in development research on new CCK2R-targeted radiopharmaceuticals and in clinical trials. Scientists report that the latest clinical studies have shown the potential of radiolabeled gastrin analogs in detection and localization of neoplastic lesions, and in targeted internal radiotherapy. The concept of teranostics is confirmed here – the use of a leading molecule aimed at a biological target for diagnosis or therapy, depending on the physical characteristics of the attached isotope. The results of the first clinical trials indicate the possibility of a wider use of radiopharmaceuticals targeting CCK2R.

Work of POLATOM scientists among the most cited publications of the Nuclear Medicine Review

The article *"Improved procedures of $Sc(OH)_3$ precipitation and UTEVA extraction for ^{44}Sc separation"*, describing the research of scientists from the Radioisotope Centre POLATOM was among the five most cited publications of the Nuclear Medicine Review journal in 2017-2021. The diploma awarded by the Editorial Board was presented to the authors during the 17th Congress of the Polish Society of Nuclear Medicine in Białystok on May 26–28, 2022. This is not the first such achievement of POLATOM scientists. Three of their articles published in 2015-2017 were similarly rewarded, for which the authors received diplomas during the PTMN Congress in 2018.


DYPLOM

WYRÓŻNIENIE

A new marker for imaging cancer cells

An international team of scientists, including scientists from the Radioisotope Centre POLATOM, proposed the use of a new chemical compound, [^{99m}Tc] Tc-DB15, for imaging prostate and breast cancer. The compound allows the detection of neoplasms thanks to the use of Tc-99m, which emits photons with energies in the gamma range during decay. This can be recorded in a SPECT tomograph to generate a 3D image of the patient with clearly visible sites of photon emission. Tc-99m, attached to the receptor antagonist, accumulates in cells with increased GRPR density, i.e. in cancer cells, which makes it possible to locate and determine the activity of neoplastic cells. Initial in vitro studies showed that the cancer cells accumulate the marker well. After the safety of the study drug was confirmed, two female patients suffering from breast cancer whose cells had GRPR receptors were subjected to this method of imaging.

Solid state physics studies help design new drugs

New specialized drugs are often developed based on studies of the biological activity of individual compounds. They can be synthesized by organic chemistry methods, which makes it possible to compare the interaction with biological agents of compounds that differ even by a single atom. Combining this type of research with software that allows modeling of the molecules, we can obtain a wide range of possibilities for finding molecules that are valuable from the medical point of view. Examples of compounds currently under study are thiazolidinones and thiourea derivatives. An important property of both groups of these compounds is the ability to slow down the action of certain enzymes - they act as inhibitors. The compounds produced were subjected to, among other things, crystallographic studies using X-ray diffractometry at the Nuclear Methods in Solid State Physics Division at NCBJ. It was possible precisely to determine their properties and thus model their behavior towards enzymes. The study shows that the produced compounds have great biological potential for medical applications.

"Tailor-made" microspheres as a chance to save the liver more effectively

Malignant liver tumors are dangerous diseases with high mortality. One promising treatment method is radioembolization, whereby millions of radioactive microspheres are introduced into the tumor tissue. When the microspheres get stuck in arteries, they cut off the tumor from the supply of nutrients. At the same time, their radiation kills sensitive cancer cells in the immediate vicinity. There is increasing evidence that in the future these microspheres can be manufactured quickly and cheaply to meet the therapeutic needs and anatomy of specific patients. Such conclusions are drawn from experiments on new microspheres with the yttrium ^{90}Y isotope, manufactured and tested with significant participation from NCBJ. New micrograins with spherical shapes are produced by the sol-gel method. This is a complex, multi-stage process, improved over several years by scientists from POLATOM and IChTJ in Warsaw. The results of the experiments confirm that the new yttrium microspheres are a promising alternative to currently available commercial agents and qualify for further biological and preclinical studies.

Even more efficient production of iodine 131 is possible in the MARIA reactor

Iodine-131 is a radioisotope commonly used to treat hyperthyroidism and some of its cancers. Tellurium dioxide used as a target material in the production of iodine is the most commonly irradiated material at the MARIA reactor. Iodine-131 is produced by the β- conversion of the unstable isotope ^{131m}Te, which is formed by neutron capture by the ^{130}Te atom. Conditions that allow neutron capture by ^{130}Te occur in research reactors such as the MARIA reactor, the cores of which are designed to house target material for a specific period of time.

The essence of the proposed change in production method is to irradiate targets of natural tellurium with ^{130}Te enrichment up to 95%, instead of the current 33.8%. This will reduce the number of neutron reactions with other tellurium isotopes, which are an unusable part of the final product, and significantly increase irradiation efficiency. The new way of irradiating targets will allow for higher ^{131}I activity, while reducing production waste and making more efficient use of the reactor's vertical channels.

3D printing can help produce valuable radiopharmaceuticals

Metastable technetium-99m is one of the most important radioisotopes in medicine. The photons it emits do not cause damage to tissue and are registered by the detectors of diagnostic equipment without much difficulty. In addition, the half-life of this radioisotope is only six hours, which means that it disappears from the patient's body soon after the test. Molybdenum-99 is most commonly produced by irradiating thin plates from a dispersion of uranium or its oxide or silicide in aluminium. NCBJ scientists proposed a different way to prepare uranium targets: spatial printing by laser powder sintering. The use of 3D printing allows the shape of the targets to be optimized so that they heat up less, and this increases the uranium-235 content in them. As a result, more molybdenum-99 can be produced per exposure. Possibly the most promising aspect relates to the potential to increase the processing efficiency of the uranium-235 itself. In each irradiated target, some of the nuclei of this isotope do not undergo nuclear transformations. The shapes of the printed targets can be designed to increase the amount of uranium recovered. Once extracted, it could be used to build more targets.

The MARIA reactor has quickly filled the gap in the global supply of life-saving radioisotopes

Molybdenum-99, the radioisotope used to make the radioactive technetium used in most nuclear medicine procedures, is made in research reactors by irradiating uranium targets with neutrons. In January 2022, during the start-up preparation of the Dutch HFR reactor, which is one of the world's few molybdenum suppliers, a technical fault was discovered in the cooling system. For this reason, it could not be launched as planned. A day later, its production was quickly taken over by the MARIA reactor operating at NCBJ. The MARIA research reactor's core has great production flexibility. A detailed core arrangement calculation was performed on the spot and approved by the Polish nuclear regulatory body (PAA). All this was arranged in a matter of hours.

Symposium: Neutron Sources

In June 2022, a symposium devoted to the development of neutron research in Poland and Europe was held in Świerk. The symposium initiated cooperation between Polish institutions, universities and scientists on the part of neutron source users (the "Neutrons for Polish Science" consortium) with operators and constructors of neutron generating infrastructure. The presentations concerned the MARIA reactor and neutron research conducted in research and academic centers in Poland, as well as conceptual, design and engineering contributions to emerging neutron sources abroad, i.e. ESS and IFMIF-DONES. The symposium was attended by scientists from leading European and Polish centers conducting neutron research and participating in the construction of future research infrastructure. The dialogue conducted among the participants pointed to the possible future for the MARIA reactor of a significant development in the construction of measuring devices for neutron diagnostics at European neutron sources (ESS, DONES) as well as in programs supporting the development of thermonuclear technologies.

The MARIA reactor supports research into thermonuclear fusion

One of the projects underway at the MARIA reactor is the testing of components of the IFMIF-DONES facility. Learning about changes in the properties of materials exposed to radiation from thermonuclear reactions is crucial to the construction of the world's first fusion power plant, DEMO. Research of this type can be carried out almost exclusively in light-water research reactors. A special thermostatic device, which was designed and built by employees of the Nuclear Facilities Operations Department, with the support of specialists from other NCBJ departments, makes it possible to reproduce in the core of the MARIA reactor the thermal and neutron conditions to which the elements of a fusion reactor will be exposed. The designed MAKARONI probe is unusual in that it was necessary to develop three small sections operating simultaneously at three different temperatures: 300, 400 and 550°C. Special ceramic materials and 3D printing were used. More devices are planned to study conductors, semiconductors and radioisotope thermoelectric generators.

The MARIA research reactor will test the components of the ITER fusion reactor

NCBJ has signed a framework agreement with the ITER Organization, under which material samples and diagnostic windows for use in the ITER fusion reactor will be tested. To this end, engineers and scientists from the MARIA reactor will design unique thermostatic capsules that will recreate the conditions in the place of their final installation. The capsules will be placed in the core of the MARIA reactor, irradiated, and then tested using specialized research equipment.

Success of irradiation of materials in the ISHTAR capsule at the MARIA reactor

The ISHTAR irradiation rig, designed and built at the Nuclear Facilities Operation Department, enables the irradiation of material samples in the MARIA reactor under conditions prevailing in high-temperature gas reactors, i.e. temperatures up to 1000°C and in a helium atmosphere. This level of temperature inside the rig is ensured through simultaneous gamma radiation and electric heating, and thermal insulation of gas gap. Tests of samples placed in the rig determine the effect of the radiation field and high temperature on the strength and structure of materials intended for use in the construction of new reactors, particularly of core elements. HTGRs are considered worldwide as one of the promising options among various new generation reactor technologies. They can produce heat at a temperature sufficient e.g. for the production of hydrogen by high-temperature splitting of water. Research on this technology is currently being carried out, among others, by Japan and China. Appropriate competences are also being built at NCBJ.

In February 2022, reactor technicians cut open a capsule that had been in the MARIA core for several cycles. The irradiated graphite samples taken from the capsule have been sent for further research. The design of the probe had not only to withstand thermal gradients but also ensure that the brittle graphite samples did not crack during months in the core. Currently, there are three installations with high-temperature HTGR reactors operating in the world: the experimental Japanese HTTR and Chinese HTR-10, and the power reactor prototype HTR-PM. The HTGR technology still requires research, especially in the development of construction materials. Light water research reactors such as MARIA provide support for this type of research. The flux of neutrons in its core is about thirty times greater than in the prototype reactors mentioned above. As a result, thanks to the unique capsules, we can observe the damage in materials equivalent to many decades of nuclear power plant operation much faster.

Implementation of design work for the HTGR reactor - contract signed

NCBJ and the Ministry of Education and Science have signed an agreement to carry out further work on a high-temperature gas-cooled reactor (HTGR) project. The initiative is supported by Poland's Ministry of Climate and Environment, which has committed PLN 60.5m ($16m) towards it. The project will develop a basic design for the device at NCBJ and establish conditions for building it in Poland within three years. HTGR technology could provide a means of meeting the needs of modern industry without harming the environment. The HTGR is a device that requires materials capable of operating under extreme conditions: high temperatures, neutron radiation and high pressure.

Following the contract concluded with the Ministry of Education and Science, NCBJ and the Japan Atomic Energy Agency (JAEA) signed an executive agreement on cooperation in research and development of technology for high-temperature gas-cooled reactors. The arrangement provides for R&D cooperation on the main HTGR research reactor project, which will be built in Poland at NCBJ, and the provision of technical information to NCBJ regarding Japanese HTGR R&D. The documentation, which JAEA will hand over to NCBJ by 2024, will be for joint use in the work of the partners.

SEFAKO will cooperate with NCBJ in the HTGR project

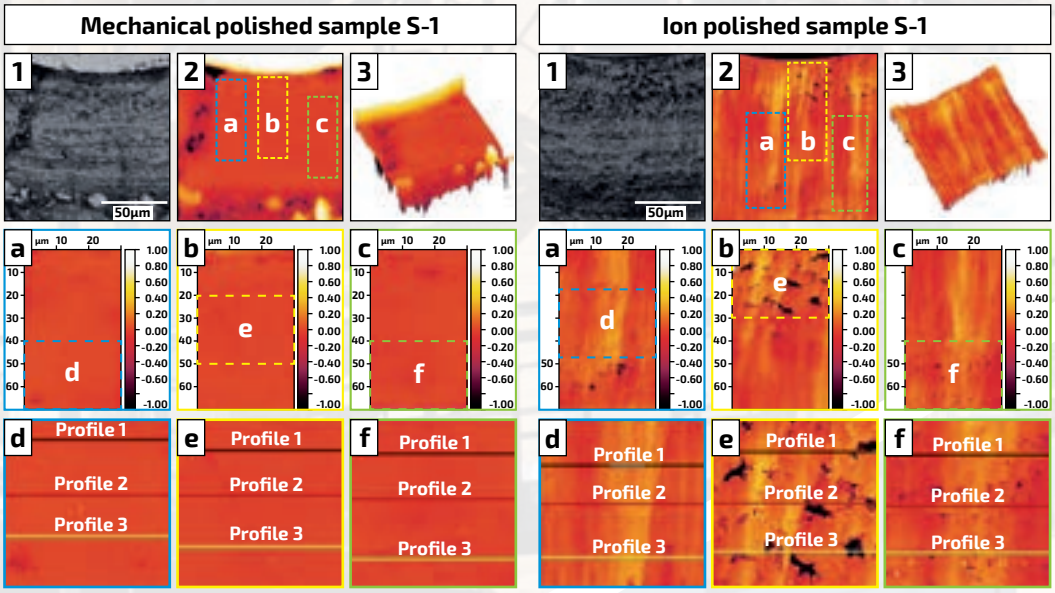
NCBJ has signed a letter of intent with the Boiler Factory SEFAKO for the design and construction of a Reboiler Equipment Complex for a high-temperature gas-cooled nuclear reactor. SEFAKO will design and build a conventional Reboiler Unit Set used to separate the high-temperature refrigerant in the form of water vapor from the secondary cycle supplied from the steam generator. The device is to be an element of a high-temperature gas-cooled reactor on which research and development works are underway at NCBJ. The Boiler Factory SEFAKO is a leading Polish producer of power boilers with experience in the design and construction of energy devices.

GEMINI 4.0 – polygeneration for industry and heating

Decarbonisation of power systems is possible thanks to the well-known and proven technology of light-water reactors. However, electricity production is only responsible for around 1/4 of CO2 emissions in Europe. Scientists and engineers propose the use of high-temperature gas reactors (HTGRs) for the purposes of cogeneration and polygeneration in other sectors. GEMINI 4.0 will help with the technical refinement of the GEMINI+ reactor design, optimal configuration of polygeneration products, as well as licensing and construction of the European fuel chain. The system design will include its application to work in complex energy and industrial systems. Additionally, NCBJ will investigate the possibilities of qualifying TRISO fuel with the use of the MARIA reactor.

TRISO fuel – fuel with its own "containment"

TRISO fuel is the main attribute and advantage of HTR reactors. It uses uranium oxide or carbide as nuclear fuel. The fissile material is surrounded by four cover layers. The use of pyrolytic carbon and silicon carbide as the building material, makes fuel pellets the size of a poppy seed extremely resistant to mechanical, chemical, radiation and temperature damage. Scientists from NCBJ conducted an experiment on the failure rate of TRISO before placement in the reactor core. In order to determine the state of individual layers of TRISO particles, cross sections were prepared. Scientists report that their proposed novel ionic method of polishing, apart from the lack of interference with the material, allows the possibility of using constant parameters, repeatability of results, or shorter time of research.



Cooperation between NCBJ and Synthos Green Energy in the area of new generation nuclear reactors

On February 4, 2022, NCBJ and Synthos Green Energy SA (SGE) signed a letter of intent on cooperation in the use of nuclear technology in industry and energy. The planned cooperation is related to the implementation by SGE of projects related to the construction of small modular light-water reactors (LW-SMR) for the production of electricity and possibly municipal heat and the construction of small modular high-temperature gas-cooled reactors (HTGR). The latter would be oriented towards cogeneration, i.e. industrial heat generation and hydrogen production. The intention of both parties is an initial analysis of potential opportunities, scope and models of cooperation.

Graphene as a magnetic field detector in fusion reactors

Thermonuclear reactors use a strong magnetic field to trap plasma, in which the synthesis reactions of light atomic nuclei take place. Due to the high temperature and strong neutron radiation, most magnetic field sensors are unable to operate in such systems. An interesting alternative seems to be detectors made from graphene. The resistance of graphene to radiation is known, but the response to neutron radiation has never been experimentally confirmed. Scientists tested the effect of fast neutrons on a graphene-based detector system, which was irradiated with fast neutrons inside the core of the MARIA reactor at NCBJ. Based on the characterization of the properties, the resistance of graphene to neutron radiation was assessed as very good. Additionally, it turned out that the structure even shows a certain self-repair potential.

JET: a record fusion energy for deuterium and tritium

An international team of scientists working at the JET tokamak reported a record energy of 59 MJ achieved during a deuterium-tritium fusion run lasting 5 seconds. Experts see this as a milestone in mastering fusion and using it as a clean energy source. A team from the Electronics and Detection Systems Division of NCBJ participated in the modernization of the gamma radiation detectors. In the modernized detectors, fast scintillators were used, which allow for measurements enabling the registration of over a million events per second. NCBJ scientists are also analyzing the gamma and X-ray spectra of the plasma structures of the JET tokamak, on the basis of which the key plasma parameters are determined.

First Transient Calculation of a Dual Fluid Reactor (DFR)

Comprehensive research and models of their operation are an important stage in the introduction of the concept of generation IV nuclear reactors. The passive safety of the DFRm reactor (the fuel is a eutectic mixture of uranium and chromium) was confirmed thanks to the precise determination of the temperature coefficient of reactivity, which turned out to be negative. This means that when the temperature in the reactor core increases, it automatically reduces the number of reactions taking place, causing a return to a safe state. An analysis of temperature reactivity coefficients was performed on the basis of a reactor model made using the Serpent code, based on the Monte Carlo method. The authors also proposed a reactivity control system and made calculations of the reactor transients.

CyberLAB shows how a cyberattack on a nuclear power plant could proceed

The NCBJ Cybersecurity Laboratory has prepared an installation illustrating the hypothetical course of an attack on a controller in a nuclear power plant. The main part of the installation is a model of a nuclear reactor. The model is connected to a nuclear power plant simulator and is intended to visualize its state. Programmable logic controllers, which are used in real industrial installations, are connected to some of the processes taking place in the simulator. In the presented case they are responsible for the pressure control in the primary circuit of the reactor. The set also includes interactive software that allows one manually to change the reactor output power level and presents its current parameters, e.g. the condition of the heating or spraying installation in the pressure regulator – used to maintain appropriate operating parameters. An important part is the script which simulates an attack on the controller responsible for pressure regulation in the primary circuit, which breaks its connection to the network. As a result of this attack, the installation fails to respond to pressure changes and, ultimately, causes an emergency shutdown of the reactor. Scientists show that devices responsible for even seemingly insignificant elements of the system can cause an emergency shutdown of a reactor when their weaknesses are found and exploited.

International Summer School "New High-Temperature Technologies for Poland"

The second edition of the "New High-Temperature Technologies for Poland" international summer school was held in Kazimierz Dolny from September 12th to 15th, 2022, organized by NCBJ. Unlike the first edition, which was held online due to the pandemic, this edition gave doctoral students and invited experts the opportunity to meet in person, facilitating personal networking and the exchange of experience. The program included 12 lectures presented by foreign experts from Sweden, Italy, Switzerland, Japan, the Netherlands, Indonesia, and NCBJ, as well as a special session for NCBJ doctoral students to present their research results and receive feedback from guests. The program also included intensive meetings between doctoral students and their supervisors, consultations, and scientific writing workshops, culminating in an interesting debate on the topic of a "Successful Nuclear Project."

Security Constrained Unit Commitment

NCBJ has developed software to optimize the work plans of the Polish National Power System, taking into account the latest guidelines of the Transmission Grid Operator and European regulations. Basic IT tools will be implemented in 2024. The extended version, which enables optimization using a full model of the power grid, requires the use of specialized calculation methods to reduce the computational complexity. Its implementation, which is expected in the near future, will allow for both the creation of safer system operation plans and the determination of spot prices on the Balancing Market, i.e. prices that differ depending on the location of the balancing energy generation.

KlastER - development of distributed energy within energy clusters

The KlastER project implemented in 2019-2022 was aimed at developing a distributed energy strategy. NCBJ was responsible for providing analytical and operational tools of appropriate quality. Among other things, solutions such as Zefir - a tool for planning transformation, or Chronos - a tool for operational management and monitoring of energy infrastructure such as electricity meters, warehouses, and generation installations were developed and tested. They have been installed in a number of locations, such as Żywiec, Krakowski Holding Komunalny, Lisewo, etc. The contractors of the project were the Ministry of Development and Technology, the AGH University of Science and Technology and the National Centre for Nuclear Research, and the project was co-financed by the National Centre for Research and Development under the GOSPOSTRATEG programme.

Support for the implementation of Flow-based Capacity Calculation processes in the Core area

A group of projects implemented for PSE S.A. included substantive support as well as the design and implementation of an application participating in the flow-based transmission capacity calculation process for the centralized European electricity market. From 2017, NCBJ employees took part in consultations and preparations for Poland's participation in the Flow-based market. As a result of this work, the Capacity Calculation Analysis (CCA) tool was created. It is prepared for the start of the daily process for the day-ahead market. The CCA tool analyzes data and prepares calculations concerning, among others, optimizing phase shifter settings or mitigating the risk of overloads from long-term interconnection allocations. Substantive support and development of the CCA application are continued to address the needs of PSE S.A. regarding the extension of the Flow-based methodology to intraday and long-term markets.

The OpTap app synchronizes phase shifters

Included in the group of projects implemented for PSE S.A. was an application for synchronizing the settings of phase shifters operating on the Polish-German border, belonging to the operators of PSE and 50Hertz. The OpTap application has been participating in the daily Day-Ahead Congestion Forecast (DACF) and Intraday Congestion Forecast processes since 2019, calculating the optimal settings of phase shifting transformers in order to minimize congestion on cross-border lines and the costs of redispatching remedial actions. In 2022, the application was expanded with new functionalities, including e.g. preparation of the DOPT report for dispatchers handling the DACF process.

Comparative analysis of RES and NPP costs

As part of the work for the National Center for Energy Analysis, the report "Energy security in the era of climate neutrality" from 2020 was reissued. The idea behind the study is to compare the costs of providing electricity with ensuring constant power availability of the set of analyzed generation sources. The tested strategies (technological sets) included those based on renewable sources (supported by gas-fired power plants or energy storage facilities) and nuclear power plants. The study included an update of the analyzed period, financial aspects (interest rates and discount rates), technological parameters and fuel prices, including a scenario analysis of the development of gas prices in the coming years. The results confirmed the conclusions from the previous edition of the study – nuclear energy is the most attractive option for implementing low- or zero-emission strategies in terms of price.

From super-sealings to the detection of dangerous cables thanks to ion beams

The safe and reliable operation of nuclear reactors strictly depends on the quality of their cabling. Materials are exposed to neutrons and gamma radiation. In practice, material defects caused by neutrons do not differ substantially from those initiated by ions, and due to this the NCBJ team could use a prototype industrial ion implantator of their own design. The research shows that the polymer insulation of cables exposed to radiation will lose its insulating properties over time. The attention of physicists was drawn to the fact that the surface layer of the polymer begins to shrink, it becomes denser than originally and up to ten times harder. The proposed method to detect changes in the electrical resistance of polymers has very significant functional advantages: it is simple, fast and allows almost immediate determination whether the tested cable has become dangerous.

How to prepare the surface of new generation titanium implants?

Currently, titanium and its alloys occupy a significant part of the biomaterial production market, especially in orthopedic and dental implantology. This is due to their biocompatibility and unique mechanical properties, similar to human bone tissue. In research conducted by scientists from the Materials Research Laboratory and the NOMATEN Centre of Excellence, a detailed surface analysis was carried out on titanium-based substrates, on which TiO_2 oxide layers were formed during the oxidation process. The scientists used for the first time a calculation method proposed earlier in the point measurements of powders, in Raman imaging of thin oxide layers. The results obtained confirmed the assumptions made at the development stage of the methodology for obtaining hybrid coatings. This can be used in the selection of parameters for the production of oxide layers in new generation biomaterials.

Metallic layers with high entropy are formed at NCBJ

In recent years, materials science has focused more and more on coating materials with layers of multicomponent alloys with high entropy. Compared to conventional alloys, they are characterized by significantly better physical and chemical properties. Recently, the first five-component, high-entropy layer was produced in the Plasma Surface Engineering Laboratory of NCBJ. To create a new metallic layer, scientists used pulse magnetron sputtering. All analyses confirmed that the coatings produced have a composition, structure and thickness in accordance with the originally assumed parameters. Light alloys with high entropy are considered to be particularly difficult to produce, due to the fact that elements such as titanium and aluminum easily form metallic phases, considered undesirable here. The achievement of NCBJ scientists proves that the initiated direction of research has great development potential.

Extending tool life by engineering the surface of materials

Due to the extensive use of engineering materials, modern tools are needed. Increasing tool life can be realized by modifying the surface layer, applying an additional hard layer, or by a combination of both. Surface engineering of materials is among the specialties of the Plasma/Ion Beam Technology Division of NCBJ. Recent studies have used double-edged drills made of high-speed steel on which nitrogen ions were implanted. The results showed that implantation of ions into drills used for machining particleboard in the furniture industry results in both an increase in tool life and a several-fold reduction in the variability of tool life, which allows optimization of the machining process and promotes automation of manufacturing processes.

Participants in the radiographic research conference visit Świerk

In September 2022, NCBJ hosted the participants of the twenty-second National Conference on Radiographic Research. The topics traditionally included, among others, contemporary trends in the development of X-ray radiography, interesting cases encountered in the course of research, technical and technological innovations and new areas of application of X-ray imaging. This year's edition was an opportunity for NCBJ employees (primarily from the Nuclear Equipment and Techniques Department and NCBJ Nuclear Equipment Division (HITEC)) to meet with representatives of industry and companies offering NDT services from centers around the country.

Scientists from the NOMATEN Centre of Excellence at NCBJ show how to link the structure of materials with their properties thanks to the tools of materials informatics

Materials structure studies, such as microscopic measurements, provide enormous amounts of data that can be used to reconstruct the microstructure of a material and become the basis for computer simulations. Materials subjected to extreme conditions – such as irradiation or high temperatures – experience changes that are difficult to understand using traditionally used models. In such cases, artificial intelligence methods turn out to be irreplaceable in order to capture these changes and relate them to specific processes taking place and physical properties. Experimental data are acquired by other research groups. In the MASIF group, on the other hand, simulations are performed on very different scales of space and time. The data sets obtained are then processed using statistical methods and artificial intelligence. In this way much useful information can be obtained from existing data sets that would otherwise be lost.

International conference on materials science – the first of its kind in Poland

The 1st NOMATEN International Conference on Materials Informatics was organized by the NOMATEN Centre of Excellence operating at NCBJ. More than 60 scientists, experts and representatives of industry from over 15 countries attended the conference on materials computing, a pioneering field that is based on a new approach to studying existing and new materials through the use of machine learning, artificial intelligence and statistical methods. The techniques allow, for example, identification in electron micrographs of defects in the material which otherwise could escape the researcher's attention. The conference was aimed at promoting Poland's unique infrastructures and research teams internationally.

NOMATEN: software for analyzing microscopic images of materials using machine learning

Microscopy is the key to insight into the microstructure and properties of materials. Microscopic images are a reflection of a material's physical properties, and can also provide information about the processes it was subjected to and their effects. Changes occur in the microstructure of materials subjected to extremes that are difficult to understand using traditionally used models. In such cases, artificial intelligence methods are proving indispensable for capturing these changes and relating them to the specific processes taking place and to physical properties. Researchers at the NOMATEN Centre of Excellence decided to create software that is friendly to researchers without advanced knowledge of machine learning. The NOMATEN team's work is a response to the widespread demand for dedicated machine learning solutions that can be applied directly by those conducting experiments and will provide them with useful results based on the data collected.

NOMATEN examines metal glass and alloys with high entropy

The NOMATEN group of scientists is looking for configurational entropy and glass transition relationships in high-entropy alloys (HEA) using dynamic simulations at the molecuar level. Configurational entropy indicates the number of available atom configurations in the alloy structure in non-crystalline materials. The research results show that the configurational entropy is a key indicator for identifying when a material with a metallic glass structure is formed from high entropy alloys. Thanks to the combination of the advantages of metals and glass, metallic glass is easy to shape, durable and also conducts heat and electricity well. High entropy alloys are one of the key theoretical and experimental research subjects of research teams in the NOMATEN Centre of Excellence responsible for simulations and machine learning, as well as the functional properties group.

NCBJ establishes research cooperation with Mercedes

Mercedes Benz Manufacturing Poland chose NCBJ as a partner in materials research on the wear of tools for machining engine components. The work will be carried out by a team of scientists operating at the NCBJ NOMATEN Centre of Excellence. The latest infrastructure installed at NOMATEN will be used to prepare the tests including an X-ray diffractometer and one of the most modern scanning electron microscopes in Poland. NOMATEN will carry out for Mercedes, among others macroscopic tests of the surface of ceramic elements before and after operation, microstructural tests, chemical and phase composition in selected areas of the tool surface, phase analysis by X-ray diffraction, tests of the surface topography of ceramic elements and mechanical tests of these elements.

Design and construction of accelerators

At NCBJ, accelerators and systems incorporating these devices are designed and built within the NCBJ Nuclear Equipment Division (HITEC) (ZdAJ) and the Particle Acceleration Physics & Technology Division.

ZdAJ specializes in designing, manufacturing, selling, and maintaining equipment centered around electron linear accelerators for the industrial and medical sectors. Its flagship product is LILLYPUT, an industrial accelerator tailored for non-destructive testing via the radiographic method, with a broad energy range up to 15MV. The division provides customized radiographic systems featuring different types of digital imaging detectors and specialized manipulator systems. These systems have been exported and are in operation globally for non-destructive testing.

Additionally, ZdAJ offers dual-energy linear accelerators for cargo inspection, which, when integrated into complete scanning systems, enable discrimination of materials and are instrumental in border protection against the smuggling of contraband and hazardous materials.

In the medical sector, ZdAJ has developed the AQURE intraoperative radiation therapy accelerator. This electron accelerator boasts a broad spectrum of emitted radiation energy and a wide range of motion in the operative field. AQURE precisely targets the surgical site immediately after tumor removal, reducing overall treatment time and potentially improving patients' quality of life. The device is versatile, suitable for treating breast cancer, abdominal tumors, sarcomas, and pediatric diseases.

ZdAJ's achievements stem from its modern infrastructure, production facilities, and bunkers essential for working with ionizing radiation-emitting devices. The Division has modern equipment, including digital machine tools, furnaces of appropriate dimensions and technological lines for chemical processing, as well as advanced measuring and diagnostic devices. It also uses the research stand of accelerating structures of the CentriX Center for Information and Implementation of Industrial Radiation Techniques (NCBJ). ZdAJ has implemented an integrated, certified quality management system and an internal control system for handling dual-use technologies and services.

As part of NCBJ, ZdAJ participates in various scientific projects and maintains collaborations with leading global scientific laboratories. Notably, it has collaborated with CERN and contributed to the modernization of the Large Hadron Collider. Such involvement in scientific projects serves as a valuable source of inspiration and ideas for the development of ZdAJ's next-generation products.

Fully equipped radiographic accelerators

A radiographic accelerator, Lillyput version 7/9, with a system of manipulators and a digital imaging system for a foreign recipient was produced at the NCBJ Nuclear Equipment Division (HITEC). The system has been launched and put into operation. The system can scan objects weighing up to 40 tons. The set includes, among others, an accelerator manipulator, a digital imaging system manipulator and an object manipulator. The system provides fully integrated synchronization and automation of manipulator movements.

A second accelerator from Świerk will be installed on the EU border

At the railway border crossing in Korosze, on the border with the Kaliningrad Oblast of the Russian Federation, a second accelerator produced by the NCBJ Nuclear Equipment Division (HITEC) has been installed. This accelerator is used for cargo screening. The entire system was built by PiD Polska, the licensee of the CANIS system developed at NCBJ. Similar to the first device of its kind successfully operating at the border crossing at Kuźnica Białostocka, the system installed in Korosze utilizes a dual-energy linear electron accelerator from the Lillyput series, which was constructed at NCBJ. The automation of the system enables smooth real-time cargo inspection without stopping the passing train, while ensuring the safety of the operators.

Opening of the new headquarters of our partner's Research and Development Centre

NCBJ has been cooperating with PID Polska for many years. In 2016 we signed an agreement for the commercialization of the Polish Cargo Control System "CANIS." The system resulting from this cooperation has been operating for two years at the railway border crossing in Kuźnica Białostocka, and the construction of new installations and the development of new solutions are planned in the near future. During the meeting which took place on 2nd of June 2022 at the new headquarters of the PID Polska Research and Development Centre, PID's scientific partners presented the progress and prospects of their own research on new technologies related to cargo inspection. The NCBJ presentation concerned the backscatter imaging method developed and patented by NCBJ scientists.

Accelerators for medicine: AQURE for intraoperative therapy

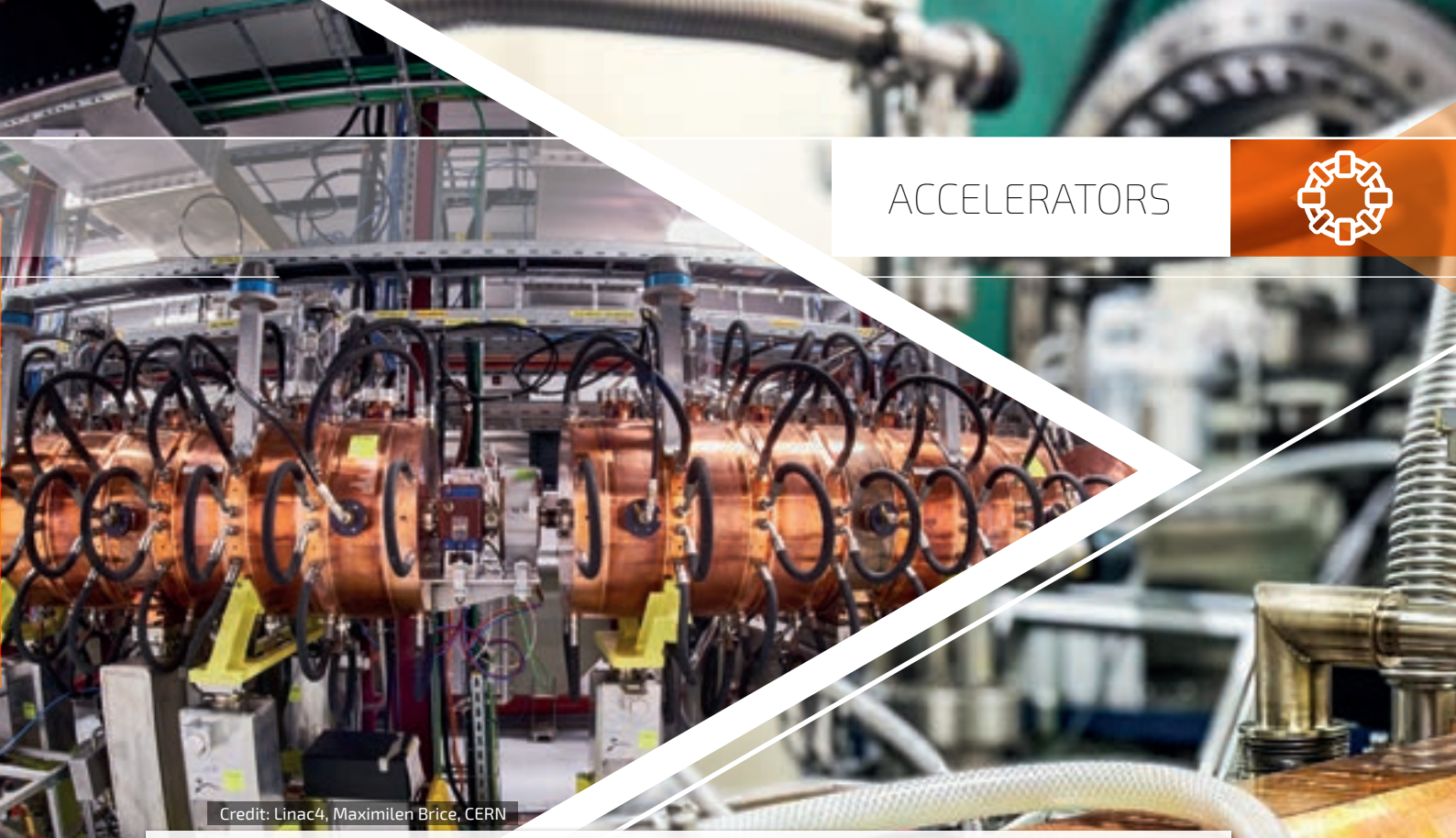
The AQURE intraoperative accelerator, constructed by a consortium consisting of Centrum Wysokich Technologii in Świerk ("HITEC ŚWIERK" Sp. z o.o.), NCBJ, and the Greater Poland Cancer Center, is a device designed for intraoperative therapy. Its final version will soon be operational at the Greater Poland Cancer Center.

Key features of the new ACURE accelerator include:

- High mobility treatment head: The treatment head is mounted on a robotic arm assembly, providing doctors with the flexibility to choose the direction for administering irradiation. The robot is placed on a motorized platform, facilitating easy movement between operating rooms.
- Energy range of 4 to 12 MeV: This range allows for effective irradiation of tissue up to a depth of 4 cm.
- High dose rate of irradiation: With a rate of up to 10 Gy/min, the accelerator enables complete irradiation of the affected area in less than 2 minutes.
- Electron applicators of various diameters: Doctors can select applicators ranging from 3 cm to 12 cm in diameter, ensuring compatibility with the specific area of the patient's body that requires treatment.
- Compatibility with non-cylindrical applicators: The treatment head construction allows for the attachment of non-cylindrical applicators, utilizing either "soft" or "hard" docking technology based on the preferences of the doctor.
- Fully automatic and user-friendly beam control system: The accelerator features an automated beam control system that is easy to operate.

FLASH type accelerator: a new method for fighting cancer

The use of ultra-short, intense electron beams is a completely new idea in oncology. Worldwide reports on the results of preclinical studies and the first clinical trials are promising. The dose rate used here is thousands of times higher than that typically used in radiotherapy. Only “flashes” lasting a few microseconds are used for irradiation. Thanks to such short exposure times, the total dose absorbed by the body remains at a safe level. The FLASH type accelerator will be built on the basis of an earlier NCBJ and WCO project, under which an intraoperative accelerator was built, allowing for irradiation in the operating room immediately after surgical removal of the main part of the tumor.



Credit: Linac4, Maximilen Brice, CERN

CERN: the first beam at the Linac4 accelerator

On February 10, 2022, CERN announced that the Linac4 accelerator, part of the LHC complex, had received its first proton beam. Linac4, an 86-meter linear accelerator, is a new source of proton beams at the LHC. The new accelerator allows for more collisions with higher energies. The main components of the so-called Pi-module accelerator structures were built at NCBJ, which required great competence due to the necessary precision of manufacture. In addition to the 12 accelerating structures, the contribution of NCBJ scientists to the construction of Linac4 also included the so-called buncher, a structure that is responsible for grouping particles into packets, which are then accelerated in further accelerator systems.

CentriX for non-destructive tests

The National Centre for Nuclear Research (NCBJ) has established the CentriX Information and Implementation Center for Industrial Radiation Techniques. The laboratories created as part of this project will be utilized by both industry and academia. Within the CentriX project, research infrastructure has been developed and acquired with dual objectives: advancing nuclear research technologies and equipment at NCBJ to serve industrial recipients, and economically utilizing this infrastructure through non-destructive testing (NDT) research and development activities for entrepreneurs.

Non-destructive testing (NDT), primarily through radiation examinations, will be conducted at the central laboratory of CentriX. These tests serve various purposes, including product inspections, quality control of raw material supplies, technical assessments of infrastructure facilities, monitoring of industrial processes, and inspection of production infrastructure.

As a result of the project, specialized laboratories have been established, including:

- Fast-X Laboratory: dedicated to research into high-speed radiography.
- Detector Systems Laboratory.
- Non-destructive Materials Testing Laboratory.
- Accelerator Structures Research Station.

How does electronics deal with ionizing radiation?

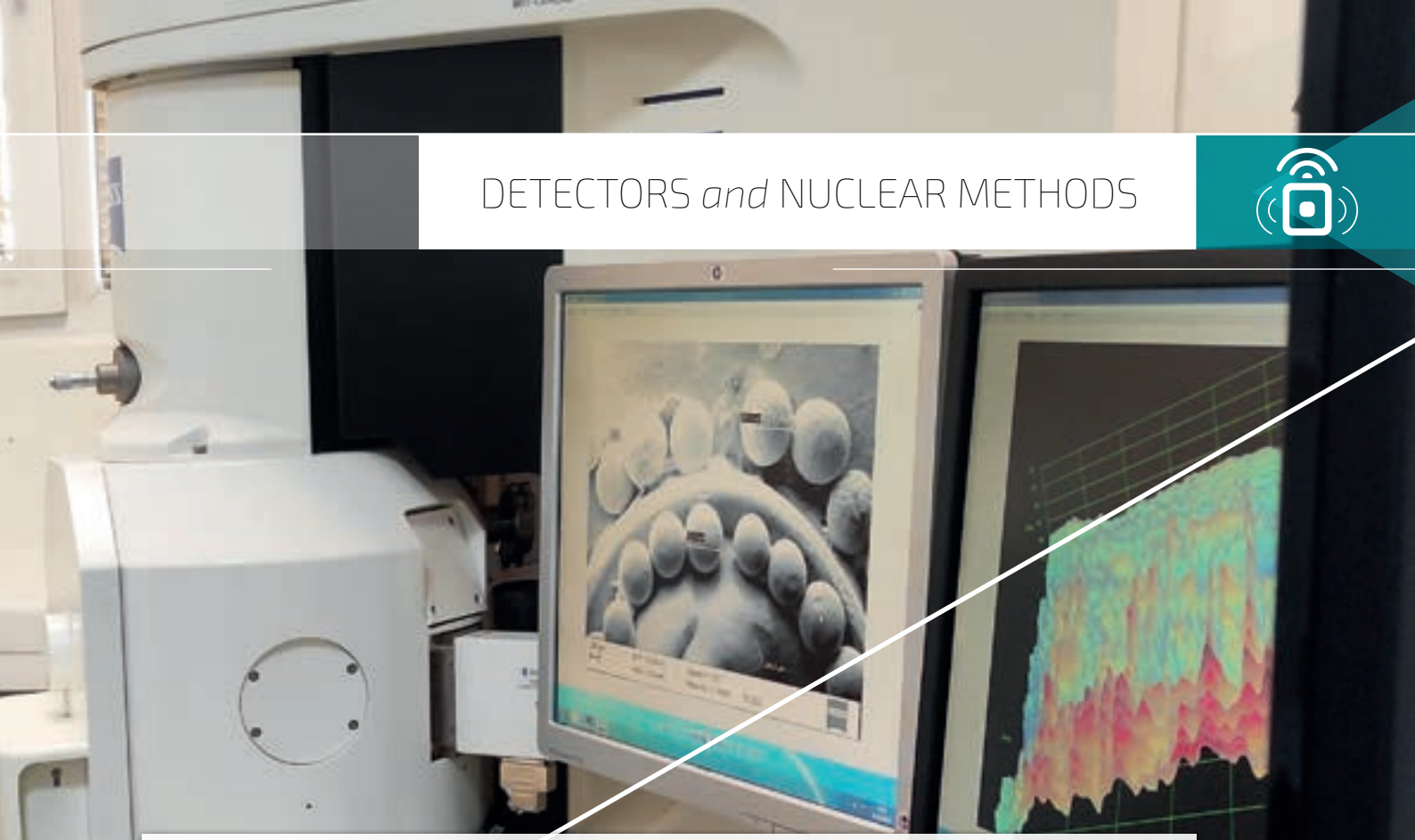
Many electronic systems in physics operate under conditions of exposure to ionizing radiation. In an experiment conducted by NCBJ scientists, samples consisting of an InGaN and GaN layer were irradiated with xenon and lead ion beams. Based on these analyses, the researchers found that InGaN was more susceptible to ionizing radiation than pure gallium nitride, while a higher energy of the ions interacting with the material did not dramatically increase the amount of damage caused. The findings were supported by Monte Carlo simulations in the McChasy-1 program, which was created and is still under development at NCBJ. The problem of exposure of electronic components to damage caused by ionizing radiation is an important part of research in other NCBJ Departments. Components for space missions such as POLAR-2, the use of linear electron accelerators instead of radioactive sources, and the impact of neutron radiation using the MARIA research reactor are being studied.

REVaMP - to use metals efficiently

In June 2022 the REVaMP (Retrofitting Equipment for Efficient Use Of VAriable Feedstock In Metal Making Processes) Project Management Meeting was held at NCBJ. The main objective of the project is to develop, adapt and apply novel retrofitting technologies to cope with increasing variability and to ensure an efficient use of the feedstock in terms of materials and energy. The Radiation Detectors and Plasma Diagnostics Division of NCBJ is responsible for the development, adaptation and application of novel sensors, based on neutron activation analysis, for characterization of metal scrap regarding chemical composition. The meeting was only the second occasion for personal meeting of the whole REVaMP consortium, consisting of 16 industrial and scientific partners from Poland, Germany and Spain.

J-PET: positron annihilation allows for even more precise imaging of lesions

Positron Emission Tomography is a method of imaging a patient's anatomy based on recorded radiation emitted from inside the human body. Scientists from the Jagiellonian University, in collaboration with researchers from NCBJ, are working on a new generation of equipment - Jagiellonian PET. Instead of the more expensive, commonly used inorganic scintillation crystals, they use organic plastic scintillators. The scanner's unique properties allow it to go beyond conventional imaging methods and create a new imaging procedure that takes advantage of the quantum effects associated with the formation and annihilation of positronium - a short-lived arrangement of an electron and a positron. The detection time of the photons formed in the annihilation gives information about the position, and the lifetime of the positronium makes it possible to distinguish between healthy and diseased cells. This gives a three-dimensional picture of photon emission from diseased tissues. The new PET imaging method is not only cheaper than the devices currently on the market, but also more precise. Extensive work is underway to develop the device and the new method.



Secrets hidden in the treasures of Vikings found in Poland

NCBJ scientists, in collaboration with researchers from various fields, are working on the archaeometric study of early medieval relics made of silver alloys. As part of the study, NCBJ scientists have performed physicochemical analyses of silver jewelry found on land in Wielkopolska. The research showed the possibility of distinguishing two types of soldering of the ornament to the surface: physical and chemical. In addition to the usual microscopic tools, i.e. scanning electron microscopy with X-ray microanalysis and optical microscopy, micro-Raman spectroscopy and X-ray diffraction were used in the analyses. The study confirmed the use of copper-based compounds as the main component of the solder, with the addition of a resin adhesive. The data can be used to trace the flow of technology during this period, and thus reconstruct an element of the bullion economy during the period of the formation of Polish statehood.

The past to the future: physicists study the functioning of the first Homo Sapiens cultures

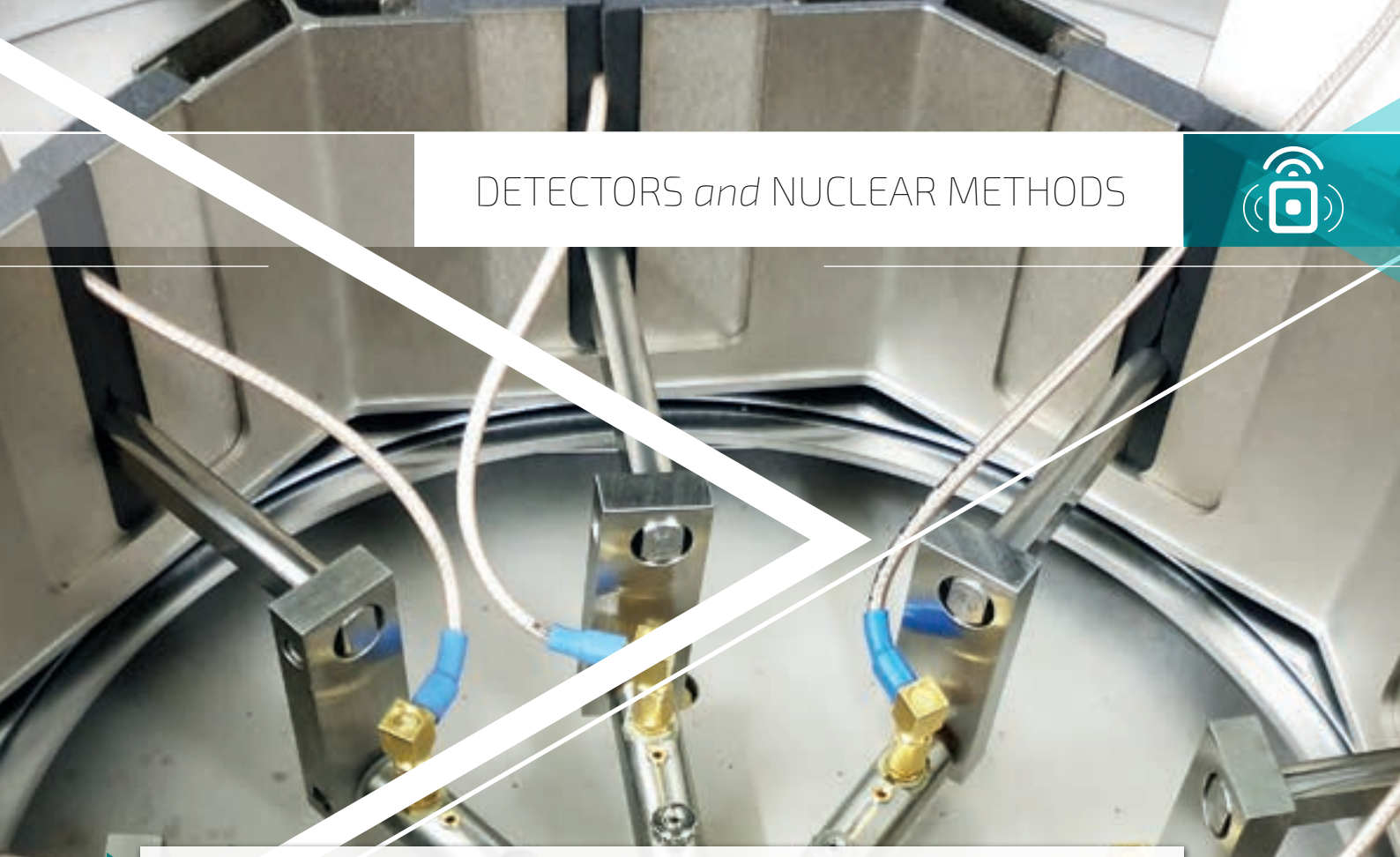
Scientists from NCBJ in cooperation with other researchers have analyzed the monuments of material culture of the late Palaeolithic community, belonging to the circle of the Magdalenian culture (18 to 11 thousand years ago), discovered near Ostrowiec Świętokrzyski in Ćmielów. Physico-chemical tests of the objects from the site in Ćmielów focused on presenting the aspects of the functioning of former hunter-gatherer communities. Before specialist analyses, it was considered that these were fragments of lamps in which the fuel was organic material. Based on the conducted archaeometric research, supported by data obtained from the experiment, the origin of these Palaeolithic objects was determined and it was discovered that they are fragments of heating plates used to heat meat dishes in an open hearth, so-called cooking-stones. The research allowed an estimate that the applied meat processing temperatures reached 800°C, and the stone used came from a quarry located 5 km from the camp in Ćmielów.

The concentration of radionuclides in polar air as a source of valuable information

Scientists from NCBJ and the Institute of Geophysics of the Polish Academy of Sciences have published the results of many years of research on radionuclide concentrations in the polar region and in Poland. The concentration of radionuclides in these studies was recorded during the years 2002-2017 at two stations: the Polish Polar Station in Hornsund and the S. Kalinowski Geophysical Observatory in Świder. During the study, isotopes of natural origin, space origin and those resulting from human activity were selected. The results of the research clearly showed the differences in the concentration of individual radionuclides during the year. A relationship between the concentration of certain nuclides and the 11-year cycle of solar activity was observed, as well as a gradual decrease of cesium content over time, due to the relatively short half-life of the isotope. Additionally, in 2011, both stations detected a significant increase in the concentration of cesium radioisotopes, which was related to the disaster at the Fukushima nuclear power plant. Both measuring stations operate to this day and still collect samples for further long-term tests.

Research confirms that a visitor from space has landed in Poland

In July 2021, three cameras of the Czech Bolide Network recorded the flight of a bolide so bright that it could be seen perfectly despite the approaching sunrise. The trajectory of the flight indicated that a potential fall of the meteorite or its fragments could have occurred over Poland. As early as August 3, on one of the dirt roads near Antonin in the Ostrów district, a good candidate was encountered: a 350 g stone covered with a pronounced abrasion crust. To verify the connection of the find with the observed bolide, specialized radioisotope tests were required. They were performed at NCBJ laboratories. This is the first time that a meteorite has been found in Poland on the basis of video footage recorded by bolide network cameras. In the case of the Antonin meteorite, a complete specimen was placed on a gamma ray detector just three weeks after the landing, which made it possible to detect 12 radioisotopes of cosmic origin, including the short-lived vanadium-48 and chromium-51. The results obtained made it possible unequivocally to link the studied specimen to the fall observed by the Czech Bolide Network.



Mini-EUSO over Poland

The Mini-EUSO telescope is a device that has been orbiting on board the International Space Station since August 2019, enabling the creation of an ultraviolet map of the Earth's night-time atmosphere and the observation of its variability over time. The project, in which Polish scientists from NCBJ participate, is the next step of the International JEM-EUSO Collaboration to study atmospheric Extensive Air Showers generated by the highest energy cosmic rays using measurements from space. The data collected by the Mini-EUSO detector provide valuable information ahead of the next major research steps, when a large telescope will be deployed on one of the ISS modules. The Mini-EUSO telescope will precisely determine the night-time UV background and measurement conditions, and define the apparatus configuration in the target experiment.

Determining the background involves mapping areas that are too bright for cosmic ray measurements. Most often these too bright areas are cities. The telescope shows the entire area of the globe available from the ISS, and has recently made measurements of the area of Poland.

POLAR-2 at the POLSA conference

In November 2021, the conference "About Lem and space" was held, organized in hybrid format by the Polish Space Agency POLSA. Scientists from NCBJ presented there the international POLAR-2 project and the Polish contribution to this mission. The POLAR-2 project is being developed in cooperation with China, European partners and the United Nations, and is a continuation of the POLAR project – a detector that measures the polarization of gamma rays. NCBJ is responsible for the design and construction of two key elements of the system: the central computer with the main trigger of the experiment and the low voltage power supply and distribution system. The scientists will also take part in the development of software, as well as the analysis of data collected by the detector.

Machine learning – a universal research tool

The conference "International Workshop on Machine Learning and Quantum Computing Applications in Medicine and Physics" was held in September 2022 in Warsaw, Poland, and was dedicated to the application of statistical methods, including machine learning, in medicine and the physical sciences. In recent times machine learning methods in particular, including so-called deep learning, which allow the analysis of complex data sets, are finding further applications. Similar techniques and tools are being used to solve a variety of problems. The conference was aimed primarily at experts applying machine learning techniques in the fields of physics and medicine. The format of the conference included presentations, but also three 6-hour "hands-on" tutorials, in which participants with the help of the presenter solved a series of exercises on their own computers. A format that differed somewhat from standard conferences created more time for discussion.

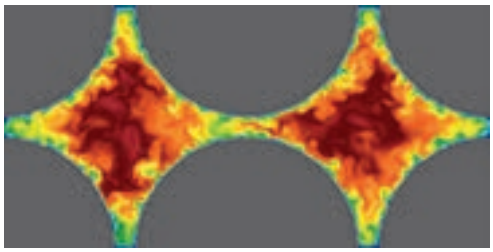
Scientists train artificial neural networks to detect real-time releases of toxins

The main task of the emergency response groups existing in all cities is quick response to all threats to people and the environment. The primary determinant of success or failure of an activity is reaction time. Some models have to be run tens of thousands of times to find the most likely source of contamination. This means that the model used must be fast in order to be applicable to a real-time fallback system. The solution to this problem, on which the MANHAZ Hazard Analysis Centre at NCBJ is working, may be the use of an artificial neural network in the reconstruction system. If this is successful, ANN can act as a dispersion model in a system that locates the source of the contamination in real time. Using ANN can reduce the response time of the reconstruction 100-fold. Taking this into account, the reconstruction time in an actual emergency can be short, resulting in the source of contamination being quickly located.

Awards for modeling of turbulent flow

Tomasz Kwiatkowski from the Nuclear Energy and Environmental Analyses Division at NCBJ received an award for a paper presented at the 13th International Topical Meeting on Nuclear Reactor Thermal-Hydraulics, Operation, and Safety (NUTHOS-13). The award-winning work deals with uncertainty analysis of turbulent coolant flow models in closely packed fuel cassettes in nuclear reactors. With the help of numerical fluid dynamics tools and using the computational power of the Świerk Computing Centre, a direct numerical simulation was performed, which provides a reference database for testing lower order turbulence models. Using this, it is possible to assess the correctness of flow and heat transfer models. An important step in the process of improving models is to understand the impact of individual model parameters on the uncertainty of the results obtained. The analyses carried out help to prepare models more effectively, which will be helpful for scientists and engineers working on the design of future nuclear installations.

The organizers of the 6th Intelligent Development Forum, held in September 2021 in Toruń, awarded promising young scientists. Mr. Kwiatkowski was awarded the title "Scientist of the Future." They recognized his research to improve currently available and widely used turbulence models for modeling the flow and heat transfer in fuel cassettes used in nuclear reactors. The results obtained will make it possible to propose a set of so-called "best practices," i.e. indicate how to perform correctly flow and heat transfer analyses in closely packed fuel cassettes.



Reverse modeling of accidental releases of hazardous substances

The accidental release of hazardous substances into the atmosphere is one of the most serious threats to the health and life of people in the area at risk. The key issue in the early phase of responding to the danger is the rapid and precise identification of the source of the release. Inverse modeling of hazardous releases is being conducted by Dr. Piotr Kopka from the Nuclear Energy and Environmental Analyses Division at NCBJ. The research concerns the implementation of probabilistic inverse models to identify the sources of hazardous material releases to the atmosphere based on measurements from sensor networks and using external data. It is particularly difficult to identify the parameters of a gas source located in a highly urbanized area. As part of the conducted research, it was possible to locate and determine the emission level of a gas source based on concentration data from the DAPPLE experiment. For the above, Dr. Kopka received an award given to young scientists by the international Nuclear and Radiological Emergency Response and Recovery organization.

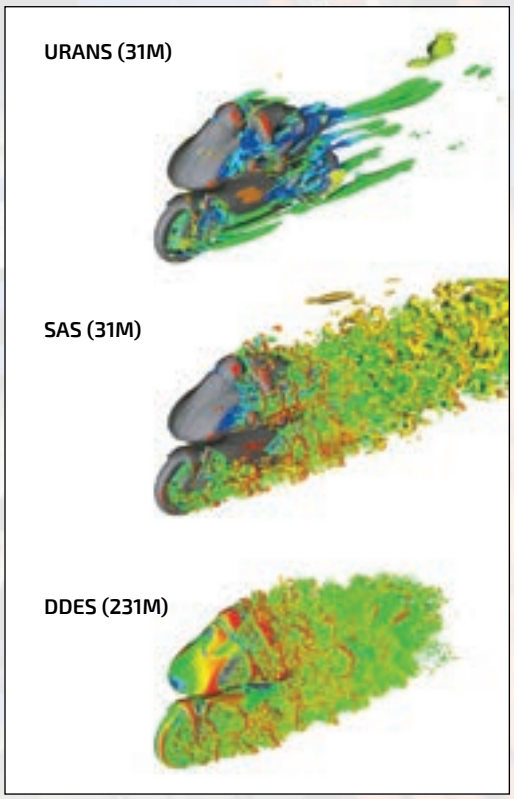
Building the Polish part of the European computer ecosystem with the participation of NCBJ

EuroHPC is an advanced network of exascale supercomputers that is poised to revolutionize society, science, and the economy through cutting-edge technology applications. As part of the Polish consortium EuroHPC PL, NCBJ is at the forefront of this transformative project, working on the development of quantum simulation and medical imaging platforms. One of the goals of NCBJ scientists is to transcend the limitations of conventional PET scanner techniques by integrating quantum information with traditional data. This process involves studying the quantum correlations of photons emitted from a patient's body during PET examinations.

The EuroHPC project aligns with the pan-European initiative for a robust exascale supercomputing system, which is instrumental in carrying out large-scale computations, simulations, and complex data analyses crucial for scientific research. The system's hybrid infrastructure combines conventional supercomputers with quantum and neuromorphic accelerators to address major research challenges. It is designed to serve a broad user base, including scientists, analysts, and entrepreneurs, while fostering research and innovation tailored to the capacities of exascale supercomputers and modern computational architectures. A key projected outcome is the InfiniBoard, a high-throughput I/O interface.

"Speed is our domain" – advanced simulations in vehicle design

Numerical simulations are vital in the automotive sector and offer competitive advantages. NCBJ employs high-performance computers that significantly outperform standard workstations. Scientists have presented a simulation of airflow around a student-designed electric motorcycle, Perun, using Computational Fluid Dynamics (CFD). The significant computing power of the Świerk Computing Centre ensures high accuracy in simulations. The scientists aimed to optimize the motorcycle's shape with the driver's position in mind, as this affects the machine's speed and range. This involved identifying sources of turbulence and minimizing aerodynamic drag, which is a complex task given the shape of the motorcycle and rider. The computational process, known as space discretization, uses a grid to predict flow behavior. Smaller elements yield more precise predictions, but due to hardware limitations, some simplifications are necessary. Using the Świerk IT Center's 1400 cores, the simulation took 15 hours, a process that would take months on a standard workstation.



CyberLAB detects and fixes another network security issue.

CyberLAB at NCBJ identified a vulnerability in certain programmable logic controllers (PLCs). The flaw triggered a buffer overflow, which could lead to controller failure, posing significant financial and safety risks. They reported the vulnerability to the security team and coordinated remediation efforts, with the manufacturer's appreciation. The team uses fuzzing testing, which involves sending modified data packets to the device, to find vulnerabilities. They previously found a critical vulnerability in 2018, contributing to cybersecurity across various industries. CyberLAB was formed through participation in an international computer security program. The scientists test industrial devices, particularly PLCs used in industrial automation. In addition to testing more devices, they offer customized cybersecurity services, such as vulnerability searches in devices provided by customers, and testing the effectiveness of security solutions like anomaly detection systems. The infrastructure supports simulations of complex industrial and corporate environments.

Community education

The National Centre for Nuclear Research (NCBJ) actively engages in educational initiatives aimed at fostering knowledge and understanding of nuclear energy. It conducts workshops on nuclear energy for high school students, providing valuable insights into this field. Additionally, NCBJ organizes student seminars to encourage the exchange of ideas and promote scientific discourse. The institute's educational program, "Detectors for Schools," offers schools the opportunity to borrow radiation detection kits, enabling hands-on lessons on various aspects of radiation, including cosmic radiation.

NCBJ actively participates in popular science events such as science festivals and science picnics held throughout the country. It provides both in-person and online educational activities and lectures, engaging the public with captivating demonstrations and informative presentations. Moreover, NCBJ organizes the "Physics Paths" competition, promoting scientific exploration through essay writing, innovative demonstrations, and young researchers' contributions.

The institute also offers specialized courses and training programs. It provides radiation safety training for NCBJ employees working in radiation-exposed environments. Furthermore, NCBJ conducts radiation-related training programs, including certification courses, for public institutions and businesses seeking to enhance their knowledge and expertise in radiation-related topics.

NCBJ facilitates visits and internships for individuals interested in exploring the institute's research and educational facilities. It also contributes to the dissemination of knowledge through the creation of comprehensive reports, analyses, presentations, and publications on nuclear energy and technologies employed in nuclear power plants.

In order to make scientific concepts more accessible to the general public, NCBJ produces popular science films that provide insights into the work carried out in various departments within the institute. These films showcase applications of and advances in nuclear research.

The educational department of NCBJ boasts specialized laboratories that allow for hands-on experiments and exercises related to radiation and nuclear physics for both students and teachers. With a highly qualified scientific staff and twenty-five years of experience in educational endeavors, the institute collaborates closely with educational institutions, organizations, and the public, sharing its expertise and promoting the understanding of nuclear energy.

NCBJ's lecture and demonstration halls are equipped with state-of-the-art resources, enhancing the audience's comprehension of ionizing radiation and nuclear energy. Through these educational initiatives, NCBJ aims to inspire and educate individuals of all ages, fostering a broader understanding of nuclear energy and its applications.

A series of short educational videos on high temperature reactor technology

A series of 6 videos was developed as part of the GoHTR project to provide an in-depth understanding of the high-temperature reactor (HTR) and its potential benefits for Poland's industrial sector. The video series addresses the need for a stable, emission-free energy source, exploring how such an investment could propel the country's economy forward. It also demystifies nuclear reactors by explaining nuclear fission, the roles of fuel elements, control rods, moderators, and reflectors, and how neutrons and heat are generated and utilized in research and power reactors. The history and evolution of reactors over the past eighty years is covered, with an emphasis on energy reactors. It highlights the differences between the two most common types of energy reactors today—the pressurized water reactor (PWR) and the boiling water reactor (BWR)—and how gas-cooled high-temperature reactors (HTRs) can fit into a low-emission energy mix. Additionally, the video series illustrates how an HTR with a hexagonal core works, its fuel structure, how heat is extracted, and safety features ensuring safe operation. The potential applications of HTRs in places and processes where efficient use of renewable energy sources is impossible are presented, emphasizing how steam generated in HTRs can meet the needs of existing industrial installations. Finally, a video focuses on TRISO fuel particles, a highly secure nuclear fuel used in HTRs, offering a safer future.

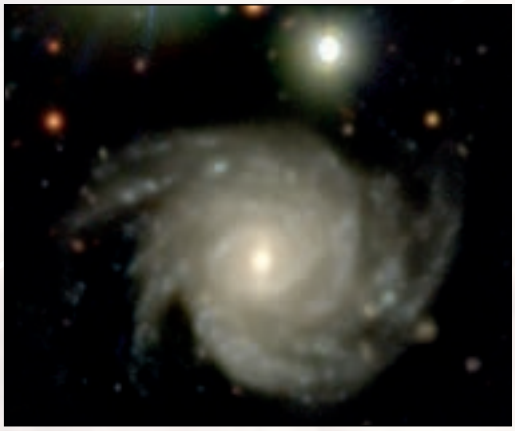
A series of short educational videos on NCBJ

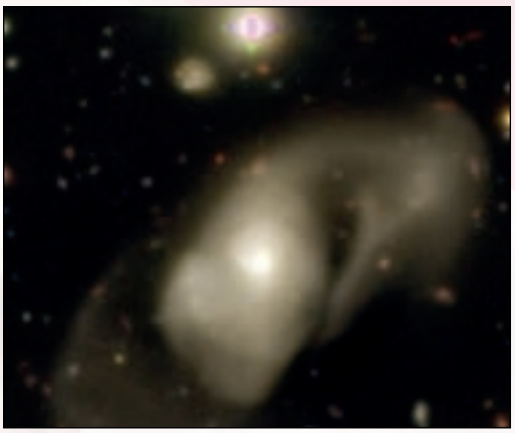
NCBJ has released a series of videos as part of its "Virtual Open Days of NCBJ and Świerk Nuclear Centre" project. This initiative aims to give a broad audience a deeper insight into the workings of various departments within the NCBJ and the Świerk Nuclear Centre. Inspired by the success of the traditional Open Days, the project provides a unique opportunity for those unable to visit in person to explore the facilities virtually.

The series comprises ten videos, each focusing on different areas that visitors can explore during Open Days. These include the Materials Research Laboratory, the Plasma/Ion Beam Technology Division, the Science and Technology Park Świerk, the Education and Training Division, the Radiation Protection Measurements Laboratory, the Radioactive Waste Disposal Department, the NOMATEN Centre of Excellence, the MARIA Reactor, the POLATOM Radioisotope Centre, and the Nuclear Equipment Division (HITEC), along with the Particle Particle Acceleration and Physics Technology Division. The project invites everyone for a fascinating virtual journey into the heart of nuclear research.

New images of tens of thousands of galaxies have been made available at the Galactic Zoo

NCBJ scientists participate in Galaxy Zoo, the world's most renowned citizen science project. It has released 20,000 high-quality images from the H20/Cosmic Dawn survey. Sourced from the Hyper-Suprime Cam on the Subaru telescope, these images include some of the most distant galaxies ever seen and offer the public unprecedented opportunities for discovery. This initiative results from international collaboration involving numerous educational and research institutions and continues to add new images as the survey progresses. The public's contributions assist astronomers in understanding the evolution of galaxies, detecting rare phenomena like gravitational lenses and galaxy mergers, and refining their understanding of the universe's expansion rate and the role of galaxy mergers in their evolution. Additionally, these contributions will provide critical insights for future missions such as the ESA Euclid mission and surveys from the Vera C. Rubin Observatory. Interestingly, unexpected discoveries made by participants have led to scientifically significant findings, emphasizing the project's collaborative nature. Thus, Galaxy Zoo empowers the public to participate in leading-edge scientific research and contribute to the next chapter of astronomy.





Dark Matter Day

NCBJ staff made a significant contribution to the successful organization of an online meeting dedicated to the enigmatic dark matter, an annual event since 2017. Traditionally, the event takes place in October and includes popular science lectures on dark matter. Dark matter, though invisible and non-emitting of electromagnetic radiation, gravitationally affects other space objects, explaining various astronomical phenomena. The event emphasized the critical role of ongoing dark matter research, including the development of novel methods to confirm the existence of dark matter particles. NCBJ scientists co-hosted the online meeting, which featured brief lectures presenting dark matter perspectives from different branches of physics. This gathering served as an educational forum and source of inspiration for new ideas in dark matter research.

Probe with CosmicWatch detectors sent into the stratosphere during the 47th Congress of Polish Physicists

At the 47th Congress of Polish Physicists, held in Bydgoszcz from September 19-23, 2021, a tandem stratospheric probe equipped with CosmicWatch detectors was launched to measure cosmic radiation. The probe was deployed using a historic method from the 19th century, honoring scientists Hugo Hergesel and Erich Regener, both from Bydgoszcz. The launch point on the 18th meridian was chosen to honor mathematician and cryptologist Marian Rejewski, also from Bydgoszcz.

Despite challenges during the mission, including the entanglement of the second balloon and parachutes, the probe landed safely without damaging any equipment. The detectors, developed as part of an educational project between the National Centre for Nuclear Research (NCBJ) and MIT, are designed to measure the quantity of ionizing particles passing through a scintillator. This mission is significant in understanding how the number of detected muons changes with altitude. This was not the first time NCBJ scientists have sent CosmicWatch detectors into the stratosphere.

Physics Paths Competition

Physics Paths is a student competition jointly organized by the National Centre for Nuclear Research in Świerk and the Institute of Physics of the Polish Academy of Sciences in Warsaw. The competition is open to students in the seventh and eighth grades of primary school, as well as students of secondary and vocational schools, regardless of their proficiency in physics.

Organizers believe that entrants do not need to be experts in physics or understand its intricate (including mathematical) aspects in order to present a compelling display of a physical phenomenon. All that is necessary is a good idea that will captivate the audience. Students who can recognize how deeply physics shapes civilization can express this understanding in a beautifully crafted essay, with basic physics knowledge and good writing skills. Creating scientific papers requires more effort, but it is not exclusive to those with an "Einstein's mind"—courage and mastery of the rules governing scientific work are all that is required.

Teachers will gladly show students the beauty of physics and how to interact with it and write about it in an engaging way. Students are encouraged to explore their ideas and choose suitable topics, but they should remember that plagiarism is strictly forbidden.

The competition concludes with a final seminar, an unforgettable meeting with scholars who will be eager to discuss the issues raised in students' works and provide guidance for further skills development. Attractive prizes, including admission to Poland's top physics faculties, await finalists. Participating in the competition is a chance for a fascinating intellectual adventure, and students are encouraged to seize it.

DEVELOPMENT OF STAFF *and* HUMAN RESOURCES

New professors

In the years 2021-2022, eight NCBJ scientists were awarded the title of professor. They were:

- Andrzej Kupść
- Agnieszka Pollo
- Jacek Sekutowicz
- Roman Zagórski
- Jerzy Cetnar
- Renata Mikołajczak
- Sławomir Wronka
- Paweł Sobkowicz

At the same time, the NCBJ Scientific Council awarded the habilitation degree to seven scientists:

- Lech Raczyński
- Stefanos Papanikolaou
- Tomasz Denkiewicz
- Marcin Kuźniak
- Andrzej Wojciechowski
- Francisco Javier Dominguez Gutierrez
- Artur Ukleja

The NCBJ and IChTJ Graduate School gains a new look thanks to participation in the STER program

The Graduate School of Physics and Chemistry at the National Centre for Nuclear Research (NCBJ) and the Institute of Nuclear Chemistry and Technology (IChTJ) is undergoing significant changes as it participates in the STER program, Internationalization of Doctoral Schools by NAWA, for the next three years. This opportunity will allow young scientists worldwide to pursue education and research in collaboration with top research centers.

The transformation of the Graduate School is due to a grant for the project "International Doctoral Program at NCBJ & IChTJ" (IDP) under the STER program. This initiative aims to boost the quality of education and research, increase doctoral students' international mobility, and support sustained international collaboration.

The IDP project will provide scholarships for highly talented doctoral students, enabling innovative research in various fields of physics and chemistry. The program will also make doctoral studies easier by involving co-supervision from foreign researchers and organization of lectures by these experts. The project will make it easier for students to participate in international research by enabling them to join large collaborations and conduct research at institutions like CERN or DESY and in projects like LIGO, VIRGO, and T2K.

The IDP also plans to hold interdisciplinary workshops with international scientists and join a global network of doctoral schools. Through the STER program, doctoral students will cooperate with leading research centers worldwide, contributing to their scientific careers and expanding our talented and energetic group.

NCBJ and IChTJ have a long-standing tradition of educating doctoral students. In 2019, an interdisciplinary Graduate School was established, offering education in various fields like nuclear physics and chemistry, radiopharmacy, and astrophysics, and close cooperation with leading research centers globally.

- Scientific Council
- D — Director General
- Nuclear Safety Commission

- DI — Deputy NCBJ Director for Innovation and Commercialisation
  - ZdAJ — NCBJ Nuclear Equipment Division (HITEC)
  - IZ — Project Management Division
  - PNT — Science and Technology Park
  - IK — Communication and Promotion Office
- DN — Deputy NCBJ Director for Scientific Matters
- DAt — Assistant of DG
- AIS — Secretary's office
- DJ — Deputy NCBJ Director for Nuclear Safety and Health Protection **Safety & Radiation Protection Department**
  - JA — Nuclear Centre Emergency Squads
  - IOR — Radiation Protection Officer
  - JE — Fissile Materials Accounting Office
  - LPD — Radiation Protection Measurements Labolatory
  - JO — Civil Defence /Defensive Measures Squad
  - WSO — Internal Security Guard
  - JP — Fire Prevention Division
- DE — Deputy NCBJ Director for Economy **Economics Department**
  - EF — Financial Controller
  - IT — IT Division
  - EZ — Procurement Division
  - EA — Administrative Division
- DBP — DBP Director **Fundamental Research Department**
  - BP1 — Nuclear Physics Division
  - BP2 — Theoretical Physics Division
  - BP3 — High Energy Physics Division
  - BP4 — Astrophysics Division
- Human Resource Management Division — DHR
- Human Resources Division — DP
- Legal Division — DRP
- Analysis and Project Settlements Division — DA
- Spokespersons — DRz
- Occupational Safety and Health Division — DBHP
- Internal Auditor — DAW
- Proxy for Integrated Management System — DZSZ
- Quality Management Division — DZJ
- Inspector of Personal Data Protection — IODO
- Proxy for Classified Information Protection — DOIN
- Classified Information Protection Division — OIN
- Director Proxies — OPm
- DFM — DFM Director **Material Physics Department**
  - LBM — Material Research Lab
  - FM1 — Nuclear Methods in Solid State Physics Division
  - FM2 — Plasma/Ion Beam Technology Division
- DUZ — DUZ Director **Complex Systems Research Department**
  - UZ1 — Information Technologies Division
  - UZ2 — Software Engineering Division
  - UZ3 — Nuclear Energy and Environmental Analyses Div.
- DEJ — DEJ Director **Nuclear Facilities Operations Department**
  - EJ2 — MARIA Reactor Operations Division
  - EJ3 — Reactor Technologies Division
  - EJ4 — Reactor Research Division
  - EJZJ — MARIA Reactor Quality Assurance Specialist
  - EJN — Irradiation Coordinator
  - EJD — Documentation Division
  - EJA — Contracts and Administration Division
  - EJR — Renovation and Modernization Division
- DIZ — IInterdisciplinary Division for Energy Analyses
- NOMATEN — NOMATEN - International Scientific Agency
- OR — Radioisotope Centre POLATOM
- DTJ — DATJ Director **Nuclear Equipment & Technology Department**
  - TJ1 — Particle Acceleration Physics & Technology Div.
  - TJ2 — Electronics and Detection Systems Division
  - TJ3 — Radiation Detectors and Plasma Diagnostics Division
  - H2 — Radiological Metrology and Biomedical Physics Div.
- D5 — Scientific Secretary **Research Support Department**
  - SD — PhD Studies / Doctoral School
  - SW — International R&D Projects and Cooperation
  - SE — Education and Training Division
  - SB — Library
- EK — **Chief Accountant**
  - KF — Financial Accounting Division
  - KR — Payroll Division
- ET — Technical Matters Department Director **Technical Matters Dpt.**
  - TN — Chief Technical Engineer
  - TE — Electric Infrastructure Division
  - TS — Sanitary Division
  - TO — Technical Service Division
  - TI — Investment and Renovation Division
  - TP — Planning and Settlement of Investments, Renovations and Operations Division
- ZTS — Bus Transport Division

NCBJ IN BRIEF

The Institute's profile of basic/applied research combines studies related to nuclear energy and various fields of subatomic physics (elementary particle physics, nuclear physics, hot plasma physics, etc.) with non-nuclear applications using various forms of radiation. The center is deeply involved in the development of nuclear technologies and the promotion of practical applications of nuclear physics methods. The main market products produced at the Centre are radiopharmaceuticals and a range of particle accelerators for science, various industries, and medicine.

The National Centre for Nuclear Research is one of the largest scientific institutes in Central Europe. The Centre operates the MARIA research nuclear reactor and has a number of advanced research instruments and laboratories, particularly useful in materials research and modification, as well as radiography. It also has its own computing center. New research infrastructures are currently being developed at the institute: the CERAD Laboratory, which will be equipped with a world-class cyclotron for the production of radioisotopes, the superconducting PolFEL free-electron laser, and the Regional Neutronography Laboratory using neutron beams from the MARIA reactor. There is also ongoing work on the concept of building a pioneering high-temperature gas-cooled research reactor at the Centre.

A particularly important area of NCBJ's activities is basic research in the fields of high energy, nuclear, and atomic physics, as well as astrophysics, astronomy, and cosmology. These are mostly conducted within broad international collaborations, including participation in the conception, analysis, and construction of apparatus for large international experiments.

The Institute's activities result in a high publication output (over 500 items per year) of high quality confirmed by the number of citations (Hirsch index H>190), as well as numerous accreditations, certificates, awards, and distinctions. This also results in a high interest from foreign students in the opportunity to undertake doctoral studies at the institute (currently, we have about 30 foreign students studying with us).

NCBJ employs around 1,300 people (July 2023). The scientific staff consists of about 70 professors and holders of habilitation (Dr. Hab.), as well as over 150 PhDs.

The potential and assets of NCBJ predestine the institute to serve as a Technical Support Organization (TSO) for the Polish nuclear program. The first step towards this goal was the granting of authorization in three areas of TSO tasks by the national regulator - the State Atomic Energy Agency (PAA).

NCBJ is located in Otwock, near Warsaw, occupying the well-guarded forty-hectare Świerk nuclear center. The Institute's fundamental research divisions are also located on the "Ochota" university campus in Warsaw.

As a research institute with the legal status of a state scientific unit, NCBJ inherits its traditions from the Institute of Nuclear Research, founded in 1955, then continued by the Sołtan Institute for Nuclear Studies and the Institute of Atomic Energy.

RESEARCH COLLABORATIONS