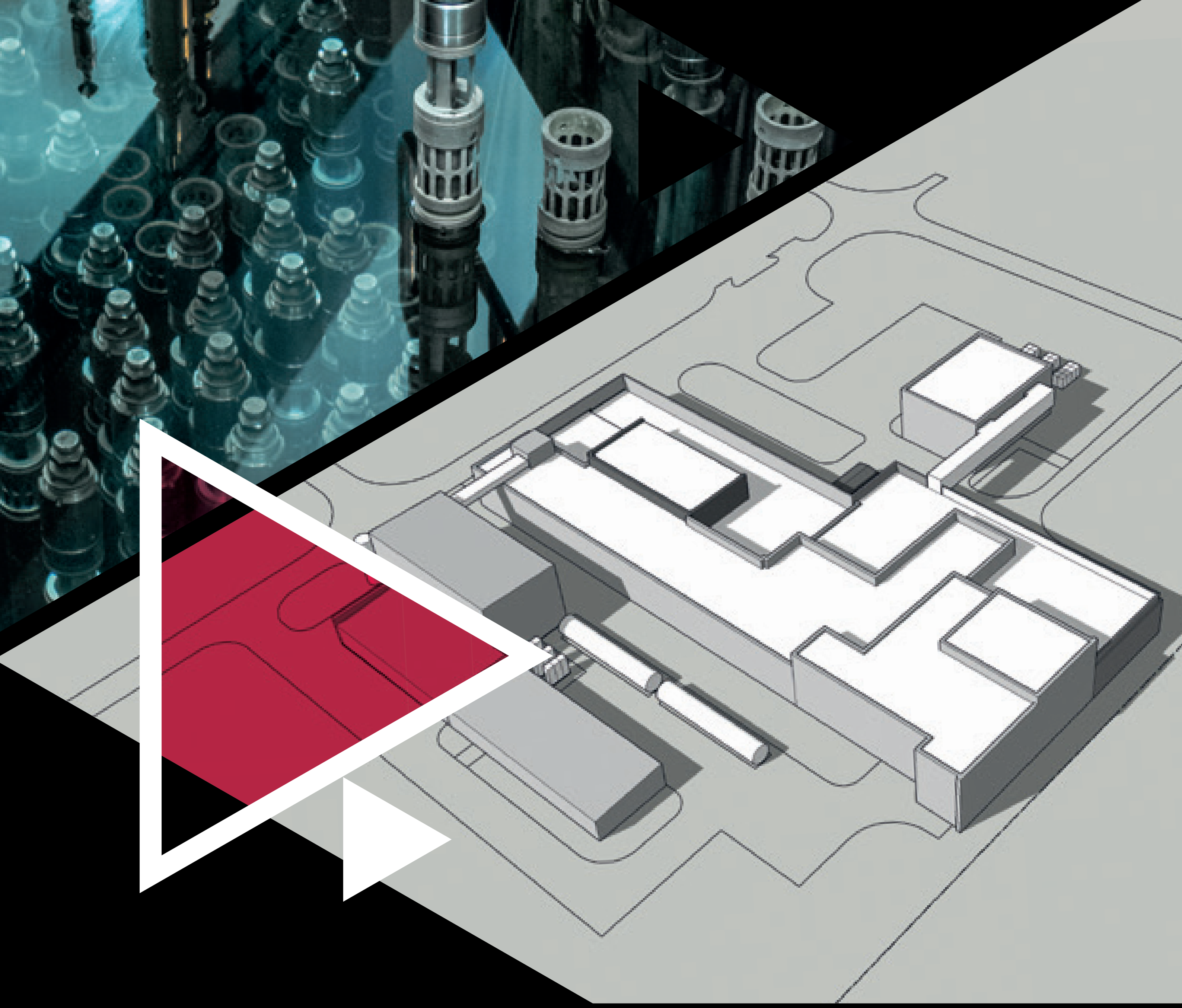


NCBJ Highlights 2019 2020

Category A+ Polish Scientific Institution

NATIONAL
CENTRE
FOR NUCLEAR
RESEARCH
ŚWIERK

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

Łódź site:

ul. 28 Płk. Strzelców Kaniowskich 69
90-558 Łódź

Secretaries' Office

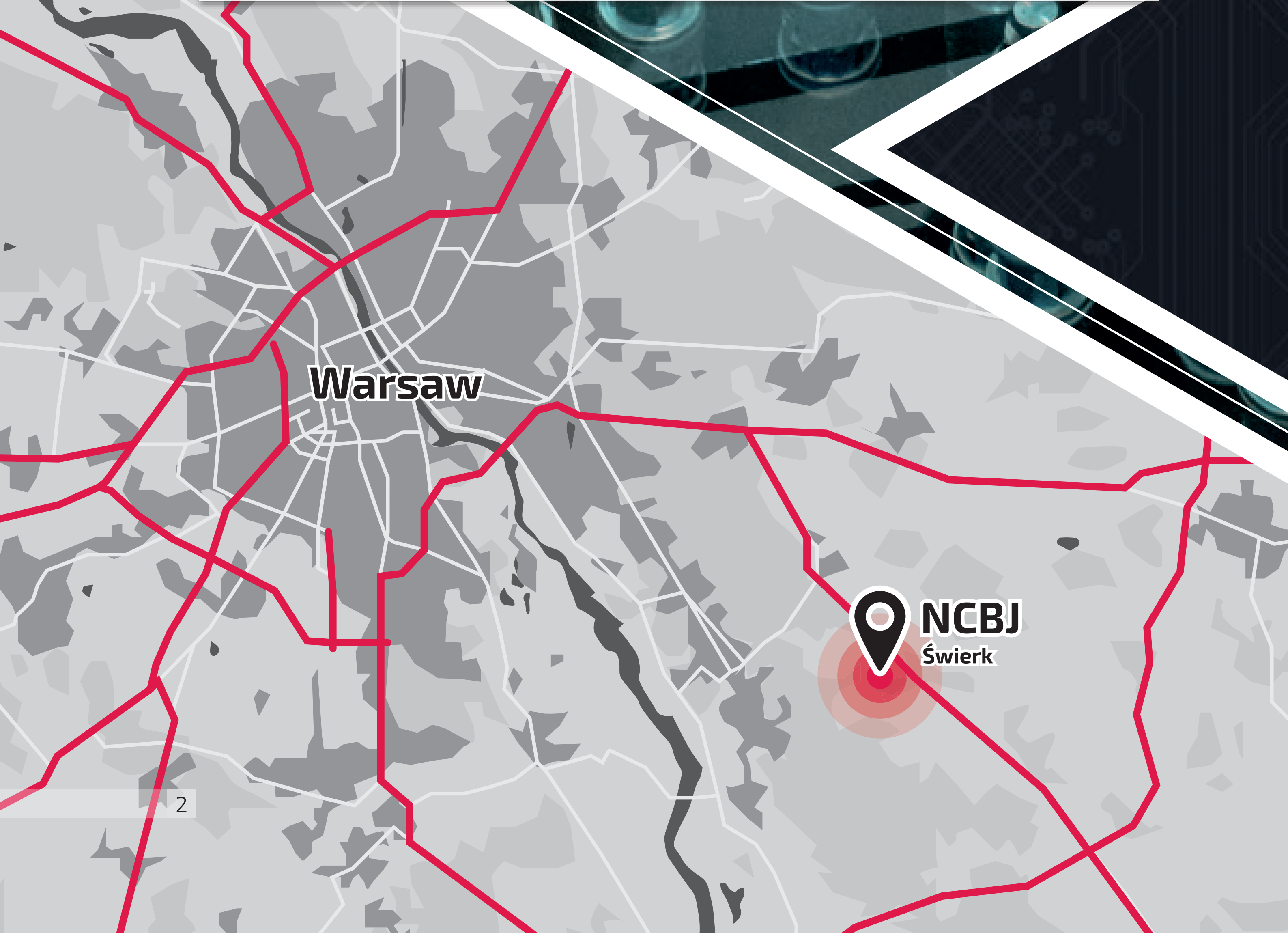
phone: +48 22 27 31 001
fax: +48 22 77 93 481
e-mail: ncbj@ncbj.gov.pl

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 2019 and 2020 will go down in the history of NCBJ as a very specific period.

After a good year, especially for the Radioisotope Center POLATOM, which saw a very good financial result for the Institute, came the "lockdown" caused by the COVID-19 coronavirus pandemic. In order to maintain the continuous operation of the Institute, 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. Thanks to the commitment of all employees, it was possible to maintain the work of the Institute almost as usual, for which I would like to thank everyone very much.

Pandemic restrictions significantly affected NCBJ's commercial activities in 2020, mainly by grounding air transport. This resulted in a decline in radiopharmaceutical exports and, as a result, the Institute's financial results in 2020 were worse than in 2019, but still good given the circumstances.

Despite the pandemic, the dynamics of NCBJ's development did not diminish. In the years 2019-2020, NCBJ implemented three large infrastructure projects on schedule: POLFEL – the Polish Free Electron Laser, CERAD – the Center for Design and Synthesis of Molecularly Targeted Radiopharmaceuticals and CENTRIX – an Industrial Radiography Laboratory.

As part of a prestigious European TEAMING grant and an FNP grant, the NOMATEN Center of Excellence for New Materials was established as a separate department at NCBJ.

Travel restrictions and the necessity for remote working in many cases did not cause a decrease in the number or quality of scientific publications. The research staff at NCBJ developed dynamically. In the years 2019-2021, 13 doctorates and 14 habilitations were awarded, and 4 members of staff received the title of professor from the President of the Republic of Poland. We were also pleased with the increase in the number of implemented projects (114 in 2019 and 121 in 2020).

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, will be implemented in cooperation with Japan. This 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.

NCBJ was recognized in 2021 for its activities in 2018-2020 with two Crystal Brussels awards for participation in European projects, and Forbes magazine awarded the Institute the Forbes Diamond – a distinction for companies that have increased their value fastest over the past 3 years.

The pandemic continues and some organizational and communication solutions, especially in the field of IT, will stay with us for longer, if not forever. After the experiences of 2020 and 2021, I am sure that NCBJ, despite the pandemic, 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

CONTENT

CONTENT

The NOMATEN project recognized

On April 23, 2019, Prime Minister Mateusz Morawiecki and Deputy Prime Minister Jarosław Gowin visited Świerk. The visit was concluded by a joint press conference with NCBJ Director Krzysztof Kurek. The topic of the conference was awarding to Polish applicants of 3 out of 13 EU grants in the Teaming for Excellence competition. The grants were expected to aid in the creation of Centres of Excellence and our NOMATEN project was one of the winners.

The NOMATEN project aims to create a strong research centre which will utilize the unique nuclear research infrastructure and experience of Polish and European scientists in order to promote research into and production of state-of-the-art innovative materials suitable for extreme conditions in industry, as well as conforming to the highest medical standards.

The project has been prepared by an international consortium: the National Centre for Nuclear Research (NCBJ), the Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA, France), and the Teknologian Tutkimuskeskus VTT Oy (VTT, Finland). The partners have received aid from the National Centre for Research and Development (NCBiR) and the Ministry of Science and Higher Education. Research will mainly focus on factors that induce great stress in materials, such as high temperatures, high pressures, radiation (especially neutrons), corrosion, intense abrasion, etc. Some of these problems are common to many different applications, for example in the nuclear and chemical industries, while some of them are very specific, applicable only to a few cases. However, many examples prove that creating innovative materials for a single specific purpose or even for unique scientific research leads to the discovery of solutions useful in other, initially unexpected fields. A special place in the research programme of the Centre is reserved for new materials created for medical use as radiopharmaceuticals.

Implementation of the project together with the best and most experienced research institutes in Europe (VTT and CEA) will open new possibilities for young researchers, providing them with suitable conditions for professional development in rapidly growing branches of science and industry. Consequently, NCBJ's prestige and research potential will increase, cementing the Institute's position as a strong research institution with European and global significance.

The NOMATEN Centre of Excellence began operating in the autumn of 2018 as a project of the International Research Agenda, which received funding from the resources of the Foundation for Polish Science. During its first months of existence researchers from NOMATEN have already contributed to two significant research projects: GoHTR, a project funded by NCBiR, related to high temperature reactor technology under the Gospostrateg programme and INLAS, a collaboration between Poland and the Republic of South Africa which aims to develop better and cleaner coal burning technology.

You can read more about the process of creating the NOMATEN Center on pages 24-25.

High position of NCBJ in the Nature Index ranking

NCBJ was classified in third place in Poland (after the Polish Academy of Sciences and the University of Warsaw) in the Nature Index ranking for the period April 1, 2019 – March 31, 2020. The ranking is based on research papers published in the period analyzed: a point is assigned, if one or more of the authors of the 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 159,648 names, including 726 from Polish scientific institutions. Among these are 7 professors employed at NCBJ: Andrzej Deloff, Jerzy Kowalski-Glikman, Andrzej Królak, Marek Moszyński, Stanisław Mrówczyński, Leszek Roszkowski, and Grzegorz Wilk. The list also includes the late Prof. Adam Sobiczewski. 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 the research team is also considered to be a major asset.

Eighth place in Poland among universities in the CWUR ranking

The National Centre for Nuclear Research ranks in the top 4.5% of 19,788 universities worldwide according to the "Global 2000 List by the Center for World University Rankings" published on cwur.org. The rankings are designed with universities in mind. Therefore, as much as 60% of the evaluation components concern the quality of education, the building of graduate careers and the quality of the academic staff. Only 40% of the points are awarded for research achievements. NCBJ, where only doctoral studies are conducted, owes its high position in the ranking mainly to its significant scientific results.

Forbes Diamonds

The National Centre for Nuclear Research was among the business entities awarded Forbes Diamonds in 2021. The list of the most dynamically developing companies in 2015-2019 was prepared by experts from Bisnode Polska commissioned by the Forbes economic magazine. Analysts valued enterprises using the Swiss method, combining the property and income method. NCBJ, with a growth dynamic of approx. 25%, was placed 39th on the list in Mazovia.

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Forbes
2021

PRIZES *and* AWARDS

Crystal Brussels Sprouts Prizes for NCBJ and Dr. Jacek Gajewski

The Crystal Brussels Sprouts Prize is awarded by a jury appointed by the National Contact Point for Research Programmes of the European Union. The prize is given for success in the research and innovation framework programs of the European Union. On December 18th, 2020, at a remotely organized Gala, NCBJ received the award in the "science – research institute" category, and Dr Jacek Gajewski received an individual award. NCBJ is among the three leaders of scientific institutions when it comes to effectiveness in obtaining grants from the Horizon 2020 program. Dr Jacek Gajewski is the representative of the NCBJ Director and coordinator of international projects. It is a great honor that the scientific director was among the winners. The Director of the National Contact Point for Research Programs of the European Union, dr inż. Zygmunt Krasiński, commented on this fact: "The role of science managers, the role of technology brokers is crucial both in this innovation research market and in the global market. Therefore, I am very happy that the winners of the individual award in this year's competition are both a world-class research leader and a research director. It is a sign of the times and these professions should work closely together."

Centenary medals for Professor Strupczewski and Professor Wrochna

On April 17, 2019, Minister Krzysztof Tchórzewski presented Medals of the Centenary of Independence to Prof. Andrzej Strupczewski and Prof. Grzegorz Wrochna. They were presented to the distinguished scientists by Prime Minister Mateusz Morawiecki. Professor Andzrzej Strupczewski is an outstanding expert in the field of nuclear energy and nuclear safety. Professor Grzegorz Wrochna is a specialist in the field of radiation detectors, as well as space research using methods developed in the field of high energy physics. Professor Wrochna was the first director of NCBJ, as well as the co-author of the concept of establishing our institute as a result of the merger of the Institute for Nuclear Studies and the Institute of Atomic Energy.

Professor Renata Mikołajczak: the chairwoman of a working group of the European Pharmacopoeia Commission

The European Pharmacopoeia (Ph. Eur.) is a compact reference document for the quality control of medicines. Its official standards include a specific and legal basis for quality control throughout the entire product life cycle. These standards are defined by the Council of Europe Convention on the development of the European Pharmacopoeia as well as European Union and national pharmaceutical regulations. The European Pharmacopoeia's quality standards become mandatory on the same day in all countries party to the Convection.

The European Pharmacopoeia Commission (EDQM, Strasbourg) is the official decision-making body of Ph. Eur. and is responsible for the development and maintenance of its content. The Commission accepts all Pharmacopoeia documents for publication and makes technical decisions by agreement. 25 representatives from Poland participate in the work of the European Pharmacopoeia Commission and its working group.

Ms. Renata Mikołajczak is a professor at NCBJ, representative of the Director for Scientific Affairs and National and International Cooperation at the POLATOM Radioisotope Centre. In the European Pharmacopoeia Commission, she will lead a working group on the development of monographs on radiopharmaceutical precursors (Precursors for Radiopharmaceutical Preparations – PRP Working Party).

Ms. Mikołajczak took up her functions based on the recommendations of the Office for Registration of Medical Products, Medical Devices, and Biocidal Products, as well as after approval by the Ministry of Health and formal approval at the 166th session of the European Pharmacopoeia Commission. She is the first person from Poland to whom the Commission has entrusted such a responsible role.

Dr. Eng. Karol Wawrzyniak joined the RES team

On April 2nd, 2020, the Minister of Climate, Michał Kurtyka, appointed a Team for the Development of the Renewable Energy Sources Industry and Benefits for the Polish Economy as an opinion-making and advisory body of the minister responsible for climate and energy. The main tasks of the Team will include the development of recommendations on development directions of the Polish renewable energy sources (RES) industry, maximizing benefits for the Polish economy on the way to climate neutrality and ensuring the energy security of the state. Six thematic areas have been established: Clean heat, Eco-transport, Local energy dimension, Hydrogen economy, Just Transition, and Large-scale zero-emission energy sources. Dr inż. Karol Wawrzyniak from the Interdisciplinary Division of Energy Analysis, NCBJ, became the person responsible for the area of the local dimension of energy. One of the innovative technologies used in the work of the team is the Zefir system developed by the Interdisciplinary Division of Energy Analysis, NCBJ.

Even heavier elements

On December 5th, 2019, a celebration of the end of the International Year of the Periodic Table of Chemical Elements established by UNESCO was held in Tokyo on the 150th anniversary of the publication of the first version of the Table of Elements by Dmitry Mendeleev. The ceremony was preceded by a four-day international Super Heavy Elements conference (SHE2019) with the participation of several dozen of the world's best scientists involved in research on the heaviest elements. Among the invited guests was Professor Michał Kowal, a co-author of promising theoretical predictions about the possibility of producing new super-heavy nuclides in laboratory conditions.

Scientists from the Faculty of Physics of the University of Warsaw and the National Centre for Nuclear Research have pointed to the possibility of producing two new super-heavy elements and several new isotopes of already discovered elements in laboratories in the immediate future. The authors took into account several possible decay channels of the newly created atomic nuclei. The novelty was the inclusion of the possibility of proton or even alpha emission, which had not before been taken into account in the model. The probability of charged particle emission is lower than the probability of two competing processes: neutron emission or fission. It turned out, however, that the determined values of cross sections for these new decay channels indicate the possibility of their observation in newly constructed colliders.

It was also noticed that it is very important correctly to take into account the dependence of the determined cross sections on the angular momentum of the system. Including this dependence in the description of each of the stages of the production of new nuclei made it possible to authenticate the results obtained by comparing them with cases where it is possible to compare the model with experimental data.

Scientists predict that there is a slight chance of producing two new elements with Z = 119 and Z = 120 in new experiments: by reactions on a ^{249}Bk (berkelium) target with a ^{50}Ti (titanium) projectile and on a ^{248}Cm (curium) target with vanadium (51V) as a projectile.

Calculations made by Polish scientists in cooperation with a group of scientists from Dubna (Russia) allow the prediction with a previously unavailable accuracy of the chances of producing new isotopes of super-heavy elements. They published the most promising channels for producing a wide variety of isotopes ranging from 112 to 118 in various configurations of nuclear collisions leading to their formation. Calculations were performed for ^{48}Ca-induced fusion processes according to plans for future experiments. Polish scientists provided the results of their calculations taking into account hitherto unconsidered effects which have a huge impact on the accuracy of the final results. Quantum effects in the fission process of the nuclear configuration were taken into account and a method of suppressing them as the temperature of the super-heavy nuclear system increased. Such calculations have not been presented anywhere in the literature so far.

The results presented in the paper agree very well with data obtained in already conducted experiments. At the same time the authors point to the most promising channels for the production of new, hitherto unproduced isotopes that could be used in planned future experiments. The excellent agreement with existing excitation functions (probabilities of the synthesis of super-heavy nuclei) allows one to have confidence in the presented forecasts. Channels emitting one proton or one alpha particle turn out to be particularly promising for some target-projectile combinations. This result is intriguing as it may lead to completely new, thus far unknown isotopes of super-heavy nuclei.

Predictions for over a thousand of heaviest atomic nuclei

Theoretical physicists from NCBJ and the University of Zielona Góra have determined and provided extremely important parameters for over 1,305 nuclei, including those of super-heavy elements, which have not been produced in laboratories so far. The studied nuclei are in the range of atomic number Z from 98 to 126 (and thus also include isotopes of elements not yet discovered) and number of neutrons N from 134 to 192.

A multidimensional microscopic-macroscopic model allowing the determination of the binding energy of atomic nuclei was used for the calculations. For ground states and the so-called saddle points, the authors determined such parameters as: nuclear masses, macroscopic energies, shell corrections and nuclear deformations – that is, the shapes of the nuclei in the ground state and in the saddle point. From them the alpha decay energies between the ground states, the separation energies of one and two nucleons and the static, adiabatic heights of the fission barriers were derived. For systems with an odd number of protons, neutrons, or both, the standard blocking BCS method was used. Ground-state shapes and energies were found by minimizing seven axially symmetric deformations. The search for saddle points was carried out using the so-called "Sinking" technique in three successive stages, using multidimensional deformation spaces. A supercomputer at the Świerk IT Centre was used for the calculations.

The authors managed to create one of the most complete data sets available "on the market", necessary for the analysis of cross sections, i.e. the production probabilities of super-heavy nuclei in individual synthesis channels.

A new description of the fission process of heavy odd nuclei

Spontaneous fission is one of the 3 main decay channels of unstable heavy and super-heavy nuclei, and its speed (or related lifetime) is one of its measurable quantities. The current theoretical method of determining the lifetimes assumes that the change of shape is slow on the scale determined by the energies of nuclear excitations. This is called the adiabatic approximation, plausible for nuclei with even numbers of both protons and neutrons, but questionable for odd nuclei (i.e. 3/4 of all nuclei) whose excitation energies can be arbitrarily low. Experimental data show that the rate of spontaneous fission of odd nuclei is 3-5 orders of magnitude lower than that of even-even, which excludes the correctness of the adiabatic approximation. The authors proposed a new way of calculating the lifetime of even-odd nuclei, using the concept of the instanton approach to quantum tunneling. The new approach could be a starting point for improvements that will lead to a consistent method of calculating the lifetimes for spontaneous fission of odd nuclei and isomers (i.e., metastable, excited nuclear states, often with high angular momentum).

Photograph: JINR

The first coherent study of galaxy collisions in the real and simulated universes

For the first time, merging pairs of galaxies have been found using an identical method in both simulations and real-world observations, using artificial intelligence. A pioneering method of identifying colliding galaxies was used. Using simulation images, a team of astrophysicists including NCBJ scientists was able to pinpoint the incidents of collisions and then train artificial intelligence (AI) to identify galaxies during such collisions. In order for the AI to do its job, images of the simulated galaxies were processed to appear as if they were being observed through a telescope. The AI was tested on other simulation images, and then analysis of images of the real universe began.

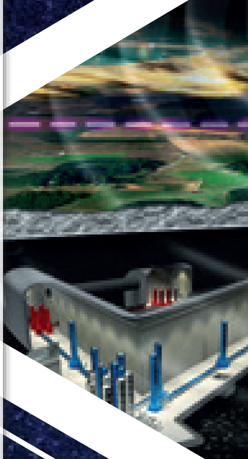
The research checked how the chances of the correct identification of a colliding pair of galaxies depend, among others, on the mass of the galaxies involved. Results based on simulations and real data were compared. For smaller galaxies, AI did just as well with simulated and real images. In the case of larger galaxies, divergences appeared, showing that simulations of collisions of massive galaxies are not realistic enough and need to be refined.

Photograph: This image of a pair of interacting galaxies called Arp 273 was released to celebrate the 21st anniversary of the launch of the NASA/ESA Hubble Space Telescope. The distorted shape of the larger of the two galaxies shows signs of tidal interactions with the smaller of the two. It is thought that the smaller galaxy has actually passed through the larger one. Credit: NASA, ESA and the Hubble Heritage Team (STScI/AURA).

Einstein Telescope – a new generation of gravitational wave detectors

Gravitational waves made it possible to expand our knowledge of the universe. However, for research into them to continue, scientists from around the world, including NCBJ, want to build a new, dedicated telescope. The Einstein Telescope (ET), a pioneering third-generation gravitational wave (GW) observatory, will enable scientists to detect any coalescence – formation – of two intermediate-mass black holes throughout the universe. It will also shed new light on the dark universe and explain the role of dark energy and dark matter in the structure of the universe. The ET will also study black hole physics in detail, and detect thousands of neutron star coalescences, improving our understanding of how matter behaves under such extreme conditions of density and pressure that no laboratory can create.

A consortium of European research institutions and universities has officially made a proposal to build such infrastructure with political support from five European countries. NCBJ is among the initiators of the project.



LIGO and Virgo – more and more results

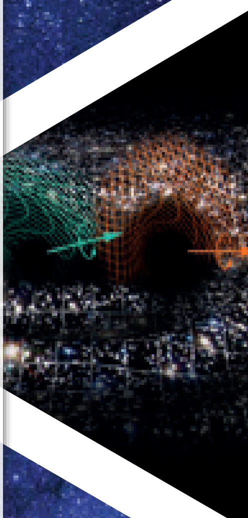
NCBJ scientists participate in the work of the LIGO and Virgo collaborations looking for gravitational wave signals generated by violent phenomena occurring in the distant universe.

In August 2019, the LIGO-Virgo detectors recorded gravitational waves from the coalescence of an atypical binary system containing a black hole and another compact, nine times lighter object that could be either the lightest black hole detected or the heaviest neutron star observed. The heavier component of this system had a mass of 23 solar masses, typical of the black hole population observed in the signals recorded by the LIGO-Virgo detectors. The lighter object, on the other hand, had a mass between 2.5 and 3 times that of the Sun. Such a large asymmetry of the mass of the system allows for new, precise tests of general relativity.

In September 2020, scientists announced the detection of gravitational waves from an extremely massive system of two black holes weighing 66 and 85 times that of the Sun, which merged to form a black hole about 142 times that of the Sun. The object created by the merger is the most massive black hole ever detected by gravitational waves. It lies in a mass range in which we have never seen black holes before: either with gravitational waves or with electromagnetic observations. Its luminous ("loudness") distance to Earth is estimated to be approximately 17 billion light years. The gravitational wave signal, GW190521, was recorded on May 21, 2019.

In October 2020, the collaborations presented a new catalog of GWTC-2 observations of gravitational waves from April to October 2019, i.e. the first part of the O3 (O3a) observation campaign. The collection contains a total of 39 events.

The events included in the new catalog include phenomena consistent with three types of collisions: two black holes, two neutron stars, and mixed systems composed of a neutron star and a black hole. The catalog includes, among others, exceptionally interesting events. The data made available to all interested researchers will enable a wide range of scientists and enthusiasts to work on it.



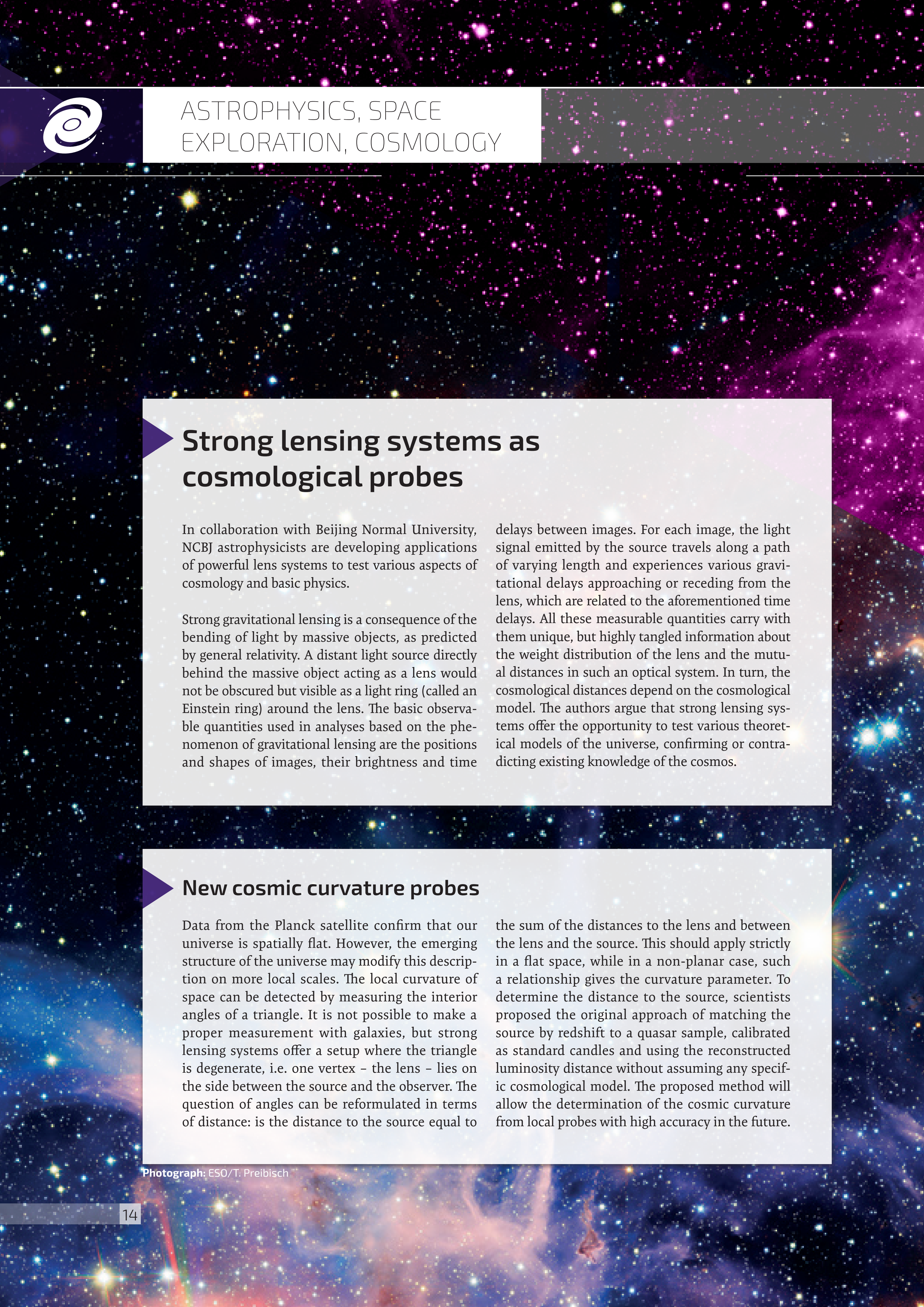
Strong lensing systems as cosmological probes

In collaboration with Beijing Normal University, NCBJ astrophysicists are developing applications of powerful lens systems to test various aspects of cosmology and basic physics.

Strong gravitational lensing is a consequence of the bending of light by massive objects, as predicted by general relativity. A distant light source directly behind the massive object acting as a lens would not be obscured but visible as a light ring (called an Einstein ring) around the lens. The basic observable quantities used in analyses based on the phenomenon of gravitational lensing are the positions and shapes of images, their brightness and time delays between images. For each image, the light signal emitted by the source travels along a path of varying length and experiences various gravitational delays approaching or receding from the lens, which are related to the aforementioned time delays. All these measurable quantities carry with them unique, but highly tangled information about the weight distribution of the lens and the mutual distances in such an optical system. In turn, the cosmological distances depend on the cosmological model. The authors argue that strong lensing systems offer the opportunity to test various theoretical models of the universe, confirming or contradicting existing knowledge of the cosmos.

New cosmic curvature probes

Data from the Planck satellite confirm that our universe is spatially flat. However, the emerging structure of the universe may modify this description on more local scales. The local curvature of space can be detected by measuring the interior angles of a triangle. It is not possible to make a proper measurement with galaxies, but strong lensing systems offer a setup where the triangle is degenerate, i.e. one vertex – the lens – lies on the side between the source and the observer. The question of angles can be reformulated in terms of distance: is the distance to the source equal to the sum of the distances to the lens and between the lens and the source. This should apply strictly in a flat space, while in a non-planar case, such a relationship gives the curvature parameter. To determine the distance to the source, scientists proposed the original approach of matching the source by redshift to a quasar sample, calibrated as standard candles and using the reconstructed luminosity distance without assuming any specific cosmological model. The proposed method will allow the determination of the cosmic curvature from local probes with high accuracy in the future.



Photograph: ESO/T. Preibisch

Tool for measuring the speed of light

Scientists from NCBJ have developed a new method of measuring the speed of light, c, which, using gravitational lensing, could significantly change existing knowledge about the history of the universe. Currently, the most accurate c measurements come from the laboratory, and not from astronomical observations as in the past. The problem of measuring the speed of light with extragalactic objects is an unexplored area and until recently was not even considered. Now, however, a new method has been proposed that uses strong lensing systems for this purpose. Examination of 118 samples of strong gravity lenses gave a value of c = (3.005 ± 0.006) × 105 km/s – which confirmed the known laboratory results, but with two orders of magnitude better accuracy than previous astronomical measurements of the speed of light! Data simulations, which will soon be available using LSST, will allow us to determine c with an accuracy of 10^{-4}. It is true that the previous laboratory measurements have much greater accuracy – of the order of 10^{-9} – but the use of distant cosmological objects to measure the speed of light is interesting in itself, also in the context of exotic theoretical ideas appearing in the literature that the speed of light in the past could have had a completely different value and this, in turn, may significantly affect the studied history of the universe.

POLAR: the mysterious polarization of cosmic gamma ray bursts

The POLAR detector is the result of cooperation between Switzerland (University of Geneva and Paul Scherrer Institute), Poland (National Centre for Nuclear Research) and China. It was launched in September 2016 on board the Chinese space laboratory Tiangong-2. In January 2019, scientists published the first scientific results in the journal Nature Astronomy.

Gamma-ray bursts (GRBs) are observed as very short-lived X-ray signals from sources that are at cosmological distances from Earth. POLAR is the largest detector designed to measure the polarization of GRB gamma quanta, large and precise enough to measure multiple flashes and reliably determine the polarization. POLAR measured 55 GRBs. Thousands of photons from the GRBs are needed to determine the polarization. The first data on the polarization of the fifty-five gamma-ray bursts shows that the determined degree of polarization of the photons in the bursts is very small in all cases. In the case of the brightest flash, it was possible to measure the polarization separately at successive moments of time. It turned out that at each point of the measurement high polarization was found, but the direction of polarization rotated with time.

Polish scientists and engineers from NCBJ were the co-creators of the key elements of the POLAR experiment.

Mini-EUSO: Ethe arth as a huge detector

On August 22, 2019, the Soyuz 2.1a rocket launched the Soyuz MS-14 module towards the International Space Station (MSK) from the Baikonur cosmodrome in Kazakhstan. Among the loads on board was the Mini-EUSO telescope, part of the JEM-EUSO project that studies large atmospheric showers of particles and photons. The JEM-EUSO project involves 306 scientists from 16 countries. NCBJ is represented by six scientists from the Lodz Cosmic Radiation Physics Laboratory of the Astrophysics Division.

The detector sent to the International Space Station will allow the creation of an ultraviolet map of the Earth's atmosphere. It will make it possible accurately to study the variability of the atmosphere's ultraviolet radiation over time. The aim of Mini-EUSO is to observe the fluorescence caused by various atmospheric phenomena: transient light events – TLE (Transient Luminous Events), fluorescence caused by the passage of meteorites and meteoroids through the atmosphere, and traces of space debris burning up in the atmosphere. Additionally, the experiment will allow a search for strange quark matter – SQM (Strange Quark Matter).

Evolution of the largest galaxy clusters

The universe has a very rich spatial structure. Modern cosmology tries to explain this picture, largely with the help of general relativity, a theory that describes gravity as the curvature of space-time. The problem that arises here is that general relativity has been well understood and tested over distances of the order of the diameter of our solar system. However, the universe is immensely larger, so that when applying this theory to a description of the universe as a whole, inevitably gigantic extrapolation is used. The current standard cosmological model has adopted just such a strategy: on a simplified view of the universe on large scales using the general theory of relativity, we superimpose all smaller inhomogeneities like galaxies or galaxy clusters.

Scientists from Poland, France, Australia and New Zealand adopted a more conservative assumption – they focused on a relatively accurate description of the small structures of the Universe and from these alone they plan to recreate its global, large-scale picture in a mathematically rigorous manner. This large-scale project has produced interesting results over the past two years. Analyzing the evolution of galaxy clusters, it was concluded that the predictions for these largest clusters differ from the standard model – according to the new model, it is better to observe more of the more massive galaxy clusters that challenge the standard model. In addition, the scientists were able to obtain reasonably accurate estimates of the curvature of galaxy clusters at some stage in their evolution. Analogous void calculations will recreate the global curvature of the universe on large scales. These considerations are one of the key aspects of dark matter and dark energy, the mysterious components of the universe. The project will be continued in the coming years, also thanks to the support of the grants obtained.

What shape are the halo of dark matter?

Little is known about the nature of dark matter except that there is a lot of it in the Universe and it definitely dominates over visible matter. To estimate the mass of the halo, it is necessary to assume its shape. For many years it was assumed that as a first approximation the dark matter halos were spherically symmetrical. This assumption is an obvious simplification – sufficient for research conducted on the basis of observations of a relatively small number of galaxies, but new, planned sky surveys will require a change in this approach. Most dark matter halos, especially the most massive ones, have an elongated shape (similar to an egg). This is mainly due to the pressure of dark matter mass and / or gas flowing into the halo. Therefore, the assumption of a spherically symmetrical halo shape is not only an oversimplification, but also significantly influences the measurements of dark matter mass in the halo of galaxies – significantly overestimating them. Scientists therefore proposed a new model to take into account possible asymmetries in the shape of the halo. This model can be successfully applied in new work based on planned large sky surveys, which will bring us closer to solving key issues. They will allow for a more detailed study of the changes that the Universe has undergone from the beginning of its existence and provide answers to questions about the nature of dark matter.

Photograph: NASA, ESA, and B. Holwerda (University of Louisville)

Dark matter even more elusive

Scientists expect that the universe – including our galaxy – consists mostly of dark matter, a substance completely unknown to us. An attempt to detect traces of it was made, among others, by the Super-Kamiokande neutrino experiment conducted with the participation of Polish scientists.

Contemporary observations and cosmological models suggest that only about 5% of the mass and energy contained in the Universe is matter in the form known to us (so-called Baryonic matter). The remaining constituents are expected to exist in both the form of an unknown type of particles, the so-called dark matter (27% of the balance), and energy filling the space – the so-called dark energy (68%). Understanding the nature of these mysterious ingredients is one of the greatest mysteries of physics and cosmology today.

Research published in 2020 searched for evidence of the existence of dark matter particles in our galaxy. The Super-Kamiokande neutrino telescope in Japan was used for this search. This telescope is optimized for recording the interactions of neutrinos produced both in sources known to us, such as the Sun or the Earth's atmosphere, and possibly in undiscovered sources. Scientists expect that the dark matter particles we are looking for should account for a minimum of 90% of the mass contained in galaxies such as ours, and that they can annihilate with each other, producing as a result of this process particles known to us from the so-called Standard Model, including neutrinos. With the help of advanced computer simulations, a number of predictions were made of the energy distribution and the arrival direction of neutrinos produced as a result of dark matter annihilation both in the center and in the halo of the Milky Way as seen in our telescope. Then, using statistical methods, it was checked whether the neutrino interactions recorded by Super-Kamiokande since 1996 contain any contribution from neutrinos from dark matter annihilation, taking into account all other sources known to us. No surplus of such a potential signal over the background was observed, and thus some properties of dark matter particles were limited. For a wide range of their expected masses, these are currently the strongest limitations derived from observations of neutrino telescopes.

The experience gained in this work to date has allowed for the extension of these studies and the determination of sensitivity predictions for the discovery of dark matter particles in new generation neutrino telescopes, such as Hyper-Kamiokande and KM3NeT.

Photograph: 19-SDIM0108-inID-mid CREDIT Kamioka Observatory, ICRR (Institute for Cosmic Ray Research), The University of Tokyo

T2K: the difference between matter and antimatter

The T2K collaboration involving scientists from NCBJ, using a beam of muon neutrinos and antineutrinos, examines how these particles and antiparticles change into electron neutrinos and antineutrinos, respectively, and looks for possible differences that indicate a symmetry violation.

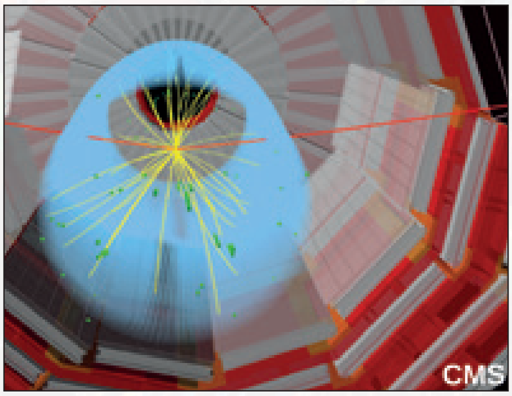
T2K published the results of an analysis of data collected with neutrino and antineutrino beams corresponding to 1.49 x 1021 and 1.64 x 1021 accelerator protons colliding with the target. T2K observed 90 electron neutrino candidates and 15 electron antineutrino candidates.

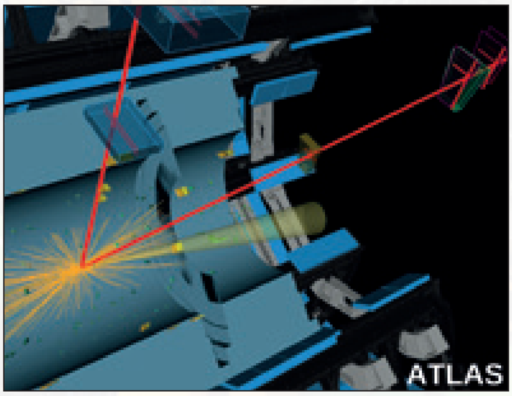
The parameter describing matter / antimatter symmetry breaking in neutrino oscillations is called the δ_{CP} phase and it can range from – 180° to 180°. Assuming the maximum gain for neutrinos (δ_{CP} = – 90°), 82 candidates for electron neutrinos and 17 candidates for electron antineutrinos were expected, while with maximum gain for antineutrinos (δ_{CP} = + 90°): 56 electron neutrinos and 22 electron antineutrinos. The results fit best with a δ_{CP} value close to – 90°. Using these data, T2K excluded a value for the δ_{CP} parameter ranging from – 2° to 165° at the 3σ confidence level (99.7%). This result is the strongest limitation on δ_{CP} so far and in conjunction with previous data suggests that the CP symmetry may be broken in neutrino oscillations.

CMS and Atlas: likely observations of Higgs decay into muons

The ATLAS and CMS experimental teams have announced results that prove that the Higgs boson decays into two muons. The physical process of decay of the Higgs boson into muons is rare, as only one Higgs boson decays into muons in approximately 5,000 tilts. The new results confirm for the first time that the Higgs boson interacts with muons – second generation elementary particles. CMS obtained evidence of this decay at the 3 sigma level and ATLAS at the 2 sigma level. The combination of the two results provides a strong premise for the existence of Higgs boson decay into a muon-anti-muon pair.

The ATLAS and CMS research teams expect that with more data recorded in the next LHC work cycle, and with the transition to high-luminosity LHC operation, the sensitivity (5 sigma) needed finally to recognize the decay of the Higgs boson into two muons as discovered and to establish constraints on theories beyond the Standard Model that could influence this mode of Higgs boson decay will be reached. NCBJ scientists take part in the CMS experiment, in particular in the analysis of the collected data.





Photographs: CERN

FASER – a new experiment at the LHC

FASER is a multidetector designed to search for long-lived particles formed in LHC collisions which may be a signal of the existence of hypothetical dark matter.

The concept of the FASER experiment was proposed by an NCBJ scientist and three other authors. The detector is located approximately half a kilometre from the ATLAS detector in the service tunnel that converges towards the LHC tunnel. The system consists of scintillators, magnets, trace detectors and a calorimeter measuring the energy of the products if the desired decay of a new particle occurs. Such particles can arise from proton collisions, for example at the collision point in an ATLAS detector. Until now, they may not have been registered due to their weak interaction with the detector matter. A chance for their possible detection is to set the detector at a certain distance from the production point and try to register the expected products of their decay.

The authors of the proposal believe that the FASER experiment will also be able to confirm the KOTO anomaly, if it is indeed a trace of new physics. The results of the KOTO experiment concern the search for very rare decays of neutral kaons to pions and to a neutrino/anti-neutrino pair. Although the expected frequency of this process under the Standard Model is almost 100 times lower than the current experimental possibilities, contrary to expectations, the observations seem to indicate a higher frequency of cases. This leaves room for speculation on the possible discovery of signs of new physics that will be tested in the FASER detector at the LHC.

Quark-gluon plasma and hydrodynamic attractor

Scientists from NCBJ and the Max Planck Institute in Potsdam use the concept of a hydrodynamic attractor to describe the dynamics of the quark-gluon plasma. Equilibrium fluids can be described in terms of very few parameters, such as temperature. They can achieve this simple state starting from very complex initial states, the full determination of which would require a huge amount of information. Initial state information is almost completely lost in the process of achieving equilibrium, but the exact way this happens is fascinating and not fully understood. This hydrodynamic model is also suitable for modeling the behavior of the quark-gluon plasma. It arises in nuclear collision experiments leading to highly complex, non-equilibrium initial states. Previous research has revealed a surprisingly universal behavior of the system when the plasma is still very far from equilibrium – a phenomenon now referred to as the "hydrodynamic attractor". The authors proposed a way to track the emergence of such universality, taking into account the large number of histories of the system corresponding to different initial conditions. They showed in simple models that this method can be used to visualize the information loss process. It was also indicated that in more complex situations it can be effectively applied thanks to the use of machine learning techniques.

Photograph: CERN

Ultra-fast connection to XFEL

A high-speed internet connection was launched allowing the transmission of scientific data at a speed of 100 Gb/s, connecting the DESY research center in Hamburg and the National Centre for Nuclear Research (NCBJ) in Świerk. The full functionality of the connection was demonstrated on 12th June during a ceremony attended by the Polish and German Deputy Ministers of Science, which took place simultaneously on both sides of the link.

Thanks to this connection the NCBJ Świerk Computer Centre (CIŚ) will become the second data collection and processing hub, alongside the DESY IT center, for data generated by experiments at the European XFEL, the most powerful X-ray free-electron laser in the world. During the ceremony, the directors of European XFEL and NCBJ signed two contracts, paving the way for the full implementation of the project to use CIŚ computing power for XFEL experiments. The agreements concern the conditions for ensuring the quality of data collection and processing services and the security of the scientific data and user data processed.

Simulation of cyberattacks for training in European Union Agency for Network and Information Security

In the NCBJ CyberLab cybersecurity laboratory, examples of network traffic taking place during a cyber attack on an industrial network were generated. The data will serve to train security experts at the European Union Agency for Network and Information Security (ENISA) and were added to Agency's training materials.

In this case a real attack on industrial systems was simulated. Data were really recorded using tcmdump-type tools. In order for them to be realistic they had to be recorded in an environment utilising genuine equipment, and that is exactly what we have in CyberLab. The data will serve the participants in the course, who learn how to analyse and detect such attacks. They will be given network traffic we recorded and, according to the exercise scenario, they will have to determine whether there has been an attack, and if there has been, of which type.

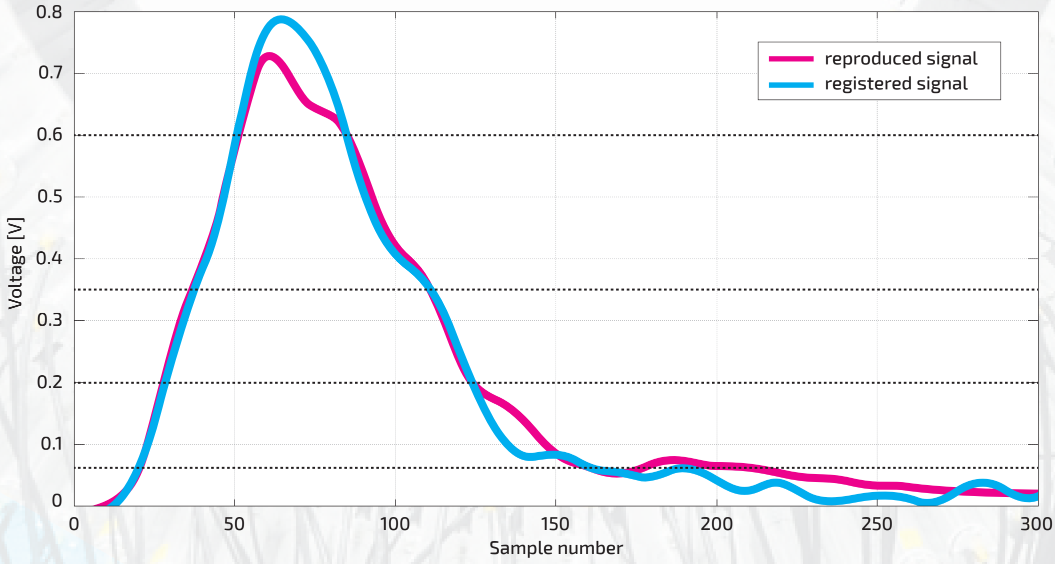
The CyberLab laboratory operates within the Science and Technology Park "Świerk" (PNT), an organizational unit of the National Centre for Nuclear Research. The CyberLab personnel is composed of employees of the Park. The Park mainly provides research services for small and medium sized enterprises on the basis of *de minimis* aid.

The signal puzzle in J-PET

J-PET is a positron emission tomograph designed and manufactured at the Marian Smoluchowski Physics Division of the Jagiellonian University in cooperation with many institutes, including NCBJ. The device differs significantly from traditional PET tomographs. One of the most important challenges facing scientists is reconstructing the process under study based on the small amount of information available about it. Scientists from the NCBJ Software Engineering Department are dealing with this problem.

J-PET is made of plastic detectors with the best time resolution in the world. The time intervals between consecutive measurements are at the level of 50 picoseconds (10-12 seconds). The entire 300 sample signal recorded corresponds to approximately 15 nanoseconds (10-9 seconds). Shorter signal durations translate into better possibilities for locating cancer changes in the patient's body, but on the other hand they require the use of dedicated computational methods. Such "fast" signals cannot be fully recorded in a tomograph consisting of hundreds of detectors; it is only possible to save a few samples.

It has been found that, based on Compressive Sensing (CS) theories, it is possible to find a "substitute" representation of signals in which most of the information about the entire time course is concentrated in only a few samples. Based on the analyses, it was shown that it is possible to reproduce the signal faithfully based on only 8 samples. In order to prepare the "signal puzzle", it was necessary to know the shapes, shifts and amplitudes of a large representative group of signals. Thanks to the regularities in the signal waveforms, scientists were able to show that there is an accurate model to solve the problem of signal sampling. Due to time measurement uncertainties at voltage thresholds, the reproduced signal is not identical to the actual waveform. However, the differences are so small that the reproduced signals contribute to the improvement of the quality of the reconstructed patient image.



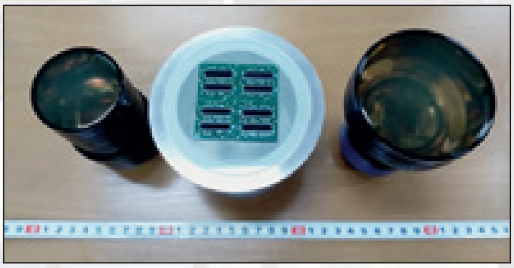
Silicon scintillators and photomultipliers for applications in high energy physics

The Department of Plasma Detectors and Diagnostics tests, *inter alia*, new scintillators for gamma radiation spectrometry, new photodetectors used in scintillation techniques in nuclear physics, high energy physics and medicine, as well as the use of detectors, in particular for neutron activation analysis in industry and in the fight against terrorism.

Limitations of the energy resolution of scintillators: this research uses charged particle spectrometry to determine the disproportionality in the area of very low energies, below 1 keV.

For the first time, NCBJ scientists have applied digital spectrometry techniques to study the energy resolution and disproportionality to understand better the limitations. The work is being carried out in cooperation with Wake Forest University in the USA and the Institute for Scintillation Materials in Kharkiv, Ukraine.

Characteristics of silicon photomultipliers: Typical measurements of gamma radiation are carried out in two stages: in the scintillator, high-energy radiation causes an optical signal, which is then recorded by a photomultiplier that converts the optical signal into an electrical one which can be read by electronics. Currently, silicon photomultipliers (SiPM) are widely used. Scientists from NCBJ conducted a number of experiments aimed at a broad characterization of SiPM with various properties, indicating their advantages, as well as disadvantages and limitations resulting from the principle of operation. They were the first to publish detailed studies, e.g. on the dependence of energy resolution on supply voltage and its optimization. They were also the first to develop the use of SiPM 1 and 2 inch matrices for γ spectroscopy with scintillators and to describe the excellent energy resolution with LSO, BGO, and CsI:Tl scintillators. The figure shows a comparison of a 3" NaI(Tl) crystal, read by a 2" x 2" SiPM, with typical classical photomultipliers used in gamma spectrometry.

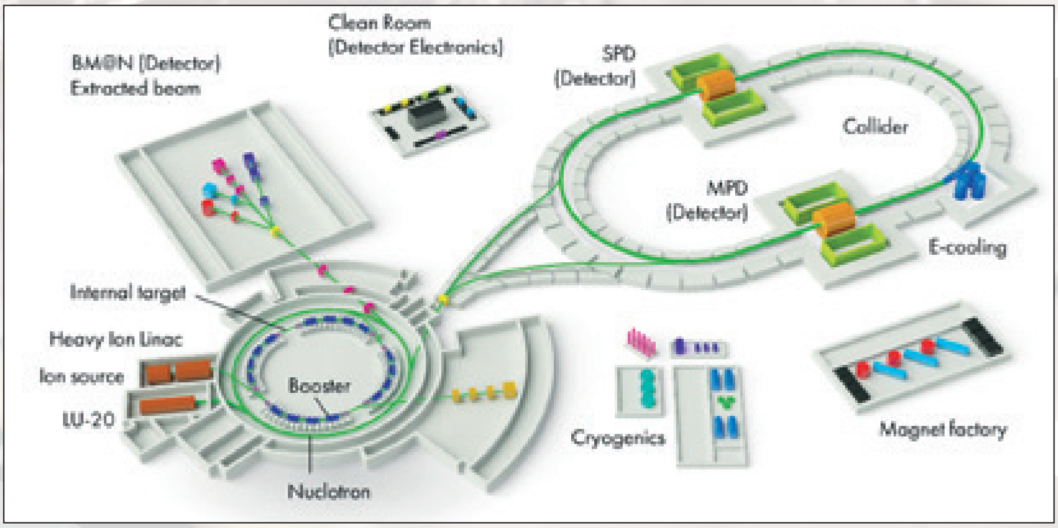


The first characterization of large OGS (organic glass scintillators) scintillators in the detection of fast neutrons was obtained at NCBJ in cooperation with INFN Legnaro and Sandia National Lab, USA. Excellent differentiation of neutrons and gamma quanta is shown by the pulse shape method.

In addition, the Department is working on the use of "phoswich" detectors for the detection of fast and thermal neutrons.

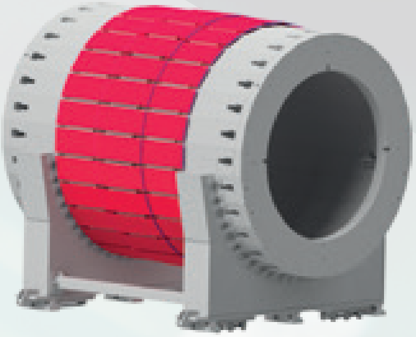
Research on radiation damage in silicon photomultipliers and scintillators induced by irradiation with fast neutrons and protons. This research shows for the first time the deterioration of energy resolution associated with the degradation of silicon photomultipliers in a spectrometric system with a non-irradiated scintillator as a function of the increasing fluency of neutron or proton radiation. Researchers have shown that SiPM radiation damage and the degradation of energy resolving power must be taken into account in gamma spectroscopy measurements whenever experiments are performed in a high background radiation area. It has been shown how decreasing the ambient temperature reduces the impact of radiation damage on the energy resolving power of the spectrometric system.

MCORD – a cosmic ray detector for the NICA accelerator



At the Joint Institute for Nuclear Research in Dubna, the new NICA (New Ion Collider fAcility) complex is under construction, which includes a set of accelerators producing counter-rotating ion beams. One of the main detection elements of the NICA complex is the Multi-Purpose Detector (MPD), which tracks hadron-hadron collision products formed at the point of intersection of the accelerated beams. The outer layer of the multidetector will be the MCORD muon cosmic ray detector (MPD COsmic Ray Detector).

The MCORD detector will be built entirely by the NICA-PL consortium established by several Polish scientific institutions. The leading role in the project is played by scientists from NCBJ, whose contribution is the design, construction and laboratory tests of muon detectors, as well as their integration with electronics created by a team from the Warsaw University of Technology. The main detection element of the detector will be plastic scintillators with semiconductor photomultipliers for reading light. In the initial phase of the project, preliminary measurements and simulations were carried out to select the optimal scintillator shape, photodetector configuration and reading electronics. Based on these analyses, the shape and size of the MCORD detector were proposed, taking into account the requirements of MPD users and the efficiency of the MCORD system and the cost of its production. The final stage, also led by NCBJ scientists, will be the installation of the full-size MCORD detector around the MPD surface in the configuration shown in the figure.



NOMATEN

Centre of Excellence in Multifunctional Materials for Industrial and Medical Applications

The aim of the NOMATEN Center of Excellence is research on materials resistant to extreme conditions (high temperatures, corrosion, radiation – especially neutron radiation) for applications in the nuclear, energy, chemical and other industries, as well as the development and production of modern radiopharmaceuticals for applications in cancer diagnostics and therapy. The project partners are the National Centre for Nuclear Research, the Commissariat à l'Énergie Atomique et aux Énergies Alternatives from France (CEA) and Teknologian Tutkimuskeskus VTT from Finland.

Launched in September 2018, the NOMATEN Center of Excellence project is developing according to plan. We managed to build a strong team of over 20 scientists – half of them from abroad. There are already four research groups: Complexity in Functional Materials (leader Prof. Mikko Alava, Director of NOMATEN CoE), Material Structure Informatics and Function (leader Dr. Stefanos Papanikolaou), Functional Properties (leader Prof. Łukasz Kurpaska), Radiopharmaceuticals (leader Prof. Marek Pruszyński). Recruitment of the fifth group leader ended in July 2021 with the selection of Dr. Iwona Jóźwik.

The list of issues that NOMATEN deals with is very broad and shows our strong expertise in the study of new metal alloys and the use of mathematical modeling and experimental methods. The research agenda includes:

- mechanical properties of High Entropy Alloys and Concentrated Complex Alloys,
- theoretical studies of thermodynamic properties of high entropy alloys,
- modeling the behavior of High Entropy Alloys as Bulk Metallic Glasses,
- combination of theoretical and experimental research on the nanoindentance of metal alloys, including research conducted jointly with Oak Ridge laboratory, USA,
- development of methods of searching for the optimal composition of high entropy alloys and simulation of plastic strains,
- research on the mechanical properties of new types of coatings using experimental methods,
- influence of irradiation on the properties of high entropy alloys and steels (ODS – hardened with oxides, Eurofer),
- materials informatics – the use of artificial intelligence to simulate and use data from experiments,
- development of software for use in materials information technology,
- establishment and development of a research group dedicated to radiopharmaceuticals under the leadership of Prof. Marek Pruszyński.

In 2020, Dr. Aleksandra Baron-Wiecheć, cooperating with NOMTEN, received the prestigious Marie Skłodowska-Curie Actions grant (H2020-MSCA-IF-2020 – 101026899) MagniFiCor. The grant will be implemented at NOMATEN MAB during the years 2022-2024 and concerns research into corrosion phenomena in conjunction with research on the mechanical properties of various materials.

NOMATEN is also expanding its research infrastructure. Thanks to the FNP grant, a scanning electron microscope (SEM) and an X-ray diffractometer (XRD) were obtained. The extensive additional equipment of both devices allows for materials testing. For example, the microscope provides the ability to observe electron energies ranging from 20 eV to 30 keV, which is an exceptionally large range. The microscope works in a focused ion beam (FIB) system with an EDS microanalysis system and a backscattered electron diffraction system (EBSD). The X-ray diffractometer allows measurements in the Bragg-Brentano and GXRD (GID) systems and is equipped with an adapter enabling in-situ measurements at temperatures above 1200C.

In 2021, NOMATEN was awarded a grant from the Polish National Agency for Academic Exchange for the organization of an international scientific conference. Its aim will be to promote research topics and scientific infrastructure to attract foreign talent to NOMATEN. The expected date of the conference is mid-2022, and the substantive side of the conference is the responsibility of the leader of the Materials Informatics – Structure and Function research group at NOMATEN, Dr. Stefanos Papanikolaou, in association with the appropriate committee.

The NOMATEN Center of Excellence is financed by the International Research Agendas program MAB PLUS (Agreement number MAB PLUS / 2018/8) of the Foundation for Polish Science, co-financed by EU funds from the European Regional Development Fund under the Smart Growth Operational Program and the NOMATEN-Teaming grant for Excellence is implemented under the Horizon 2020 Framework Program of the European Union, contract number 857470.

New capabilities of the Materials Research Lab (LBM)

The laboratory's research focuses on the structural and mechanical characteristics of materials dedicated to nuclear technologies. These types of materials are operated in environments with intense neutron fluxes, complex cyclic stress fields, high temperatures and highly corrosive coolants. For this reason it is necessary that they meet very stringent quality requirements during their service life, which can reach as much as several dozen years. The laboratory equipment allows the monitoring of the constructional and mechanical properties of materials subjected to irradiation in a reactor core. LBM has the Accreditation Certificate No. AB 025 issued by the Polish Center for Accreditation (PCA) and has recently significantly expanded the scope of its approved tests. Several mechanical and structural methods have been added to the portfolio of laboratory experiments.

In the years 2019-2020, LBM examined, *inter alia*, ODS (Oxide Dispersion Stained), RAFM (Reduced Activation Ferritic / Martensitic), AFA (Alumina Forming Alloys), Amorphous Al_2O_3 coatings, nickel-based alloys (mono and polycrystals), zirconium alloys and various grades of nuclear graphite. The laboratory specializes in simulating real conditions of use (temperature and radiation damage) and assessing the impact of these parameters on the behavior of the tested material. The work was carried out under several national and international projects.

Conducting advanced research requires specialized high-level research equipment. The laboratory has, among others, a Raman spectroscope with a high-temperature chamber (up to 1000°C) for the structural characterization of non-metallic materials, emission spectroscopy for the analysis of the chemical composition of metals, a Vickers microhardness tester and metallographic microscope. Moreover, the INSTRON 8501 testing machine was modernized. Currently, many mechanical tests can be performed in the temperature range from – 100°C to 1000°C. A new metal powder laboratory has also been established, where our scientists conduct research on the mechanical fusion of metals in a controlled argon atmosphere. Scientists will receive new equipment in 2021.

PRELUDE grant for testing steels strengthened with new oxides: Yttrium oxide Y_2O_3 is a typical and widely used ODS steel reinforcing oxide. Information on the use of other refractory oxides is very limited and incomplete. This gap will be filled by research conducted at the Materials Research Laboratory as part of a Preludium grant of the National Science Center. A project entitled "Influence of the type of reinforcing oxide on the microstructural and mechanical properties of ODS steels" provides for the production of ODS steel reinforced with Al_2O_3 aluminum oxide and ZrO_2 zirconium oxide. The characteristics of the produced materials will take into account not only basic material tests but also the evaluation of the degradation of materials subjected to ion implantation processes as a simulated environment of ionizing radiation.

OneNet project – One Electrical Network Infrastructure for Europe

The "OneNet" project, financed by the European Commission, was launched on October 1, 2020. It aims to meet the challenges posed by Transmission Network Operators (TSO), Distribution Network Operators (DSOs) and consumers on the European electricity market. The electrical network is changing from a fully centralized to a highly decentralized system. Grid operators need to adapt to this changing environment and adapt their current business model to accommodate faster responses and adaptive flexibility. This is an unprecedented challenge that requires an unprecedented solution. The OneNet project aims to develop and demonstrate the key instruments of a European approach to energy flexibility. Many projects have dealt with this in the past, but the scope and size of OneNet is second to none with a total budget in excess of € 28 million (European Commission co-financing of around € 22 million). The key elements of the project are: the definition of a single market for Europe, the definition of a common IT architecture and common IT interfaces, and the creation of large-scale demonstration devices to implement and demonstrate scalable solutions developed by the project. These demonstrators are organized into four clusters covering countries from each region of Europe and testing innovative use cases that have never been validated before. Operators, consumers and stakeholders across Europe are encouraged to participate. To this end, throughout the duration of the project and beyond, the project will develop and maintain the initiative of the open forum "GRIFOn", a platform for freely discussing results with all relevant stakeholders outside the project and collecting their views.

Zefir system for planning the energy transformation

As part of the LeadAIR program organized by Forum Energii, the Zefir system is being used to support local governments in the fight against smog. Zefir was created by the Interdisciplinary Department of Energy Analysis (IDEA) as part of the KlastER project.

Zefir is a modern tool for planning energy transformation developed as part of the Gospostrateg cluster project, co-financed by the National Center for Research and Development under the program "Development of distributed energy in energy clusters". Thanks to the system, each commune will be able to plan investment and modernization aimed, for example, at eliminating smog, reducing carbon dioxide emissions or energy self-sufficiency. The system allows not only independent parameterization of technology or tailored calculations, but also interactive visualization of results. The commune receives a detailed and holistic action plan, showing: costs, economic and environmental effects of the implementation of the planned goals of distributed energy development at the level of the entire area and of each inventoried building individually.

Chronos – optimal use of energy

NCBJ has signed a cooperation agreement with the Zgorzelecki Cluster (ZKlaster). The aim of the collaboration is to develop new business models using the flexibility of the energy cluster, as well as to implement and develop the Chronos intelligent control system, created and developed at the Interdisciplinary Department of Energy Analyses IDEA at NCBJ. Researchers will perform an economic analysis of methods for graphing sources of flexibility – consumers whose needs can be consciously shaped and suppliers who can change the level of installed power utilization – and energy storage. An analysis of the participation of entities in energy markets, optimization of connection capacity and other elements relevant to control schemes will also be performed. The result of the collaboration – apart from the obvious savings for recipients from Zgorzelec – will be the development of the Chronos System, which enables Energy Clusters to use optimally their energy sources and their flexibility based on predictive algorithms operating and communicating with the cluster infrastructure 24 hours in advance and in real time. The creators of the system indicate the potential large savings that can be obtained thanks to its use and strive to introduce it to common use by other interested entities.

The influence of solar activity on failures of power transmission lines

The geo-efficiency of phenomena caused by the Sun is manifested, *inter alia*, by their influence on the energy infrastructure through geomagnetically induced currents (GIC). Scientists from the NCBJ Department of Nuclear Energy and Environmental Analysis, the University of Mathematics and Life Sciences in Siedlce, AGH and the Space Research Center of the Polish Academy of Sciences conducted a quantitative analysis of the number of failures in energy infrastructure elements in southern Poland that may be related to space weather phenomena. Two time frames of very different levels of solar activity (SA) over the 24th cycle of solar activity were analyzed: in 2010 in the early growth phase of SA, near the solar minimum, and in 2014, in the solar maximum phase. It turned out that the number of failures was twice as high in the period January – July 2014 than in 2010.

The increase in the number of electrical network failures coincides with the increase in geomagnetic activity reflected in the increase in the geoelectric field disturbance reflected in the GIC. This suggests a link to the effects of space weather. The delay in the emergence of the increase in the number of electrical network failures may be related to a certain cumulative effect resulting from transients and their propagation in the distribution network.

The next phase of HTGR research reactor design work

The National Centre for Nuclear Research and the Ministry of Education and Science have signed a contract for the implementation of another batch of design work for a gas-cooled high-temperature reactor. The event, which took place on May 12, 2021 in Otwock-Świerk, was attended by Minister of Education and Science Przemysław Czarnek, Minister of Climate and Environment Michał Kurtyka and the director of the National Centre for Nuclear Research Krzysztof Kurek. The agreement stipulates that the conditions for the construction of a high-temperature research reactor in Poland will be prepared within three years at the National Centre for Nuclear Research. NCBJ will develop the basic design of such a device at an initial level of detail. The Ministry of Education and Science will allocate adequate resources for this.

Gospostrateg GoHTR

The GOSPOSTRATEG-HTR project is the first step towards the implementation of High Temperature Reactor (HTR) technology in Poland. The project is implemented by the consortium: the Ministry of Climate and Environment, the National Centre for Nuclear Research and the Institute of Nuclear Chemistry and Technology (IChTJ). The project includes such tasks as the development of diagnostic and testing methods for construction materials and devices for performing core tests, testing and analyzing selected chemical aspects of the production and use of TRISO fuel in a nuclear reactor, as well as the analysis of the necessary changes in the legal environment and the potential benefits of socio-economic and industrial units for the Polish economy. In phase B, the licensing (certification) process of HTGR reactors will be prepared on the example of a research reactor, preparation of draft legal regulations for the implementation of HTR investments; developing a strategy in the social, economic and industrial aspect of the project, piloting test procedures for the use of structural materials for the design of the HTR reactor, including research in the MARIA reactor core. The technical and economic basis for the construction of a fuel production block for high-temperature reactors will also be prepared.


Ceramic internals

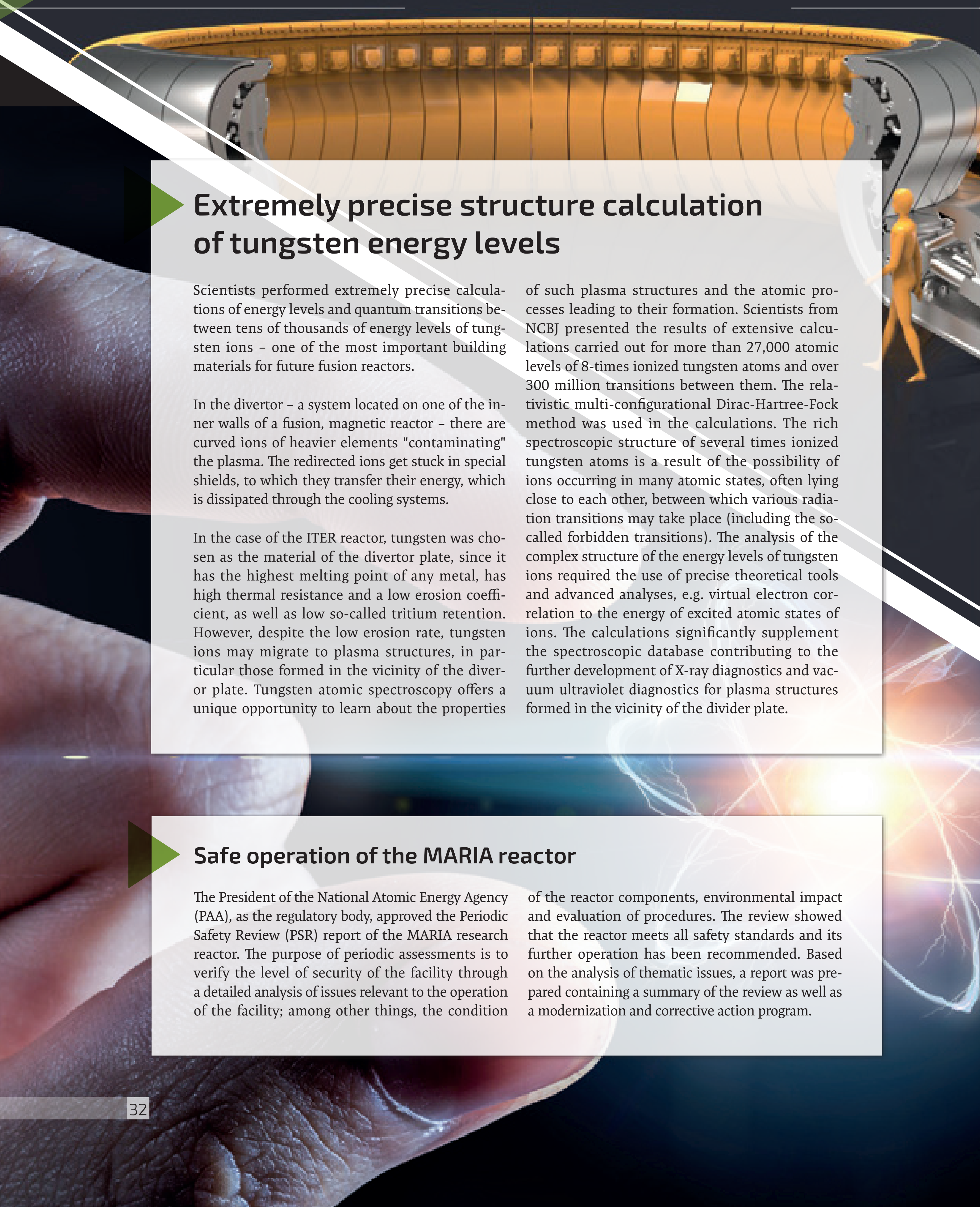
Gemini+: recommendations for a high-temperature reactor concept

The aim of the Gemini+ project (under the H2020 Program – Euratom) was to provide a conceptual design for a high-temperature nuclear cogeneration plant for the supply of process steam to industry, a licensing framework for this system and a business plan for full-scale demonstration. The selected rector's solution uses the concept of a core in the form of graphite blocks with separate holes for the placement of fuel moldings and holes for the flow of the coolant – helium. The hot helium is directed to the steam generator, then cooled to the circulator and back to the reactor. The generated steam is processed in the secondary circuit of the heating plant with a small turbine – generator and reboiler, in which steam is produced for the end user. The recommended net power could reach as much as 165 MWth.

Online Hot Reactors Summer School

On June 1-5, 2020, the first international "Hot Reactors Summer School" was organized. The remote formula of the school allowed for the expansion of the subject of, among others, the European project "Gemini+" for the technology of high-temperature HTGR reactors and the concept of a gas-cooled fast neutron reactor called "Allegro" developed by the V4G4 center of excellence operating within the Visegrad Group.

The school was implemented as part of an interdisciplinary international doctoral program created in October 2018 as part of the project "New concepts of nuclear reactors and safety analyses for the Polish Nuclear Power Program" financed by the National Center for Research and Development (POWR.03.02.00-00.I005 / 17). The aim of the project is to create an interdisciplinary team of young research staff dealing with advanced concepts and technologies for future generation IV nuclear reactors (hence the acronym for the "phd4gen" project), which could also practically support the development of Polish nuclear energy, or at least be competent to assess nuclear technologies of the future. The main technologies under study are the HTGR gas cooled high temperature reactor technology and the DFR twin fluid reactor concept.



Extremely precise structure calculation of tungsten energy levels

Scientists performed extremely precise calculations of energy levels and quantum transitions between tens of thousands of energy levels of tungsten ions – one of the most important building materials for future fusion reactors.

In the divertor – a system located on one of the inner walls of a fusion, magnetic reactor – there are curved ions of heavier elements "contaminating" the plasma. The redirected ions get stuck in special shields, to which they transfer their energy, which is dissipated through the cooling systems.

In the case of the ITER reactor, tungsten was chosen as the material of the divertor plate, since it has the highest melting point of any metal, has high thermal resistance and a low erosion coefficient, as well as low so-called tritium retention. However, despite the low erosion rate, tungsten ions may migrate to plasma structures, in particular those formed in the vicinity of the diveror plate. Tungsten atomic spectroscopy offers a unique opportunity to learn about the properties of such plasma structures and the atomic processes leading to their formation. Scientists from NCBJ presented the results of extensive calculations carried out for more than 27,000 atomic levels of 8-times ionized tungsten atoms and over 300 million transitions between them. The relativistic multi-configurational Dirac-Hartree-Fock method was used in the calculations. The rich spectroscopic structure of several times ionized tungsten atoms is a result of the possibility of ions occurring in many atomic states, often lying close to each other, between which various radiation transitions may take place (including the so-called forbidden transitions). The analysis of the complex structure of the energy levels of tungsten ions required the use of precise theoretical tools and advanced analyses, e.g. virtual electron correlation to the energy of excited atomic states of ions. The calculations significantly supplement the spectroscopic database contributing to the further development of X-ray diagnostics and vacuum ultraviolet diagnostics for plasma structures formed in the vicinity of the divider plate.

Safe operation of the MARIA reactor

The President of the National Atomic Energy Agency (PAA), as the regulatory body, approved the Periodic Safety Review (PSR) report of the MARIA research reactor. The purpose of periodic assessments is to verify the level of security of the facility through a detailed analysis of issues relevant to the operation of the facility; among other things, the condition of the reactor components, environmental impact and evaluation of procedures. The review showed that the reactor meets all safety standards and its further operation has been recommended. Based on the analysis of thematic issues, a report was prepared containing a summary of the review as well as a modernization and corrective action program.

MARIA microspheres for patients with liver cancer

The MARIA reactor is one of the main irradiation centers for microspheres containing radioactive holmium, which are used in the treatment of liver tumors. The technology developed at NCBJ at the request of Quirem Medical – the global manufacturer of QuiremSpheres theraperutical microspheres – serves patients in several specialized clinics in Europe.

Microspheres with a diameter of approx. 30 micrometers made of polylactide holmium (a polymer of lactic acid) are used for local radiotherapy, mainly in the case of liver tumors. At the production stage, the stable isotope holmium-165 is injected into them, which can be transformed into the radioactive isotope holmium-166 by neutron bombardment. Holmium-166 has very useful properties. Its half life is relatively short (approx. 27 hours). As it decays, it emits beta radiation with an energy of about 2 MeV, which is capable of destroying cancer cells.

A team of scientists working at the MARIA reactor in cooperation with Quirem Medical has begun to develop a technology for irradiating holmium microspheres. Polactide microspheres are very sensitive – they can already start to degrade after reaching a temperature of 60 °C. The task required the adaptation of the reactor's infrastructure and the development of new technological solutions. The cooling system of the containers placed in the reactor has been improved. It was also necessary to place special radiation detectors in the reactor core to monitor the irradiation conditions and to create a computer-based process control system.

Currently, the MARIA reactor irradiates vials with microspheres for the needs of over 100 patients per year. They are used in over a dozen clinics all over Europe.

Study of coolant flows

In collaboration with the University of Illinois at Urbana-Champaign (UIUC), scientists are experimenting with instabilities in low-pressure natural circulation loops in nuclear reactors. A multivariate dataset has been developed for the biphasic instability in the natural low pressure circuit based on a direct transient local measurement.

A doctoral project carried out at NCBJ was nominated by the international association NUGENIA to be presented in the competition for young scientists at the cyclical world conference FISA 2019 / EuradWaste'19. The project concerns the study of the influence of turbulence in the flowing cooling material on the safety of nuclear reactors. It assumes checking simplified models and possibly proposing their improvement on the basis of comparison with the advanced model verified experimentally.

Another doctoral dissertation written at NCBJ was devoted to the phenomenon of drying of the fuel element wall, which may occur in BWR reactors, leading to a radical reduction in cooling efficiency. The theoretical basis of the CATHARE-3 system code used to estimate the effects of the phenomenon was analyzed. Modifications to phenomenological equations were proposed and the uncertainties of calculations obtained with the model used to simulate the phenomena of detachment and deposition of water droplets on the walls of the fuel element were analyzed. Flow parameters corresponding to high and low uncertainties were identified. For the purposes of these analyses, the original DARIA system code was created.

The offer of the Radioisotope Centre POLATOM

The POLATOM Radioisotope Centre 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. We export our products to over 70 countries. POLATOM is the main Polish producer of radiopharmaceuticals and other radioactive products.

The current trade package of POLATOM includes:

- A wide range of scintigraphic ^{99m}Tc labeling kits for organ examination and cancer diagnosis,
- Preparations of radioactive 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,
- Industrial closed sources,
- Radioactive standard solutions,
- Radiochemical reagents,
- A wide range of special radioactive preparations tailored to users' needs,
- Accessories and service for nuclear medicine units:
  - for calibration and servicing of dose calibrators,
  - installation and maintenance of isotope equipment,
  - transhipment and transport of radioactive materials.

POLATOM's activities in all areas meet European and international standards; within the scope of the quality assurance system, POLATOM complies with the PN-EN / ISO 9001: 2015-10 standard.

Its standard of radiopharmaceutical production is confirmed by a GMP Certificate, and its qualifications in the field of ionizing radiation metrology confirmed by a Calibration Laboratory Accreditation Certificate according to PN-EN / ISO 17025.

In 2020, NCBJ prepared a short film presenting OR POLATOM. It is publicly available on the institute's YouTube channel:

https://youtu.be/WqnYdnNFamg

CERAD

Laboratories and infrastructure with an area of 2,500 m^2, worth nearly PLN 117 million, are being built at NCBJ as part of a project co-financed by the European Union called "Center for Design and Synthesis of Molecularly Targeted Radiopharmaceuticals – CERAD." Each passing month brings visible progress in the construction work. The newly constructed buildings will be equipped with top-class research and production devices, but the most important of them will be a cyclotron accelerating protons and alpha particles to an energy of 30 MeV and deuterons to an energy of 15 MeV. Having one of the most modern accelerators of this type in the world will allow NCBJ to produce radioactive isotopes such as 89Zr or 211At. OR POLATOM will be able to produce new, innovative radiopharmaceuticals for diagnostics and therapy, based on biologically active ligands operating at the cellular and molecular level.

Intensive work is underway on the cyclotron, which will soon be assembled within the walls of the emerging "CERAD" laboratory. The supplier of the device is the Belgian company IBA (Ion Beam Applications S.A.).

International comparison of ^{55}Fe radioactive solution activity measurements

In the years 2019-2020, the POLATOM Radioisotope Centre conducted an international, key comparison of measurements of the radioactive concentration of a ^{55}Fe solution. The purpose of the comparison was to check – after 14 years since the previous international comparison – the measurement competencies of laboratories from different countries, to determine the reference value of the key comparison (KCRV) and to support the validation of the Extended International Reference System (ESIR) at the BIPM in France. Measurements at POLATOM were made using the National Standard for Radioactive Activity of Radionuclides. POLATOM sent participants a 55Fe solution for measurement and, additionally, a series of sources ready for measurement in polyethylene bottles containing a liquid scintillator mixed with a radioactive solution. The results of measurements from 12 centers participating in cooperation with ENEA-INMRI (Italy) were analyzed. Most of them used the TDCR (Triple-to-Double Coincidence Ratio) method, developed at Świerk in 1979. The results obtained by all the centers, except one, were consistent within the uncertainty of measurements. After analysis and discussion with participants, the KCRV reference value was determined with a standard deviation of 0.23%.

PLN 16 million for the study of tandem therapy

The project entitled "The use of the LutaPol / ItraPol tandem therapy (^{177}Lu / ^{90}Y-DOTATATE) as an effective tool in the treatment of neuroendocrine neoplasms" has received over PLN 16 million of support. Scientists from NCBJ will carry out the research in cooperation with the Military Institute of Medicine, Oncology Center – MS-C Institute, Świętokrzyskie Cancer Center, the University Hospital in Krakow and Collegium Medicum of the Jagiellonian University.

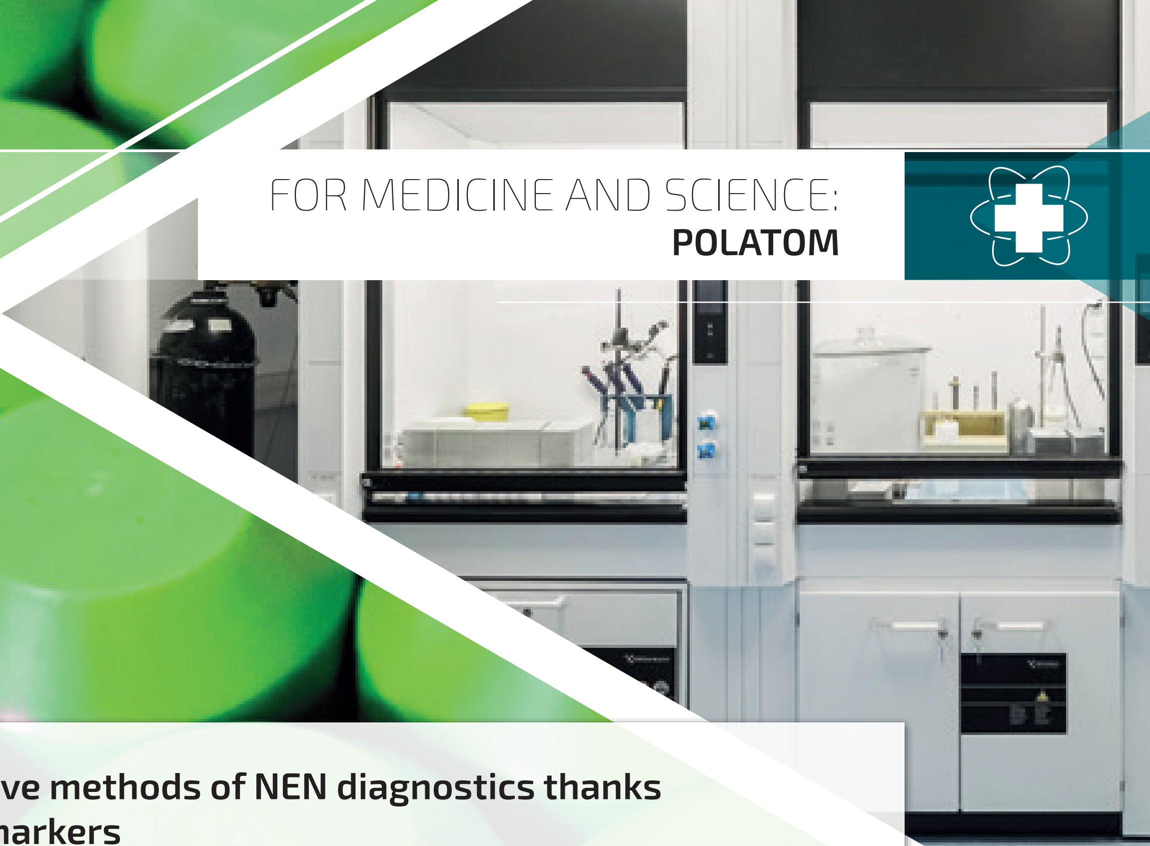
LutaPol and Itrapol are two radiopharmaceuticals developed and produced at OR POLATOM, which in 2014 were awarded the title of "Polish Product of the Future of the Scientific Unit". Their use in tandem therapy, i.e. combining the simultaneous action of these two drugs, with different radiation energies and different tissue spreads, may allow the treatment of endocrine neoplasms that are not eligible for surgical treatment. NCBJ was the only successful applicant in the competition of the Medical Research Agency which is not a medical university or hospital.

Multisom – Multivariate formulations of the DOTA-TATE peptide

Peptide receptor radioisotope therapy (PRRT) with radiolabeled somatostatin analogues such as DOTA-TATE peptide is a method of targeted treatment of patients with disseminated neuroendocrine tumors (NETs). Depending on the type of tumor, the peptide used for treatment is labeled with one isotope or a combined treatment (a combination of the high-energy ^{90}Y and lower energy ^{177}Lu beta emitters) is used. There is a growing interest in theranostic isotopes, e.g. ^{44}Sc – used in the PET technique or ^{47}Sc – used in therapy.

The aim of the Multisom project was to develop various pharmaceutical formulations of the DOTA-TATE peptide that could be used to obtain radiopharmaceuticals with various radioisotopes. The great advantage of the kit is the ability to prepare a radiopharmaceutical at the injection site, which will significantly improve the availability of treatment.

The developed radiopharmaceutical kits were evaluated on the basis of the radiolabeling efficiency, the obtained radiochemical purity and the pH of the final product. The results confirmed the high quality, as evidenced by, *inter alia*, high marking efficiency (> 98%). Research has shown that the MultiSom kit developed by POLATOM can be effectively labeled with the isotopes ^{177}Lu, ^{90}Y, ^{44}Sc and ^{47}Sc. When the radioisotope meets the GMP (Good Manufacturing Practice) requirements, the ready-to-use radiopharmaceutical with the DOTA-TATE peptide can be prepared immediately before administration, personalized for each patient.



More effective methods of NEN diagnostics thanks to TECANT markers

Neuroendocrine neoplasms (NENs) are a heterogeneous group of neoplasms biologically characterized by overexpression of somatostatin receptors (mainly the second subtype – SSTR2) on cell membranes. There are imaging techniques using radiopharmaceuticals that bind to SSTR2 that can predict and evaluate the response to an applied NEN treatment. Recently, it has been shown that new radiopharmaceuticals based on SSTR2 antagonists provide better visualization of the neoplastic lesion than those used so far (eg DOTA-TATE or DOTA-TOC), and also show great potential for PET imaging and therapy.

The ERA-PerMed 'TECANT' project compared two peptides in preclinical studies, two SSTR2 antagonist peptides for ^{99m}Tc labeling: TECANT 1 based on the LM3 antagonist and TECANT 2 based on BASS. In vitro and in vivo pharmacological properties were taken into account in order to select the best candidate for clinical trials. Among others, biodistribution, cellular uptake, and stability. MicroSPECT / CT studies were also performed which confirmed earlier results and identified [^{99m}Tc] Tc-TECANT 1 as the more attractive SSTR2 marker. After toxicity tests, a multi-center clinical trial is planned in 2021.

Nov-GenTech – accelerator production of ^{99m}Tc

Technetium 99m is the most widely used isotope in nuclear medicine. It is produced in generators where the source of technetium-99m is another radioactive isotope, molybdenum-99, obtained from uranium irradiated, among other places, in the MARIA nuclear reactor at NCBJ. The aging and reduction in the number of production nuclear reactors, as well as the growing production costs, has resulted in increased interest in alternative methods of obtaining ^{99m}Tc, e.g. by irradiating targets in accelerators. OR POLATOM has developed a method for the direct production of ^{99m}Tc based on protons accelerated in cyclotrons (e.g. the one developed in the CERAD project) and the ^{100}Mo (p, 2n) ^{99m}Tc reaction. Scientists also proposed the use of a more accessible linear accelerator and the 100Mo (γ, n) ^{99}Mo photonuclear reaction. NCBJ has developed an efficient method of producing a ^{100}Mo target for irradiation in a linear accelerator. The dissolution process of a molybdenum target weighing about 10 g was optimized, and a method of ^{99m}Tc separation from a large excess of molybdenum was developed. Based on a newly developed extraction resin, showing high selectivity in relation to ^{99m}Tc, an innovative inverted generator system was proposed that enables separation of ^{99m}Tc from ^{99}Mo with low specific activity.

PolFEL: the project progress

The Polish free electron laser will be able to generate coherent electromagnetic radiation with a wavelength of up to 55 nanometers, which is partly within the vacuum ultraviolet range. Researchers will also be able to use radiation with longer wavelengths, including terahertz and infrared radiation. A great advantage of this device will also be the ability to work in a continuous wave mode.

Four basic elements can be distinguished in the design of PolFEL: an electron source equipped with a superconducting photocathode, four superconducting cryomodules accelerating electrons to an energy of up to 180 MeV, three undulator lines, in which electrons will emit photons moving in a 'slalom' in a heterogeneous, specially shaped magnetic field, and experimental stations – three for beams of photons and one for an electron beam.

Progress in work carried out by the PolFEL consortium with the participation of cooperating institutions is as follows (mid-2021):

- A conceptual design of the device was prepared
- Requirements for PoLFEL laboratory buildings have been defined
- Experimental line designs advanced
  - A significant part of the VUV line has been designed
  - Theoretical assumptions were developed for the design of a photon-sharing line with energy from several dozen keV to MeV, based on the Compton backscattering phenomenon
  - The method of leading the THz beam from the area of the electron beam was designed
- The Radiological Protection Project was prepared
- The ground was tested for vibration, based on a theoretical model, and the principles of anti-vibration protection were developed
- The superconducting accelerator modules made using TESLA technology (RI Research Instruments) have been contracted out
- A helium cryogenics project was completed
- Tender procedures were prepared for:
  - the performance of construction work related to cryogenics
  - the liquid helium distribution system in the accelerator tunnel
  - the system of the refrigerator and helium condenser
- The electron gun cryomodule was designed together with the concept of the laboratory for the trigger laser and the chamber for introducing the trigger laser beam into the gun cryomodule and leading it to the photocathode.
- The conceptual design of the electron beam collector was completed and the design of electron optics devices was advanced
- The development of terms for the elements of the electron diagnostics system has been advanced (profile, position, current, energy, power losses)
- Based on the acquired additional funds, the foundations of the project were extended, including:
  - a laboratory for research into the technology of completely superconducting electron launchers
  - a biomedical research station equipped with, *inter alia*, the imaging systems of the SNOM
  - a test station for accelerating cryomodules.

Superconducting photocathode

The amount of light generated in the laser depends largely on the efficiency of the cathode used to supply the electrons. NCBJ scientists are developing an innovative superconducting photocathode, thanks to which the currently under construction Polish free electron laser PolFEL will be able to work effectively in the continuous wave mode, distinguishing it from other devices of this type in the world. A special "hybrid" photocathode will consist of a thin layer of lead placed on a high purity niobium substrate. Both of these materials are superconductors at low temperatures. To create a thin layer of lead on a niobium substrate, scientists used, *inter alia*, the IBIS plasma cannon – a unique device designed and manufactured in Świerk, allowing for surface modification based on original technology in which a multi-rod plasma injector is used. PolFEL will most likely be the first FEL to use a superconducting electron gun.

PolFEL Undulators

Undulators are the key elements of a free electron laser in which the energy of an electron beam is converted into coherent electromagnetic radiation. One of the necessary conditions for the laser action to take place is to maintain the maximum overlap of the photon and electron beam in the area of the undulators. This condition imposes requirements on the precision of the undulator construction and the control of the position of both beams. At NCBJ, with the support of partners, parallel work is underway to design and manufacture three different types of undulators for the following photon energy ranges: VUV, IR, THZ. The undulators will be equipped with a unique sequence of neodymium magnets arranged in the Halbach matrix configuration. The design assumptions of the accelerator building and the limitations resulting from the compactness of the devices in the accelerator tunnel are also a big challenge. Designers prefer a modular design for the undulators and the development of an appropriate assembly procedure.

New laser Lab

A laser system generating high-power femtosecond pulses (about 300fs) was installed in a new laboratory set up at Świerk. The strongest laser beam has a peak power in a pulse greater than 1GW. The system has an additional laser module called the Optical Parametric Amplifier, which allows for smooth tuning of the wavelength of laser radiation from deep ultraviolet to near infrared. The above laser system will allow *inter alia* research in the field of light-matter interaction, testing of optical modules transforming the Gaussian laser impulse in the field of deep ultraviolet, testing of the optical module for Compton Backscattering, testing of the optics for pump-probe spectroscopy and testing the Scanning Near-field Scanning Microscope (SNOM), which will allow the imaging of samples (biological or meta-materials) in the range of terahertz radiation with a breach of the diffraction limit.

Polish accelerator on the UE border

At the Kuźnica Białostocka – Grodno railway border crossing point, an X-ray machine for scanning railway carriages has been installed. It was built with the use of solutions developed at the National Centre for Nuclear Research. The heart of the system, called Canis, is an electron accelerator with switching energies of 6 and 9 MeV manufactured by the NCBJ Nuclear Apparatus Department. Its construction uses original solutions patented by scientists from Świerk.

Canis is used for fully automated scanning of trains crossing the external border of the European Union. Thanks to the technology of alternating low and high energy X-ray radiation, the scanner has the ability to distinguish materials with different atomic numbers, enabling the identification of organic and inorganic materials. This will allow customs officers quickly to detect illegal goods, explosives, drugs, firearms, etc. It will also be possible to detect caches and additional structural elements of all types of freight wagons and containers.

Identification of the transported materials is carried out in the Canis system in a similar way to that used in airport baggage scanners. Scanning beams of two different energies are used, which are scattered or absorbed in different ways by the X-rayed materials of different densities. In accelerator systems, it is very difficult to obtain beams with two different energies scanning the same area almost at the same time, while the Canis system uses a design solution patented by NCBJ, which allows the energy of the scanning beam to be changed many times in just a second. This allows for smooth passage of wagons through the scanning area in accordance with the requirements set by customs officials.

In radiographic systems and CARGO inspection systems, accelerators are used to accelerate the electrons. The heart of the accelerator is the accelerating structure. In this type of accelerator it is usually approx. 1 meter long and accelerates electrons to energies from a few to several megaelectron volts. The production of accelerating structures is a complicated process that requires precision and accuracy down to hundredths of a millimeter when machining details of the resonance cavities and then joining them in the soldering process. For this reason, there are only a few manufacturers of this type of equipment in the world.

CentriX – new kind in industrial radiography

Thanks to the CentriX project, four laboratories are being established at NCBJ whose activities will focus on a wide spectrum of research related to ionizing radiation.

The Fast-X Laboratory is the largest part of the project. The laboratory is developing stations equipped with e-, X and n radiation sources and modern imaging detectors, largely based on technologies developed at the National Centre for Nuclear Research. Our own unique solutions will be complemented by the most modern X-ray devices and detectors available on the global market. The laboratory will allow specialized radiographic and tomographic examinations, among others in the area of high energy, high resolution and ultra-high speeds in applications such as precise examination of large-size objects, material identification and X-ray film recording at a speed of 100 thousand frames per second. In turn, the beams of fast neutrons produced by the modular accelerator will be used for industrial neutron radiography and for research into new isotopes for medicine.

The Detection Systems Laboratory will conduct research on ionizing radiation: natural and artificially produced. There is a dedicated stand for the study of natural radiation of very low intensity, simulating the conditions of its occurrence, consisting of model blocks that will correspond to chemical patterns, e.g. Si, Al, Ca. Prototype devices are also being built here, as well as a laboratory for researching artificially produced ionizing radiation.

The Accelerating Structures Testing Station will be used to optimize the process of producing copper accelerating structures.

The Nondestructive Materials Research Laboratory will be involved in ultrafast and non-destructive structural testing of materials using the confocal Raman microscope purchased as part of the project.

Work related to the launch of the CentriX laboratories will be completed in 2021.

Grants and Projects

Every year, NCBJ implements several dozen different grants and projects financed from Polish, European and non-European sources. The largest of them are investment projects worth tens of millions of euros – CERAD, PolFEL, CentriX and Nomaten. Many projects are carried out as part of national or international consortia. The effects of the work of some of them have been described in previous notes. We are particularly pleased with the numerous grants obtained by our scientists – individually or as leaders of larger teams. We present some of them here.

Some recently obtained research grants

HARMONIA Agnieszka Pollo, VIPERS and further: the evolution of galaxies in the large-scale structure of the Universe. The aim of the project is to use the world's only huge three-dimensional "map" of the Universe from 8 billion years ago, created thanks to the measurements of the VIPERS project – VIMOS Public Extragalactic Redshift Survey. Thanks to this project, not only are the locations in space of about 90,000 distant galaxies from the period when the Universe was twice as young as it is today determined, but also the possibility of studying their physical properties. In the project, scientists will measure, weigh, compare and classify these galaxies using the latest machine learning methods ... and compare them both with our nearby galaxies and those much more distant. They thus intend to find out what evolutionary paths and processes led to the formation of today's types of galaxies.

SONATA-BIS, Przemysław Małkiewicz, The quantum origin of cosmological expansion and primal structures in the universe. This project examines the extension of the standard cosmological model to the cosmological contraction phase (i.e. contraction of space), which precedes the current expansion. The universe becomes very small and dense, and then bounces back into expansion thanks to the so-called quantum effects of the gravitational field. Taking quantum effects into account improves the GTA equations and leads to a non-singular dynamics of the universe. We will use the proposed model to make accurate predictions of primordial gravitational waves, the measurement of which is the goal of many ongoing or planned experiments.

SONATA BIS, Justyna Łagoda, Precise measurements of neutrino oscillations in the improved T2K experiment. The T2K experiment is preparing to enter its second phase. The distant detector is being renovated and improved; it will be more sensitive, especially to anti-neutrino interactions. The intensity of the neutrino beam will also be enhanced. Before that, a lot of work has to be put into understanding the operation of improved detectors (simulations, calibration, determination of systematic errors), reconstruction of the recorded interactions and their selection, as well as understanding the processes constituting the background to the signal we are looking for. It is essential to develop IT tools, such as event reconstruction algorithms and selection methods (including machine learning), as well as advanced statistical methods that will allow us quickly and efficiently to compare data with models for large numbers of events and many model parameters. This project is concerned with participating in the development of such tools and data analysis with their help.

SONATA BIS, Katarzyna Małek, ASTROdust: a comprehensive description of dust attenuation in galaxies based on one million galaxies observed by the Herschel satellite. The main goal of this project is statistically to study dust

suppression in galaxies and its dependence on galaxy type in different space ages. An unprecedentedly large sample of one million galaxies observed in the infrared by the Herschel satellite will be used for this research. Scientists plan to construct correct damping curves for different types of galaxies and study how they have changed over time over the past 10 billion years. This will lead to a re-evaluation of the basic physical properties of star-forming galaxies and provide new tools for astronomers who study these fascinating objects.

SONATA, Jan Jakub Ostrowski, Cosmology without the theory of perturbations. This project has three main stages. The first is an attempt to apply exact, heterogeneous solutions to Einstein's equations to characteristic parts of the Universe such as, for example, voids or galaxy clusters. The second stage will be to build a comprehensive description from these fragments, e.g. by averaging (this is an unsolved theoretical problem). In the third stage, I plan to model the propagation of light in the obtained model, which would allow us to confront the predictions with observations and probably enrich our understanding of phenomena and concepts related to, for example, the concepts of dark matter and dark energy.

SONATA, Paweł Sznajder, Study of the three-dimensional structure of the nucleon in the planned electron-ion collider. The author proposed a coherent research program aimed at a better understanding of hadronic structures. This program is based on the use of the generalized parton distribution (GPD) formalism – a fruitful QCD theory developed in the 1990s. It is planned to analyze the production of mesons, take into account nuclear effects and initial states, develop a new Monte Carlo generator dedicated to exclusive processes, and develop the so-called weighing methods. The project is of great importance for the future electron-ion collider (EIC) to be built in the US.

OPUS, William Pearson, Galaxy Collisions: Star Formation During the Most Powerful Collisions in the Universe. In this project, using new observations from the Kilo-Degree Survey (KiDS), the author intends to determine how the rate of star formation changes in the subsequent stages of the galaxy collision process. It will be an unprecedented research project using the latest, recently developed methods based on machine learning techniques and the latest advances in artificial intelligence (AI). This will allow the researcher accurately to determine the time remaining until the collision of two nearby galaxies, or the time elapsed since their collision began. As a result of the project, catalogs of galaxy merging times will be created, and the SI algorithm developed as part of the project will be published.

OPUS, Kenji Shinozaki, Searching for macroscopic dark matter with high sensitivity terrestrial and space cameras. Nuclearites are a type of hypothetical dark matter particles called "strange quark matter". Scientists believe that they can be looked for in observations similar to observing meteors. The project involves the search for nuclearites as part of the Mini-EUSO and DIMS experiments. The DIMS Group plans to build four automatic cameras and observe meteors, especially those coming from outside the solar system. As part of the project, another camera set to search for nuclearites will be added.

OPUS, Andrzej Sandacz, the COMPASS experiment – study of the internal three-dimensional structure of the nucleon. The aim of this project is to study experimentally the internal, three-dimensional structure of the nucleon at the level of its elementary components by means of QCD studies, which go beyond the previously commonly used one-dimensional description. The description of the three-dimensional structure of the nucleon is possible either under the TMD (Transverse Momentum Dependent Distibutions) formalism or under the GPD (Generalised Parton Distributions) formalism. In this project, the TMD and GPD distributions will be studied on the basis of measurements of three processes: exclusive production of mesons and photons in deep inelastic muon scattering (GPD subject), semi-inclusive deep inelastic muon scattering on transversely polarized deuterons (TMD subject) and production of muon pairs in the Drell-Yan process in the scattering of pions on nucleons (TMD subject). The measurements will be carried out as part of the COMPASS Collaboration at CERN by scattering high energy muons or π mesons on nucleons.

PRELUDIUM, Sebastian Trojanowski, Axion dark matter in scenarios with low heating temperature of the Universe after the period of cosmological inflation. Sebastian Trojanowski is one of four initiators of a new experiment at the Large Hadron Collider, called FASER, which will focus on looking for traces of so-called new physics, going beyond our current knowledge of matter, as well as analyzing the properties of the most elusive among the particles known to us so far, the so-called neutrinos. In his research, Dr. Trojanowski also deals with the issue of the so-called dark matter, which is one of the dominant components of the universe around us, although its nature remains mysterious.

PRELUDIUM, Tomasz Kwiatkowski, The use of turbulent LES and hybrid models for precise prediction of coolant flow and heat transfer in tightly packed fuel cartridges. The main aim of the proposed research is to validate and / or calibrate the available and commonly used models of turbulence occurring in the coolant flow of nuclear reactors. The implementation of this project will determine how good the current low-order turbulent models are for modeling coolant flow and heat transfer in tightly packed fuel cartridges. The author predicts that, as a consequence, a set of so-called best practices, i.e. indications of how such analyses should be carried out will be produced.

PRELUDIUM BIS, Andrzej Kupść, How to observe CP symmetry breaking in hyperon decays. The author of this project and supervisor of a future PhD student who will be entrusted with it, anticipates that the grant will develop a new method of testing CP symmetry for processes involving baryons containing a strange quark, where CP symmetry violation has not been experimentally found so far. This method will use baryon-anti-barion pairs created by annihilation of an electron-positron or proton-antiproton pair in one of the currently planned experiments. Data collected in the BESIII experiment in Beijing will be used to develop the method. Baryonic states produced in such annihilations are quantum entangled (meaning that there are correlations between the quantum state of the baryon and the anti-baryon), and their spins are polarized.

100% of our projects on the Polish Map of Research Infrastructures

In 2020, the Minister of Science and Higher Education published a list of strategic research infrastructures included in the Polish Map of Research Infrastructures. Among the 70 approved projects were 7 proposals prepared by scientists from the National Centre for Nuclear Research. They include four projects of new national research structures and three projects of participation by Polish scientists grouped in consortia led by NCBJ in international projects.

Among the new national infrastructures on the Map is the already begun investment of building **the Polish free electron laser PolFEL** and its extension by a second stage significantly increasing its research possibilities. The second proposal of NCBJ is the construction of **a new research laboratory at the MARIA nuclear reactor**, allowing for effective use of the strong neutron flux generated in the reactor, e.g. for materials and biological research. Another **NOMATEN CoRE project** is to be used for research and synthesis of new materials intended for applications in extreme conditions, as well as in medicine. According to the applicants, it will be a significant supplement to the recently established NOMATEN Center of Excellence with its own research laboratories located in Świerk. In these laboratories it will be possible to manufacture, modify and test comprehensively new materials with unique properties. The last, but perhaps the most important, project of the new national research infrastructure planned at NCBJ is **the European experimental EUHTER gas-cooled high-temperature nuclear reactor**, the construction of which would lay the foundation for the introduction of high-temperature reactor technology into European industry.

Among the international projects included in the list of strategic research infrastructures created with the participation of Polish scientists and coordinated by NCBJ, two are already well advanced and one in preparation.

Already advanced projects include research and development of **the European XFEL X-ray free electron laser infrastructure** in Hamburg and participation in the observations of the Large Synoptic Survey Telescope which is being built in Chile. A completely new venture is **the Hyper-Kamiokande experiment**. This experiment, located in Japan, is to expand significantly our knowledge of neutrinos – the least known particles of the Standard Model so far.

Scientists from NCBJ also participate in the work of consortia coordinated by other units, whose projects are also included on the Map. These include among others participation in **CERN experiments** or in **IT infrastructure construction** projects submitted by AGH and PSNC (ICB PAN).

The full list of selected projects is available on the website of the Ministry of Science and Higher Education.

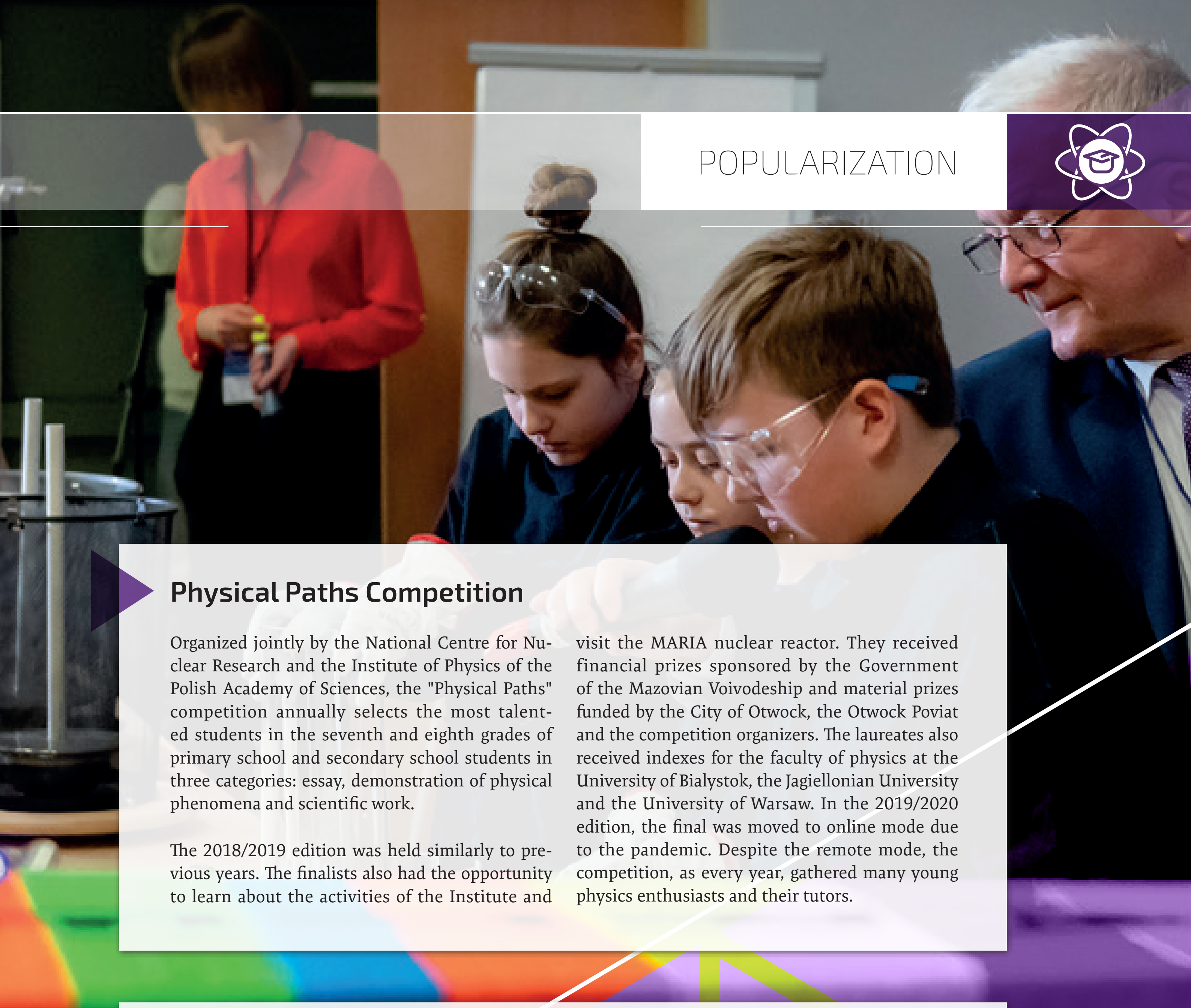
Placing a project on the Polish Research Infrastructure Map does not automatically guarantee its financing, but it significantly increases the chances of obtaining the necessary funds.

Science picnics and festivals

Scientists and educators from NCBJ participate in many events throughout Poland. The most important are the Science Picnic of Polish Radio and the Copernicus Science Center, the Science Festival in Warsaw, the Science Picnic EXPLORATIONS in Rzeszów and the Silesian Science Festival in Katowice. We also participated in the Family Science Picnic in Otwock, SITMN Engineering University in Głogów, the popular science meeting "To conquer the skies" in Bydgoszcz and in Sejny Meetings with Science. Our employees also prepared a seminar for secondary school physics teachers at WODN in Sieradz, workshops as part of the CREDO project conference, CREDO Workshop 2019 in Krakow and a lecture for teachers at the Bogolubow-Infeld program seminar in Poznań. During the classes and demonstrations prepared by us, we talk about ionizing radiation and its common presence in the life of every human being. Participants can observe traces of natural radiation in a cloud chamber as well as examine the activity of many radioactive objects and substances in daily use. Cosmic radiation is presented using the Cosmic Watch muon counters. A unique attraction is also the opportunity to see a rich VR gallery of three-dimensional photos of the MARIA reactor. A special attraction of our stand at the Warsaw Science Picnic in 2019 were guests from Hamburg, who talked about the European XFEL free electron laser, co-owned by NCBJ. XFEL is a two-kilometer accelerator of electrons, which after acceleration enter a specially shaped magnetic field and, oscillating within it, emit laser radiation with well-controlled parameters. There were two VR sets at the stand, allowing visitors to take a virtual walk through the European XFEL tunnel and the FXE research station. A large-format map of the DESY center was also shown, allowing the viewer to appreciate just how huge this project is.

Popular lectures

NCBJ offered the Institute's non research employees a series of popular lectures devoted to the issues studied by our scientists. Before the pandemic, 11 such meetings were organized. They included, *inter alia*, lectures about particles, large experiments, reactors, accelerators, detectors and plasma. The lectures were inaugurated by members of the NCBJ management. The recordings of the lectures were made available on the institute's YouTube channel.



Physical Paths Competition

Organized jointly by the National Centre for Nuclear Research and the Institute of Physics of the Polish Academy of Sciences, the "Physical Paths" competition annually selects the most talented students in the seventh and eighth grades of primary school and secondary school students in three categories: essay, demonstration of physical phenomena and scientific work.

The 2018/2019 edition was held similarly to previous years. The finalists also had the opportunity to learn about the activities of the Institute and visit the MARIA nuclear reactor. They received financial prizes sponsored by the Government of the Mazovian Voivodeship and material prizes funded by the City of Otwock, the Otwock Poviat and the competition organizers. The laureates also received indexes for the faculty of physics at the University of Bialystok, the Jagiellonian University and the University of Warsaw. In the 2019/2020 edition, the final was moved to online mode due to the pandemic. Despite the remote mode, the competition, as every year, gathered many young physics enthusiasts and their tutors.

Online popularization

The pandemic thwarted the organizers of science popularization events, but despite its limitations, scientists found ways to reach a large audience.

To meet the difficulties related to the sars-cov-2 virus pandemic, we have introduced remote education to our offer. During the pandemic NCBJ prepared for the first time a special lecture-presentation on the Dark Side of the Universe for the 2020 Warsaw Science Festival. Of course, the recording was presented on the internet.

We offer workshops for schools, lectures and training for teachers via the Internet on an ongoing basis. Our Education and Training Department offers online workshops for schools, online lectures, online training for teachers, and even online laboratory classes. The latter offer is addressed to secondary schools that would like to enrich their lessons with laboratory classes in the form of an Internet teleconference. Classes are conducted with the use of equipment located in our Laboratory of Atomic and Nuclear Physics, which is unique in Europe. The classes offered allow students to familiarize themselves with the equipment used in the laboratory and the observation of phenomena in the field of nuclear physics, including the properties and interactions of ionizing radiation with matter. During the classes we provide a theoretical introduction, presentation of the equipment and stand, conduct the experiment and discuss the results obtained.

New professors

In 2019-2020 the group of institute professors increased by 21 new members

- **Dr. Mikko Alava** was elected director of the NOMATEN Center of Excellence and joined the NCBJ team as an institute professor
- **Prof. dr hab. Marek Biesiada** joined the team of the Astrophysics Division of the Department of Basic Research (DBP)
- **Dr hab. Konrad Górski** joined the team of the Interdisciplinary Division of Energy Analysis
- **Dr hab. Janusz Kocik** joined the Department of Exploitation of Nuclear Facilities and became the head of the Division of Biochemical Research

17 scientists of the institute obtained habilitation during the years 2019-2020. They were:

- **Tolga Altinoluk** from the Division of Theoretical Physics of DBP. Thesis title: Particle production and correlations in the Color Glass Condensate approach (habilitation at NCBJ)
- **Paweł Bielewicz** from the Division of Astrophysics, DBP. Thesis title: Observational constraints on the topology of the Universe (habilitation at CAMK)
- **Michał Bluj** from the Division of High Energy Physics of DBP. Thesis title: From the reconstruction of the tau lepton to the observation of the decay of the Higgs boson into tau-tau pairs in the CMS experiment at the LHC (habilitation at NCBJ)
- **Piotr Goldstein** from the Division of Theoretical Physics of DBP. Thesis title: Continuous generalizations of the Painleve test (habilitation at NCBJ)
- **Ernest Grodner** from the Nuclear Physics Division of DBP. Thesis title: Verification of the hypothesis of violation of chiral nuclear symmetry (habilitation at NCBJ)
- **Kamila Kowalska** from the Division of Theoretical Physics of DBP. Thesis title: Status of supersymmetric extensions of the Standard Model in the light of data from the Large Hadron Collider (habilitation at NCBJ).
- **Łukasz Kurpaska** from the Materials Research Laboratory of the Department of Materials Physics. Thesis title: Influence of temperature and degree of damage on functional properties of selected materials used in the nuclear industry (habilitation at the AGH University of Science and Technology)

- **Katarzyna Małek** from the Division of Astrophysics, DBP. Thesis title: Classification and modeling of infrared energy spectra of galaxies (habilitation at the Jagiellonian University)
- **Przemysław Małkiewicz** from the Division of Theoretical Physics of DBP. Thesis title: Construction, analysis and interpretation of quantum dynamics of classically singular cosmological systems (habilitation at NCBJ)
- **Katarzyna Nowakowska-Langier** from the Division of Plasma and Ion Technologies of the Department of Materials Physics. Thesis title: Shaping the structure of coatings in an active low-temperature plasma in selected PAPVD methods (habilitation at the Warsaw University of Technology)
- **Marek Rabiński** from the Division of Plasma Detector Physics and Diagnostics of the Department of Nuclear Apparatus and Techniques. Thesis title: Research on plasma dynamics in the development of the IPD method of impulse coating in surface engineering (habilitation at NCBJ).
- **Jacek Rożynek** from the Division of Theoretical Physics of DBP. Thesis title: Nucleons in dense and hot nuclear matter. (habilitation at NCBJ). Jacek! We miss you very much!
- **Jacek Rzadkiewicz** from the Division of Nuclear Apparatus and Techniques. Thesis title: Development of methods for analyzing high-resolution X-ray spectra generated during collision processes, braking processes and in plasma structures as well as designing conditions for registering the process of nuclear excitation by electron capture (habilitation at NCBJ).
- **Enrico Sessolo** from the Theoretical Physics Division of DBP. Thesis title: Dark matter signals in New Physics models (habilitation at NCBJ)
- **Piotr Tulik** from the Division of Radiological Metrology and Biomedical Physics of the Department of Nuclear Object Operation. Thesis title: Recombinant radiation quality index – applications with the use of ionizing radiation in medical procedures (habilitation at the Warsaw University of Technology)
- **Jakub Wagner** from the Division of Theoretical Physics of DBP. Thesis title: Research on exclusive production of particles in large time-scale processes (habilitation at NCBJ).
- **Paweł Ziń** from the Division of Theoretical Physics of DBP. Thesis title: Description of phenomena caused by quantum and thermal fluctuations in ultra-cold atomic gas systems (habilitation at NCBJ).

Education of students

NCBJ and the Institute of Nuclear Chemistry and Technology have signed an agreement to run a joint doctoral school. The directors of the institutes, Professors Andrzej Chmielewski and Krzysztof Kurek, signed an appropriate agreement. Students will be able to obtain a PhD in Physics or Chemistry. The foundations of the program are: “The need to establish a doctoral school by two scientific and research units: the National Centre for Nuclear Research (NCBJ) and the Institute of Nuclear Chemistry and Technology (IChTJ) has existed for a long time. It results from the common history of the institutes dating back to the 1950s, the complementarity of their research, and recently from the growing needs of the economy and science awaiting specialist training of staff for the Polish Nuclear Power Program (PPEJ) and constantly developing applications of ionizing radiation. It is also necessary to strengthen the numbers of trained personnel of Polish science due to its increasing position in the global research area and the emphasis placed on innovation. Both research institutions and universities, as well as state administration units implementing programs related to atomic science, expect educated employees with extensive interdisciplinary knowledge in the field of nuclear physics and chemistry. Talented graduates of doctoral studies with in-depth specialist knowledge in the field of nuclear physics, astrophysics, as well as radiochemistry, radiation chemistry and radiobiology will significantly contribute to the Polish scientific staff. Globalization of scientific research and the open research space in Europe guarantee work not only within Poland, but also in numerous foreign institutions. "

Students will receive scholarships, with the minimum amount stipulated by statute. After two years and a positive evaluation of the student's learning results, the amount of the doctoral scholarship is increased, which is also regulated. Both institutes apply rates higher than the minimum rates.

At the same time, NCBJ conducts doctoral studies for students who began before the change in regulations in this area, as well as specialized courses: **Radfarm** Interdisciplinary Doctoral Study as part of the project: Radiopharmaceuticals for molecularly targeted diagnostics and medical therapy, and the Interdisciplinary **PhD4GEN** PhD studies conducted as part of the project "New reactor concepts and safety analyses for the Polish Nuclear Power Program".

^{99}Mo accelerator production method: RadFarm's first internship abroad

Molybdenum-99, which undergoes nuclear decay to technetium-99m, is the main isotope used in nuclear medicine. It is obtained mainly in nuclear reactors, such as the Polish research reactor MARIA at the National Centre for Nuclear Research (NCBJ) in Otwock-Świerk. However, the production of this isotope in nuclear reactors has significant limitations, so scientists are looking for new ways efficiently to produce molybdenum-99, for example by using accelerators. A PhD student of RadFarm at NCBJ is also working on this issue. The key nuclear reaction leading to the formation of molybdenum-99 from the point of view of this work is the emission of a neutron by a molybdenum-100 nucleus contained in a target, caused by a high-energy photon hitting the target. The photon beam necessary for this nuclear reaction to take place is produced by the stopping of electrons initially accelerated in an accelerator on the atomic nuclei of a conversion target made of, for example, tantalum or tungsten.

The internship trip to Canadian Isotope Innovations gave the Polish PhD student an opportunity to take part in the Canadian Light Source experiment as part of the IAEA project. In the experiment carried out at CLS, the irradiation of a target containing molybdenum-100 was carried out at using a linear electron accelerator with a beam energy of 35 MeV, and at NCBJ an accelerator with an energy of 30 MeV is currently being built, similar to that available at CLS.

Diamond Grant for a FUW student for research at NCBJ

A student of the Faculty of Physics of the University of Warsaw (FUW) has been awarded a Diamond Grant. The project is entitled "Loop corrections and factorization in the process of exclusive production of photon pairs with high invariant mass". The aim of the work is to calculate the loop corrections in the production of two photons in the photon + proton reaction: $p\gamma \rightarrow p\gamma\gamma'$, with the use of perturbative quantum chromodynamics. The results obtained will be used to prove the factorization theorem for two particle production processes. This theorem, successfully used in the production of one particle, is one of the basic tools for interpreting data and describing the structure of the proton and other particles made of quarks and gluons. In addition, numerical predictions for the analyzed process may be of great importance in the preparation of future experiments at leading laboratories, e.g. JLab, COMPASS, LHC and the Electron Ion Collider (EIC), which is being developed in the United States, i.e. an electron-ion collider, on which scientists from NCBJ are also working.

HR strategy – „HR Excellence in Research"

In 2019 the National Centre for Nuclear Research received the prestigious HR Excellence in Research logo. The European Commission awards this distinction to institutions that contribute to increasing the attractiveness of working conditions for researchers in the European Union and provide employees with a transparent recruitment process, job stability and career development opportunities. The European Commission supports institutions implementing the provisions of the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers and promotes such institutions among international organizations and researchers as providing the best conditions for work and development.

The "HR Excellence in Research" logo is a commitment to the application of HRS4R standards and continuous improvement. NCBJ's plan is to create an attractive place for people with a passion for science from around the world.

HR EXCELLENCE IN RESEARCH

The HR Excellence in Research logo is not awarded forever. Institutions with this title are systematically evaluated in terms of maintaining the standards adopted by the European Commission. The next report and summary of the implementation of the activities as well as the update of the existing plan will take place in September 2021.

HR strategy

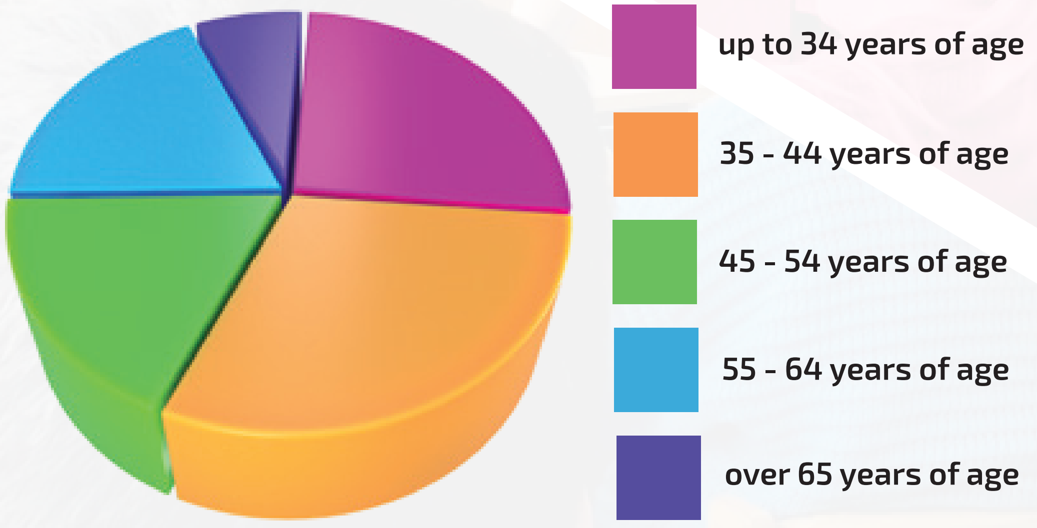
In the period 2019-2021 a number of actions for the development of scientific staff were carried out in accordance with the Action Plan. The HR Strategy for NCBJ was created for NCBJ employees in scientific and research and technical positions. It defines the desired values of organizational culture in relation to people, teams and research departments of the Institute. The HR strategy also defines the most important directions of NCBJ activities in the areas of improving human resource management in relation to research workers: i.e. supporting and strengthening the attitudes of responsibility both in relation to the implementation of research plans and the practical application of the 40 principles described in the European Charter for Researchers, some of which concern the research workers themselves, and partly constitute the obligation of the research institution as an employer. An area that is constantly being improved is the recruitment process, the main goal of which is to facilitate the employment of the best candidates for scientific positions in accordance with the OTM-R (Open, Transparent and Merit based Recruitment) Policy at NCBJ. The OTM-R recruitment policy applies to all scientific positions and to all potential candidates, regardless of the stage of career advancement and the expected or held academic degrees.

Future Leaders program

"Future Leaders" – a "talent management" training and development program – was implemented, addressed to the future scientific staff of NCBJ. The program lasted from May 2020 to March 2021. Fifteen people were registered from the NCBJ science and research departments to take part in a series of training workshops. Participants developed and implemented individual competence development plans needed by a leader (such as managing oneself and one's career, managing a research team / group, other leadership skills). They also worked individually with fifteen mentors invited to the program. An important element of the program was work in 3-person project teams; the results will be used and implemented in the future. The object of the projects was, *inter alia*, to improve ways of managing projects and teams.

One of the results of the program is a planned platform open to all NCBJ leaders for the exchange of experience (best practice sharing). Recruitment for the second edition of the Future Leaders program will start in the second half of 2021.

Employment



Hoża is just history now

The last desks have been removed from the old NCBJ pavilion at ul. Hoża 69. Our Warsaw divisions are now located at ul. Pasteura 7 on the university's Ochota Campus. Specifically, on the second, fourth and fifth floors of a building shared with the Faculty of Physics and other units of the University of Warsaw.

At the new location, as in Hoża, are the headquarters of the Department of Basic Research of NCBJ: the Division of Nuclear Physics (BP1), the Division of Theoretical Physics (BP2), the Division of High Energy Physics (BP3) and the Division of Astrophysics (BP4). Pasteura 7 in Warsaw is not the only NCBJ location outside Świerk: the Cosmic Radiation Laboratory of the NCBJ Astrophysics Department is located in Łódź and the Interdisciplinary Division for Energy Analyses in Warsaw in Mokotów.

The Warsaw telephone numbers of institute employees have also changed. Current numbers can be checked on the YP pages – some are visible only from computers connected to the NCBJ network.

Software Engineering Division

A new Software Engineering Division was established in the Department of Complex Systems Research. It deals with the development of algorithms and scientific software that require high computing power. The work of the Division is mainly focused on the development and maintenance of dedicated software for the super computer installed at NCBJ (Centrum Informatyczne Świerk). The solutions under development include Machine Learning (ML) and Artificial Intelligence (SI), High Performace Computing (HPC), Cloud Computing and development of SaaS and PaaS services. The Division conducts scientific research and technical activities in these fields. The employees of the Division are involved in multidisciplinary research projects, in particular in medical diagnostics.

Organizational structure

Scientific Council	
Director General	D
Nuclear Safety Commission	

Deputy NCBJ Director for Innovation and Commercialisation	DI
NCBJ Nuclear Equipment Division (HITEC)	ZdAJ
Project Management Division	IZ
Technology Transfer Division	ITT
Division of Analysis and Settlement	IA
Science and Technology Park	PNT
Public Tenders Division	IZP

DFM Director **Material Physics Department**	DFM
Material Research Lab	LBM
Nuclear Methods in Solid State Physics Division	FM1
Plasma/Ion Beam Technology Division	FM2

DATJ Director **Nuclear Equipment & Technology Department**	DTJ
Particle Acceleration Physics & Technology Div.	TJ1
Electronics and Detection Systems Division	TJ2
Radiation Detectors and Plasma Diagnostics Division	TJ3

Deputy NCBJ Director for Scientific Matters	DN

DBP Director **Fundamental Research Department**	DBP
Nuclear Physics Division	BP1
Theoretical Physics Division	BP2
High Energy Physics Division	BP3
Astrophysics Division	BP4

DUZ Director **Department of Complex Systems**	DUZ
Information Technologies Division	UZ1
Software Engineering Division	UZ2
Nuclear Energy and Environmental Analyses Div.	UZ3

Scientific Secretary **Research Support Department**	DS
PhD Studies / Doctoral School	SD
International R&D Projects and Cooperation	SW
Training and Education Division	SE
Library	SB
Communication and Promotion Office	SK

Assistant of DG	DAt
Secretaries' Office	AIS

Human Resource Management Division	DHR
Human Resources Division	DP
Legal Division	DRP
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

Interdisciplinary Division for Energy Analyses	DIZ

NOMATEN - International Scientific Agency	Nomaten

POLATOM Radioisotope Centre	OR

Deputy NCBJ Director for Nuclear Safety and Health Protection **Nuclear Safety & Radiation Protection Dpt.**	DJ
Nuclear Centre Emergency Squads	JA
Radiation Protection Officer	IOR
Fissile Materials Accounting Office	JE
Radiation Protection Measurements Labolatory	LPD
Civil Defence /Defensive Measures Squad	JO
Internal Security Guard	WSO
Fire Prevention Division	JP

DEJ Director **Nuclear Facilities Operations Department**	DEJ
MARIA Reactor Operations Division	EJ2
Reactor Technologies Division	EJ3
Reactor Research Division	EJ4
Radiological Metrology and Biomedical Physics Division	H2
MARIA Reactor Quality Assurance Specialist	EJZJ
Irradiation Coordinator	EJN
Documentation Division	EJD
Contracts and Administration Division	EJA
Renovation and Modernization Division	EJR

Deputy NCBJ Director for Economy **Economics Department**	DE
Financial Controller	EF
IT Division	IT
Procurement Division	EZ
Administrative Division	EA

Chief Accountant	EK
Financial Accounting Division	KF
Payroll Division	KR

Technical Matters Department Director **Technical Matters Dpt.**	ET
Chief Technical Engineer	TN
Electric Infrastructure Division	TE
Sanitary Division	TS
Technical Service Division	TO
Investment and Renovation Division	TI
Planning and Settlement of Investments, Renovations and Operations Division	TP

Bus Transport Division	ZTS

ACCREDITATIONS, CERTIFICATES, PERMITS

- **Certificate** J-2358/4/2021 for NCBJ OR POLATOM in the field of: design, production, sale of isotope products and radiopharmaceuticals, service of isotope equipment, transport and forwarding services for radioactive materials. POLATOM meets the requirements of PN-EN ISO 9001: 2015-10. Period of validity: from March 2021 to March 1924

- **Certificate** No. AP 120 for the Accreditation of the Laboratory for Radioactivity Standards, issued by the Polish Center for Accreditation. The laboratory meets the requirements of PN-EN ISO / EIC 17025: 2018-02. Accreditation was granted on December 19, 2008 and extended to December 18, 2024.

- **GMP certificate issued by GIF** (Chief Pharmaceutical Inspector) for NCBJ – as a manufacturer meeting Good Manufacturing Practices contained in Directive 2003/94 / EC as part of manufacturing operations (sterile products, packaging, quality control tests).

- **GMP certificate issued by GIF** – confirms that the manufacturer meets the requirements of Good Manufacturing Practice contained in Directive 2003/94 / EC in the field of manufacturing operations (small-volume liquid forms, capsules). Deadline for inspection 09/04/2019 (valid for 3 years)

- **GIF permit** No. 195/0348/15 for NCBJ for the production or import of a medicinal product of March 28, 2021.

- **GIF permit for running a pharmaceutical warehouse** (no. NZOH..5100.2.2020.MG.4) of February 17, 2020 – Medicinal products for people.

- **Certificate** No. M-34/3/2021, Department of Nuclear Apparatus, PN-EN ISO 13485: 2016–04, research and development work, design, production, installation, sale of high-tech devices, products for the production and use of ionizing radiation in medicine; valid until 01/21/2022

- **Certificate** No.W-63/10/2019, Department of Nuclear Apparatus, meets the requirements of Art. 11, sec. 2 of the Act of November 29, 2000 on foreign trade in goods, technologies and services of strategic importance for state security as well as for the maintenance of international peace and security in the field of: export, intra-EU transfer, brokerage service, technical assistance, import, transit of goods, technologies and services of strategic importance, valid until 01/21/2022.

- **Certificate** No.J-2569/3/2019, Department of Nuclear Equipment, PN-EN ISO 9001: 2015–10, research and development work, design, production, installation, sale and service of high-tech equipment, including products for the production and use of ionizing radiation in science and industry, valid until 01/21/2022

- **Testing Laboratory Accreditation Certificate** No.AB 025, Materials Research Lab, meets the requirements of PN-EN ISO / IEC 17025: 2018-02; The AB025 accreditation remains in force – issued on July 8, 2020. The accreditation status and the validity of the Laboratory's accreditation scope can be confirmed on the PCA website www.pca.gov.pl

- **Testing Laboratory Accreditation Certificate** No.AB 567, Radiation Protection Measurements Laboratory, Contamination Measurement Unit, meets the requirements of PN-EN ISO / IEC 17025: 2018-02, AB567 accreditation remains in force – issued on July 29, 2019.

- **Calibration Laboratory Accreditation Certificate** No.AP 070, Radiation Protection Measurements Laboratory, Dosimetric Equipment Calibration Unit, meets the requirements of PN-EN ISO / IEC 17025: 2018-02, AP 070 accreditation remains in force – issued on 03 July 2019

NCBJ is a Polish research unit of the A + category

Publications

- over 500 peer-reviewed publications in 2020
- h-index > 184
- 10th place in Southern and Eastern Europe in the "Nature Index 2016 Rising Stars" ranking

Projects and grants (September 2021)

NCBJ participates in 124 projects co-financed from international and domestic sources (9.2021):

- 21 projects under the European Union's Horizon 2020 program
- 34 grants from the National Science Center
- 6 grants from the National Center for Research and Development
- 29 projects financed by the Ministry of Science and Higher Education
- 12 projects under the European Regional Development Fund, ESF
- 22 projects financed from other sources

Employees, academic staff (2020)

- about 1,200 employees
- over 80 professors and staff with habilitation
- about 250 people with a doctoral degree
- over 250 people with an engineering degree
- approximately 300 people under 35 years of age

NCBJ headquarters in Otwock-Świerk (20 km south-east of the center of Warsaw)

- an area of over 40 ha
- MARIA research nuclear reactor – 30 MW, > 10^{14} neutrons / cm2s
- radiopharmaceuticals production plant,
- accelerator production plant,
- Świerk IT Center (CIŚ) – almost 1.5 PFLOPS, over 200 terabytes of RAM, 26 petabytes of disk space and approx. 16 petabytes in a tape robot
- research and construction laboratories with unique devices
- doctoral school
- education center – visits, lectures and laboratories for students, institutions and the general public
- Science and Technology Park – usable area of 3500 m^2

RESEARCH COLLABORATIONS