2020

JOINT INSTITUTE FOR NUCLEAR RESEARCH

DUBNA

Joint Institute for Nuclear Research

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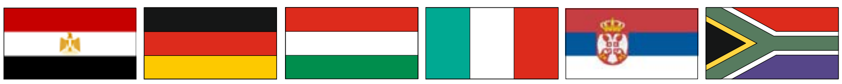
JINR MEMBER STATES

Republic of Armenia
Republic of Azerbaijan
Republic of Belarus
Republic of Bulgaria
Republic of Cuba
Czech Republic
Georgia
Republic of Kazakhstan
Democratic People’s Republic of Korea
Republic of Moldova
Mongolia
Republic of Poland
Romania
Russian Federation
Slovak Republic
Ukraine
Republic of Uzbekistan
Socialist Republic of Vietnam



AGREEMENTS ON GOVERNMENTAL LEVEL ARE SIGNED WITH THE FOLLOWING STATES:

Arab Republic of Egypt
Federal Republic of Germany
Republic of Hungary
Italian Republic
Republic of Serbia
Republic of South Africa

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INTRODUCTION

The year 2020 became the time of hardship for all of us; the coronavirus infection affected each one, but in the conditions of the COVID-19 pandemic the scientific community of JINR continued the implementation of the planned issues. The pace of activities to develop the systems of the NICA collider was not slowed down. The installation of two new clusters of the Baikal neutrino telescope allowed the deep-water detector to reach the effective volume of 0.35 km^3, which made Baikal-GVD one of the world's three largest telescopes in terms of effective area and volume for observation of natural neutrino fluxes and the largest telescope in the Northern Hemisphere. The supercomputer "Govorun" occupied the 22nd position in the world ranking of the highest productive data storage systems of the HPC class. The user programme of the research nuclear facility IBR-2 continued to be implemented. The first experiment on the synthesis of moscovium isotopes was started at the Factory of Superheavy Elements. Further development of international cooperation was aimed at deepening the ties with partner scientific research organizations, integration of JINR into the global research infrastructure and attracting of young staff. All through the year the workout and full discussion of the main trends were held of the strategic plan of JINR development, including the development of the system of indices for monitoring the accomplishment of the strategic plan.

Today we can state with satisfaction that the tough tasks in the conditions of the pandemic of the coronavirus infection did not hinder the JINR community to obtain important results in implementation of the flagship projects of JINR.

The key element of the research facility MPD was successfully transported and delivered to the construction site of the NICA project. Before arriving at Dubna the case with the magnet was transported by sea from the port of Genoa (Italy) to St. Petersburg. The cryostat with superconducting wiring of the magnet for the MPD detector was designed by Russian scientists (specialists from JINR and SDPC "Neva-Magnit") and manufactured in Italy by ASG Superconductors, one of the world's few producers of the unique equipment for large-scale scientific research projects.

On 20 November, Chairman of the RF Government M. Mishustin made the technological start-up of the superconducting Booster synchrotron (Booster), one of the blocks of the international megascience project "NICA Complex". Single-charged helium ions were injected into the Booster and stable beam circulation was obtained. The achieved bright result is the completion of long-standing joint work of the accelerator physicists and engineers of JINR in cooperation with partners from NPI SB RAS, INR RAS, ITEP, IHEP NRC KI, and many other Russian and foreign organizations.

At the end of December, the check assembly of the magnetic core of the solenoid magnet of the experimental facility MPD of the NICA complex was successfully completed — the final upper block was installed. The magnet yoke — 13 blocks, as well as two supporting rings, were assembled with ultimate accuracy. A collaboration of over 500 scientists from 40 scientific centres of five continents takes an active part in developing detector systems of MPD and preparation of experimental research at it.

Another important result is the workout and application of the new experimental method to study the inner structure of the atomic nucleus and neutron stars in the BM@N experiment that registered for the first time all products of the reaction in knocking out nucleons and nucleon pairs from atomic nuclei and opened new scientific prospects for research of the nucleus structure.

First results were obtained at the accelerator complex “The Factory of Superheavy Elements” on the synthesis of isotopes of element 115 (moscovium) in the reaction of interaction of ions of calcium-48 and americium-243. It gave the start to the unique programme of JINR in studying nuclear-physical and chemical properties of superheavy elements scheduled for years. Soon experiments will be conducted on the synthesis of new elements with atomic numbers 119 and 120 — the first elements of period 8 of the Mendeleev Table.

The 6th and 7th clusters of the optical modules of the deep-water neutrino telescope of the cubic-kilometer scale Baikal-GVD, developed jointly with scientists from INR RAS (Troitsk) in Lake Baikal, were deployed and put into operation. It is well-known that the Baikal-GVD telescope is a flagship project of the JINR neutrino programme and is considered as a basic facility of the Institute.

In 2020, the Institute celebrated 60 years since the launch of the first pulsed fast neutron reactor IBR, the only reactor in the world that works with variable level of criticality. In the conditions of the COVID-19 pandemic, the stable operation of the IBR-2 reactor for physics experiments under the user programme allowed the accomplishment of 8 of the planned 10 cycles. Considerable progress was achieved in designing of a new neutron pulsed source of the 4th generation in collaboration with leading scientific organizations, in particular, with those of Rosatom. After a number of technological systems were seriously upgraded, the IREN facility started its regular operation.

Uninterruptible operation was organized of the net and information-computer infrastructure of the Institute, as well as of all services, including videoconference communications. Considerable results were obtained in the development of the unique Multifunctional Information and Computing Complex (MICC), in organization of systems of distributed data processing for many experiments, primarily at the NICA accelerator complex, in development and extending of applications of hybrid and parallel calculations, in solution of tasks of modelling of complex processes, computer physics and many others. Considerable upgrading of the Tier1 level centre was carried out for the CMS (CERN) experiment owing to extending of the configuration of storage systems and calculations, and the transition was accomplished to the new software that allowed bigger effectiveness and scalability of the complex. Integration of all computer resources of the Institute was accomplished on the basis of the DIRAC platform as an important step in the development of distributed data processing at JINR. It is an important contribution to the development of the digital platform for megascience projects.

Research in theoretical physics has traditionally been focused both on supporting the JINR experimental programme and on independent theoretical developments. In many areas, JINR theorists act as flagships of development and generators of ideas that determine the world scientific agenda. Among the best achievements over the past year, one can note the determination of the fundamental constants of quantum electrodynamics with record precision based on the study of HD^+ molecular ions, the investigation of the effect of nuclear temperature on the process of core-collapse supernova explosions, the development of a statistical method for generating fluorinated graphene structures and analysis of their properties, lattice simulations for studying characteristics of rotating quark–gluon matter, the study of the asymmetry of the electron–positron pair production in the interaction of a high-energy photon with a polarized laser pulse, the discovery of the mechanism of staggered radiative decay of long-lived oscillating states, and many others.

The programme of research in space radiobiology with the Nuclotron beams was actively developed; it attracts much interest in connection with an opportunity to study radiation damage in the structure and functions of the central nervous system in animals, especially in primates. New experimental and theoretical data were obtained that revealed mechanisms of forming and repair of DNA radiation damage in cell cultures of the nervous system, and estimations were conducted for radiation pressure and risks for spacemen. In the same list are studies in astrobiology that revealed new mechanisms of the synthesis of complex organic biomolecules at irradiation of non-organic substances with proton beams in the presence of meteorites as catalysts. A big cycle of research of fossil microorganisms (microfossils) in meteorites was carried out. The first illustrated atlas of microfossils in the Orgueil meteorite was issued.

JINR scientists, along with scientific community of the world, made their invaluable contribution to the struggle against the coronavirus pandemic. Properties of the coronavirus were studied in JINR laboratories. Physicists who work in the sphere of blood filters and filters for various gases, substances, liquids, etc., proposed to apply filters in fighting the coronavirus infection. Such nuclear membranes can be very efficiently used in test systems for quick diagnostics of coronavirus. Dubna scientists and pharmacists conducted at the IBR-2 reactor a very interesting study of the cell walls from the point of view of their resistance to penetration of coronavirus through them. The obtained results have been published and are applied in the production of medical anti-coronavirus preparations.

In the pandemic conditions, one of the alternative forms of the JINR University Centre activities was the new online programme INTEREST (INTErnational REmote Student Training); 50 students from 14 countries took part in it last year. The programme allows motivated young people from any country of the world to carry out research projects at JINR without leaving their own home.

A presentation of new auditoria of the IT school “Big Data Analytics” was held at Dubna University under the joint project of the University and JINR for training high-class specialists in information technologies, primarily, for megascience projects of the Institute.

In 2020, the Joint Institute ceremonially celebrated two significant anniversaries: 110 years since the birth of Mikhail Grigorievich Meshcheryakov, one of the founders of the city and the Institute, leader of the work to develop the first accelerator at Dubna — the synchrocyclotron, and 90 years since the birth of Nikolai Nikolaevich Govorun, an outstanding scientist who was one of the initiators of the elaboration of algorithms of parallel calculations, in particular, in studies of lattice models of quantum chromodynamics.

As a result of fruitful efforts in deepening of ties with partner scientific research organizations and integration of JINR into the global research infrastructure, agreements were signed with the Helmholtz Centre of Heavy Ion Research (GSI, Germany) on participation of scientific organizations of Germany in the implementation of the NICA project and with the Ministry of Science and Technology of China on participation of China in the construction and operation of the NICA complex.

In October, the Federation Council Committee on Science, Education and Culture held a guest meeting in Dubna with the agenda of development and efficient use of scientific-technical potential of science cities of Russia. Chairperson of the FC Committee L. Gumerova underlined that the choice of the place for the guest meeting was determined by the status of JINR as an international science centre that knows no borders, countries, religions and is united only by the idea of service for science for the sake of peace and progress. In this connection it is symbolic that the year 2021, a jubilee year for the Joint Institute for Nuclear Research, was declared by RF President V. Putin the Year of Science and Technology.

At the November session of the Committee of Plenipotentiaries of JINR, the leadership of the Institute was transferred to new young and talented candidates. Academician G. Trubnikov was elected JINR Director. By the decision of the CP, Academician V. Matveev became JINR Scientific Leader. Thus, we doubled our forces and the Institute received an impetus for further development with the support of the Government of the Russian Federation and JINR Member States to bring to life the ambitious strategy of development that was worked out by leading specialists.

Anticipating the upcoming 65th jubilee of the Institute, I would like to express my confidence that no obstacles will prevent us to celebrate this date with our colleagues and friends in JINR Member States and partner states.

V. MATVEEV
Director
Joint Institute for Nuclear Research

2020

GOVERNING AND ADVISORY BODIES OF JINR

ACTIVITIES OF JINR GOVERNING AND ADVISORY BODIES

SESSIONS OF THE JINR COMMITTEE OF PLENIPOTENTIARIES

A regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States was held on 19 June by videoconference. It was chaired by the Plenipotentiary of the Government of the Russian Federation, V. Falkov.

Having heard and discussed the report presented by JINR Director V. Matveev, the CP took note of the information about the actions by the JINR Directorate to ensure JINR activities under conditions of the pandemic of the COVID-19 coronavirus infection, of the decisions on the mode of JINR's operation set for the period of suspension of scientific and educational activities at the Institute as well as on health protection measures for the staff. The CP noted the efforts being made by the JINR Directorate towards gradual resumption of JINR activities in full, along with careful monitoring of the epidemiological situation.

The CP endorsed the work carried out by the International Working Group on the preparation of a single, integrated draft of the Strategic Plan for the Long-Term Development of JINR, supported the recommendation of the Scientific Council for considering the presented draft as a basis, and commissioned the JINR Directorate to continue work on strategic planning towards developing the Seven-Year Plan for the Development of JINR for 2024–2030 taking into account the opinions of the Member States and defining precisely their participation in major research projects and the required human and material resources.

The CP took note of the brief overview of the development of the scientific programmes of JINR's major research infrastructure facilities: the NICA complex, the Factory of Superheavy Elements, the Baikal-GVD project, the IBR-2 reactor with its spectrometer complex, and the Multifunctional Information and Computing Complex.

The CP endorsed the measures taken to implement the recommendations of the Committee for the analysis of the expenditure and schedule for implementing the NICA complex project.

Based on the information on the execution of the JINR budget for 2019, the CP approved the consolidated final adjustment of the budget income and expenditure.

The CP took note of the information on the approval of the revised budget of JINR for 2020 with the total income and expenditure amounting to US$ 277 538.4 thousand. It allowed the JINR Director to introduce adjustments to the JINR budget in 2020, including those to the expenditure items "Salaries" and "International cooperation", within the approved budget in accordance with the Regulations for the Introduction of Adjustments to the JINR budget.

The CP supported the proposals of the JINR Directorate on ensuring a competitive level of remuneration for JINR's highly qualified staff and wished to be informed about the efficiency of using the Incentive Fund for highly qualified staff.

Following the report "Selection of an organization for auditing JINR's financial activities for 2019" presented by JINR Vice-Director R. Lednický, the CP approved, on an exceptional basis in the current year, the audit company LLC AC "Korsakov and Partners" for auditing JINR's financial activities for 2019 and identified the LLC "MS Audit" (Dubna) as a backup company. The CP approved the plan for auditing

JINR's financial activities for 2019 presented by the JINR Directorate.

Having heard the report "Draft Staff Regulations of JINR" by A. Ruzaev, Deputy Director of JINR for Human Resources, the CP approved the Staff Regulations of JINR enacting them from the date of taking this decision.

Having heard the report "Endorsement of appointments of Vice-Directors of JINR" presented by JINR Director V. Matveev, the CP took note of the information about the endorsement of appointments of First Vice-Director G. Trubnikov, Vice-Directors S. Dmitriev and B. Sharkov until the completion of the term of office of the JINR Director on 31 December 2021 as well as on the issuance of JINR's Order No. 233 of 20 April 2020 "On the terms of office of the JINR Directorate members". The CP expressed gratitude to M. Itkis for his many years of work as a member of the JINR Directorate, for his enormous contributions to the activities of JINR and to the development of international scientific cooperation.

Having heard and discussed the information "Calling of the election and nomination of candidates for the position of Director of JINR" presented by CP Chair V. Falkov and JINR Director V. Matveev, the CP called the election of the JINR Director for the CP session in November 2020; it also commissioned the JINR Directorate to prepare for this session proposals on instituting the position of Scientific Leader of JINR, his status and powers.

Having heard the report "Establishment of the Prize of the JINR Committee of Plenipotentiaries of the Governments of the JINR Member States" presented by A. Sorin, Chief Scientific Secretary of JINR, the CP accepted the proposal by the JINR Directorate to establish this prize "For initiating, developing, and implementing large-scale projects at JINR completed to the highest international standards and requirements". The JINR CP Prize is intended to stimulate creative teams of JINR staff and their partners in Member States for major achievements in the development of research infrastructure which open fundamentally new opportunities for conducting world-class scientific research.

Taking into account the report by the JINR Directorate on implementing the tasks of the Seven-Year Plan for the Development of JINR for 2019 and the statement of the JINR CP dated 25 March 2019, in which the CP noted the successful completion of the major stage in the construction of a unique accelerator complex aimed at obtaining breakthrough results in the field of the synthesis of new superheavy elements and in which the CP appreciated highly the scientific and technological quality of the realization of the project to build the DC-280 cyclotron and the participation in it of most JINR Member States, also taking into account the obtaining of all the licenses necessary for conducting experiments, the CP conferred the JINR CP Prize upon the JINR team headed by FLNR Scientific Leader Yu. Oganessian.

Following the report "Changes in the membership of the JINR Scientific Council" presented by A. Sorin, Chief Scientific Secretary of JINR, the CP elected A. Aprahamian (University of Notre Dame, USA) as a new member of the JINR Scientific Council.

Based on the information "Resumption of the full membership of the Republic of Uzbekistan in JINR" presented by B. Yuldashev, Plenipotentiary of the Government of the Republic of Uzbekistan, the CP expressed readiness to resume full participation of the Republic of Uzbekistan in the activities of JINR. It commissioned the Working Group under the CP Chair for JINR Financial Issues together with the Plenipotentiary of the Government of the Republic of Uzbekistan and the JINR Directorate to work out the financial conditions for renewing the full participation of the Republic of Uzbekistan in the activities of JINR.

A regular session of the Committee of Plenipotentiaries of the Governments of JINR Member States was held on 23 November in the videoconference format under the chairmanship of the representative of the Russian Federation N. Bocharova.

Having heard and discussed the report presented by V. Matveev, Director of JINR, the Committee of Plenipotentiaries took note of the information by the JINR Directorate on the operation of JINR under conditions of the COVID-19 pandemic, on the recommendations of the 128th session of the JINR Scientific Council, on the new scientific and technological results obtained at JINR as well as on the most important events which occurred at JINR in the second half of 2020.

The CP noted with satisfaction the significant achievements of the JINR staff in developing JINR facilities and producing new scientific results, in particular:

— the pace of work on the construction of the NICA collider systems, the completion of the installation of equipment for the fast beam extraction from the booster, the preparation for the start of cooling of the magnetic structure as well as the plans to inject and accelerate the first beam in the new synchrotron by the end of November 2020;

— the completion of the operation to transport to JINR the superconducting magnet made in Italy, which is a key element of the MPD detector of the NICA accelerator complex;

— development and application, by the international collaboration established at JINR, of a new experimental method to study the internal structure of the atomic nucleus and neutron stars in the BM@N experiment, which made it possible for the first time to register all the reaction products upon knocking out nucleons and pairs of nucleons from atomic nuclei and to open up new scientific prospects for studying nuclear structure;

— the beginning of the first experiment on the synthesis of moscovium isotopes at the Factory of Superheavy Elements;

— the victory of the JINR project "Superheavy nuclei and atoms: Limits of nuclear mass and boundaries of the Periodic Table" in the competition of the Ministry of Science and Higher Education of the Russian Federation for awarding grants in the form of subsidies for realizing large scientific projects in the priority areas of scientific and technological development of Russia;

— the installation of two new clusters of the Baikal Neutrino Telescope, whose deep-water detector has reached an effective volume of 0.35 km^3, thus making Baikal-GVD one of the world's three largest telescopes in terms of effective area and volume as well as the largest in the Northern Hemisphere;

— the further implementation of the User Programme at the IBR-2 facility under conditions of the COVID-19 pandemic;

— the impressive statistics on the use of JINR grid sites contributing to data processing by international collaborations — the Tier1 site, which ranks second among the world CMS Tier1, and the Tier2 site, the best in RDIG (Russian Data Intensive Grid) as well as the publication of scientific results achieved using the "Govorun" supercomputer resources.

The CP supported the organizational measures being taken by the JINR Directorate for the successful implementation of the NICA project and endorsed the amendments to the Regulations for the Supervisory Board of the project "NICA complex of superconducting rings for heavy-ion colliding beams" regarding the procedure for forming the composition of the Supervisory Board, determining the status and powers of an observer, and the procedure for holding meetings and voting.

The CP endorsed the efforts by the JINR Directorate to deepen relations with partner research organizations and to integrate JINR into the global research infrastructure, in particular, the signing of agreements with the Helmholtz Centre for Heavy Ion Research (GSI, Germany) on the entry of German research institutions into the implementation of the NICA project and with the Ministry of Science and Technology of the Peoples' Republic of China (PRC) on the PRC's participation in construction and operation of the NICA complex.

The CP endorsed the activities of the JINR Directorate for the development and comprehensive discussion of the main directions of the strategic plan for the development of JINR, including work on the development of a system of indicators for monitoring the implementation of the strategic plan.

The CP approved the recommendations of the 127th and 128th sessions of the Scientific Council and the JINR Topical Plan of Research and International Cooperation for 2021.

Having heard and discussed the report "Election of the Director of JINR" presented by N. Bocharova, Chair of the CP, guided by the CP's decision of 19 June 2020 on the calling of the election of the Director of JINR for November 2020, to hold, at this CP session, the election of a new Director of JINR on the basis of the early termination of office of the current Director from 1 January 2021 in accordance with paragraph 2.1 of the Regulations for the JINR Director, the CP approved Grigory Trubnikov as candidate for the position of the Director of JINR. The CP endorsed the programme presented by the candidate for the position of the Director of JINR, G. Trubnikov. The CP conducted the election of the JINR Director by secret ballot using the software and technical tools of a videoconference. The CP elected G. Trubnikov as Director of JINR for a term of five years taking office on 1 January 2021.

The CP expressed profound gratitude to Academician of the Russian Academy of Sciences V. Matveev for his successful work as Director of JINR.

The CP adopted the terms of office of the Vice-Directors of JINR, the Chief Scientific Secretary of JINR, and the JINR Chief Engineer until 1 January 2021 and recommended that the newly elected Director appoint acting members of the JINR Directorate from 1 January 2021. The CP commissionned the Director to propose, for approval at the CP session in March 2021, the candidatures of JINR Vice-Directors, Chief Scientific Secretary, and Chief Engineer.

Having heard and discussed the report "On the Scientific Leader of JINR" presented by N. Bocharova, Chair of the CP, the Committee of Plenipotentiaries introduced the position of JINR Scientific Leader for RAS Academician V. Matveev and recommended that the newly elected Director of JINR carry out the corresponding appointment.

Having heard and discussed the report "Progress of implementation of the Seven-Year Plan for the Development of JINR for 2017–2023 and proposals for updating the Plan" presented by A. Sorin, Chief Scientific Secretary of JINR, the Committee of Plenipotentiaries endorsed the efforts by the JINR Directorate to provide a detailed analysis of the progress of implementation of the Seven-Year Plan for the Development of JINR for 2017–2023 as well as to propose its updating.

The CP appreciated the prepared Brief Report on the Progress of the Current Seven-Year Plan for the Development of JINR over 2017–2020 and proposals for its updating for 2021–2023.

The CP noted with satisfaction the work accomplished by the JINR Directorate and staff to implement the Seven-Year Plan for the Development of JINR over 2017–2020 in the main areas of JINR activities, namely:

— a large volume of work performed on the implementation of the NICA Complex project in the current seven-year period, including within the framework of the Agreement between the Government of the Russian Federation and JINR;

— the successful progress of work at the SHE Factory, in particular, the achievement of the design parameters of the Factory's facility — the DC-280 cyclotron and of the new gas-filled separator, GFS-2, and the beginning of first experiments on the synthesis of element 115 (moscovium) in the reaction $^{243}\mathrm{Am} + {}^{48}\mathrm{Ca}$;

— the significant progress with the Baikal-GVD gigaton neutrino telescope;

— the ongoing major activities for further development of the IBR-2 facility and the full implementation of pre-design work on a new neutron source of JINR;

— the integration of computing resources of the HybriLIT platform, including the "Govorun" supercomputer, into the distributed data processing environment;

— the development of radiobiological research;

— the implementation of training programmes; efforts to attract students to research underway at JINR as well as to raise staff qualifications and promote science popularization.

The CP took into account the objectively necessary development of the NICA project in accordance with the recommendations of the scientific advisory committees (MAC, DAC, PAC, Scientific Council) and the decisions of the Supervisory Board of the megaproject "NICA Complex", the new regulations on construction that required a significant change in the building design to accommodate the NICA heavy-ion collider and the corresponding infrastructure complications as well as took into account the adverse external circumstances associated with COVID-19, which affected the cost and timing of the project, and admitted the necessity to sign an additional agreement No. 5 to the general contract with STRABAG JSC (contract No. 100/2795 dated 18 September 2015 for construction of buildings and structures (permanent construction facilities) for the placement of the NICA heavy-ion collider at the JINR VBLHEP site in Dubna with a partial reconstruction of building No. 1) with an increase in the cost of the contract in accordance with the new project documentation, which received a positive conclusion from the Federal Autonomous Institution "GlavGosEkspertiza of Russia" No. 50-1-1-3-007355-2019 in the USRZ dated 3 April 2019; took note of the estimated increase in the total project value of US$ 61.7 million; agreed with the adjustment of the commissioning dates for the main facilities of the NICA complex presented in the project: booster — 2020; initial configuration of the collider — 2022–2023; collider design configuration — 2025; development of experimental zones and channels for NICA complex extracted beams — 2021, launch of the first stage of the MPD facility — 2022, commissioning of the second stage of the MPD facility — 2025, commissioning of the initial configuration of the SPD detector — the date will be determined after the project's approval.

The CP supported the proposal by the JINR Directorate to organize, in 2021–2023, work on the establishment at JINR of an interlaboratory international Innovation Centre for Nuclear Physics Research (Innovation Centre), the main tasks of which will be development of technologies and methods in the field of nuclear and radiation medicine, radiation materials science as well as training of professional personnel and advanced training of specialists of JINR Member States in the field of radiation biology and medical physics. Taking into account the prospects for the development of technologies for radiation materials science and applied research with heavy-ion beams for JINR Member States, within the framework of the Innovation Centre programme, the CP supported development of a DC-140 accelerator-cyclotron in the period 2021–2023 and requestd the Directorate to present a project for the establishment of this Innovation Centre at the CP session in November 2021.

The CP endorsed in general the directions proposed by the Directorate for updating the Seven-Year Plan for the Development of JINR in terms of implementing the JINR major projects and requested the final version of the updated Seven-Year Plan to be presented at the CP session in March 2021.

Having heard and discussed the report "Draft budget of JINR for the year 2021, provisional contributions of the Member States for the years 2022, 2023, and 2024" presented by M. Vasilyev, Acting Head of the JINR Finance and Economy Office, the Committee of Plenipotentiaries approved the JINR budget for the year 2021 with the total income and expenditure amounting to US$ 223 811.4 thousand.

The CP allowed the JINR Director in 2021 to introduce adjustments to the JINR budget, including adjustments to the expenditure items "Salaries" and "International cooperation", within the approved budget in accordance with the Regulations for the introduction of adjustments to the JINR budget.

The CP approved the scale of contributions of the JINR Member States for the year 2021 and agreed with the inclusion in the JINR budget for 2021 of the amounts of contributions of the Member States, with respect to which the decision on suspension of memberships had been taken, in order to preserve the established proportions of contributions of the Member States.

The CP approved the contributions of the Member States for the year 2021 and the repayment of contribution arrears of Member States in 2021.

The CP determined the provisional volumes of the JINR budget in income and expenditure for the year 2022 amounting to US$ 217.4 million, for the year 2023 amounting to US$ 222.8 million, for the year 2024 amounting to US$ 228.4 million, as well as the provisional amounts of the Member States' contributions for the years 2022, 2023, and 2024.

The CP resolved to compensate JINR's budget deficit in 2021, arising from the unpaid contribution by the Democratic People's Republic of Korea, at the expense of other incomes and receipts of the JINR budget.

The CP approved the budget for the use of the special-purpose funds of the Russian Federation, allocated in accordance with the Agreement between the Government of the Russian Federation and JINR on the construction and exploitation of the NICA complex of superconducting rings for heavy-ion colliding beams, for the year 2021 in the amount of 3 787 442.7 thousand rubles.

The CP approved the consolidated adjustment of the JINR budget for the year 2020 over 9 months and allowed the JINR Director to index the salary and tariff parts of the compensation package of the staff members, taking into account the possibilities afforded by the JINR budget in 2021, in accordance with the JINR Collective Bargaining Agreement for 2020–2023.

The CP approved the directions for using the Incentive Fund in 2021, proposed by the JINR Directorate. The CP requested the Plenipotentiaries to consolidate funds for financing the grants of Plenipotentiaries and programmes of cooperation between JINR and scientific organizations and universities of JINR Member States on the main scientific projects implemented at JINR.

Having heard and discussed the report "Results of the meeting of the JINR Finance Committee held on 19 November 2020" presented by A. Khvedelidze, Chair of the Finance Committee, the Committee of Plenipotentiaries approved the Protocol of the meeting of the Finance Committee and commissioned the Working Group under the CP Chair for JINR Financial Issues and the JINR Directorate to analyse the use of the rule of lower limits for contributions used in calculating Member States' contributions, to prepare proposals to clarify the method of calculating the lower limits for contributions and to submit them for consideration to the Finance Committee meeting and the CP session in March 2021.

Having heard and discussed the report "Resumption of the full membership of the Republic of Uzbekistan in JINR" presented by B. Yuldashev, Plenipotentiary of the Government of the Republic of Uzbekistan and President of the Academy of Sciences of the Republic of Uzbekistan, the Committee of Plenipotentiaries resolved to resume, from 1 January 2021, the full participation of the Republic of Uzbekistan in the activities of JINR and to write off the current arrears of contributions of the Republic of Uzbekistan to the JINR budget for the period

GOVERNING AND ADVISORY BODIES OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

COMMITTEE OF PLENIPOTENTIARIES OF THE GOVERNMENTS OF THE JINR MEMBER STATES

Republic of Armenia	– S. Harutyunyan
Republic of Azerbaijan	– N. Timur oglu Mamedov
Republic of Belarus	– A. Shumilin
Republic of Bulgaria	– L. Kostov
Republic of Cuba	– A. Diaz García
Czech Republic	– M. Vyšinka
Georgia	– A. Khvedelidze
Republic of Kazakhstan	– E. Kenzhin
Democratic People's Republic of Korea	– Li Je Sen
Republic of Moldova	– V. Ursachi
Mongolia	– S. Davaa
Republic of Poland	– M. Waligórski
Romania	– F.-D. Buzatu
Russian Federation	– V. Falkov
Slovak Republic	– S. Dubnička
Ukraine	– B. Grynyov
Republic of Uzbekistan	– B. Yuldashev
Socialist Republic of Vietnam	– Le Hong Khiem

Finance Committee

One representative
of each JINR Member State

SCIENTIFIC COUNCIL

Chairman: V. Matveev
Co-Chairman: C. Borcea (Romania)
Scientific Secretary: A. Sorin

A. Aprahamian	– United States of America
F. Azaiez	– Republic of South Africa
Ts. Baatar	– Mongolia
U. Bassler	– Switzerland
C. Borcea	– Romania
M. Budzyński	– Republic of Poland
Bum-Hoon Lee	– Republic of Korea
L. Cifarelli	– Italian Republic
A. Dubničková	– Slovak Republic
A.-I. Etienvre	– French Republic
P. Fré	– Italian Republic
S. Galès	– French Republic
P. Giubellino	– Federal Republic of Germany
B. Grynyov	– Ukraine
M. Hnatič	– Slovak Republic
M. Jeźabek	– Republic of Poland
Jiangang Li	– People's Republic of China
G. Khuukhenkhuu	– Mongolia
S. Kilin	– Republic of Belarus
M. Kovalchuk	– Russian Federation
G. Lavrelashvili	– Georgia
P. Logatchov	– Russian Federation
A. Maggiora	– Italian Republic
S. Maksimenko	– Republic of Belarus
S. Maskevich	– Republic of Belarus
V. Matveev	– Russian Federation
J. Mnich	– Federal Republic of Germany
Sh. Nagiyev	– Republic of Azerbaijan
D. L. Nagy	– Republic of Hungary
N. Nešković	– Republic of Serbia
I. Padrón Díaz	– Republic of Cuba
G. Poghosyan	– Republic of Armenia
S. Pospišil	– Czech Republic
I. Povar	– Republic of Moldova
E. Rabinovici	– State of Israel
V. Rubakov	– Russian Federation
K. Rusek	– Republic of Poland
V. Sadovnichy	– Russian Federation
A. Sergeev	– Russian Federation
M. Spiro	– French Republic
H. Stöcker	– Federal Republic of Germany
Ch. Stoyanov	– Republic of Bulgaria
Gh. Stratan	– Romania
Tran Duc Thiep	– Socialist Republic of Vietnam
R. Tsenov	– Republic of Bulgaria
M. Waligórski	– Republic of Poland
I. Wilhelm	– Czech Republic
B. Yuldashev	– Republic of Uzbekistan
M. Zdorovets	– Republic of Kazakhstan
G. Zinovjev	– Ukraine

Programme Advisory Committee for Particle Physics

Chairperson: I. Tserruya (Israel)
Scientific Secretary: A. Cheplakov

Programme Advisory Committee for Nuclear Physics

Chairperson: M. Lewitowicz (France)
Scientific Secretary: N. Skobelev

Programme Advisory Committee for Condensed Matter Physics

Chairperson: D. L. Nagy (Hungary)
Scientific Secretary: O. Belov

INTERNAL ORGANIZATION OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

DIRECTORATE

Director V. Matveev
First Vice-Director G. Trubnikov
Vice-Director S. Dmitriev
Vice-Director V. Kekelidze
Vice-Director R. Lednický
Vice-Director B. Sharkov
Chief Scientific Secretary A. Sorin
Chief Engineer B. Gikal

Bogoliubov Laboratory of Theoretical Physics

Director D. Kazakov

Research in
- **symmetry properties of elementary particles**
- **field theory structures**
- **interactions of elementary particles**
- **theory of atomic nuclei**
- **theory of condensed matter**

Frank Laboratory of Neutron Physics

Director V. Shvetsov

Research in
- **nuclei by neutron spectroscopy methods**
- **fundamental properties of neutrons**
- **atomic structure and dynamics of solids and liquids**
- **high-temperature superconductivity**
- **reactions on light nuclei**
- **materials by neutron scattering, neutron activation analysis and neutron radiography methods**
- **dynamic characteristics of the pulsed reactor IBR-2**

Veksler and Baldin Laboratory of High Energy Physics

Director V. Kekelidze

Research in
- **structure of nucleons**
- **strong interactions of particles**
- **resonance phenomena in particle interactions**
- **electromagnetic interactions**
- **relativistic nuclear physics**
- **particle acceleration techniques**
- **interactions of multicharged ions in a wide energy range**

Laboratory of Information Technologies

Director V. Korenkov

Research in
- **provision of operation and development of the JINR computing and networking infrastructure**
- **optimal usage of international computer networks and information systems**
- **modern methods of computer physics, development of standard software**

Dzhelepov Laboratory of Nuclear Problems

Director V. Bednyakov

Research in
- **strong, weak and electromagnetic interactions of particles, particle structure**
- **nuclear structure**
- **nuclear spectroscopy**
- **mesoatomic and mesomolecular processes**
- **particle acceleration techniques**
- **radiobiology**

Laboratory of Radiation Biology

Director A. Bugai

Research in
- **radiation genetics and radiobiology**
- **photo radiobiology**
- **astrobiology**
- **radiation protection physics**
- **mathematical simulation of radiation-induced effects**

Flerov Laboratory of Nuclear Reactions

Director S. Sidorchuk

Research in
- **properties of heavy elements, fusion and fission of complex nuclei, cluster radioactivity, reactions on an isomer hafnium target**
- **reactions with beams of radioactive nuclei, structure of neutron-rich light nuclei, nonequilibrium processes**
- **interactions of heavy ions with condensed matter**
- **particle acceleration techniques**

University Centre

Director S. Pakuliak

Directions of activities:
- **education programme for senior students**
- **preparation of qualification papers by students and postgraduates**
- **holding international student practice courses and schools**
- **popularization of achievements in modern science**
- **advanced training of the Institute personnel**

Central Services

- **central scientific and information departments**
- **administrative and economic units**
- **manufacturing units**

from 1 January 2004 to 30 September 2020 in the amount of US$ 3271.1 thousand (60% of the current arrears) and to approve the schedule of repayment of the remaining part of the current arrears of the Republic of Uzbekistan to the JINR budget in the amount of US$ 2180.8 thousand.

The CP commissioned the Working Group under the CP Chair for JINR Financial Issues together with the Plenipotentiary of the Government of the Republic of Uzbekistan and the JINR Directorate to consider the issue of repayment of the restructured arrears of the Republic of Uzbekistan that arose before 1 January 2002 in the amount of US$ 1051.7 thousand and the arrears that arose for 2002–2003 in the amount of US$ 1081.8 thousand, and submit proposals for consideration at the Finance Committee meeting and the CP session in November 2021.

Having heard and discussed the report "Results of the audit of JINR's financial activities performed for the year 2019" presented by D. Korsakov, Director of the audit company "Korsakov and Partners", the Committee of Plenipotentiaries approved the auditors' report and the Accounting Report of JINR for the year 2019 taking note of the Plan of measures on the follow-up of the audit of JINR's financial activities of the year 2019, prepared by the JINR Directorate.

The Committee of Plenipotentiaries welcomed the initiative of the Plenipotentiary of the Government of the Republic of Bulgaria, L. Kostov, to declare 2021 as the Year of Bulgaria at JINR and presented a detailed plan of events to be held in Bulgaria and at JINR at the next CP session in March 2021.

SESSIONS OF THE JINR SCIENTIFIC COUNCIL

The 127th session of the JINR Scientific Council took place on 20–21 February. It was chaired by JINR Director V. Matveev and Professor C. Borcea of the H. Hulubei National Institute of Physics and Nuclear Engineering (Bucharest, Romania).

V. Matveev delivered a comprehensive report covering the highlights of the year 2019 for JINR, the decisions of the latest session of the JINR Committee of Plenipotentiaries in Hanoi, Vietnam (November 2019), the current state of the JINR priority research programmes, the activities in the area of human resources training and staff qualification raising at JINR as well as recent events in JINR's international cooperation.

The Scientific Council heard reports concerning progress in implementing the Seven-Year Plan for the Development of JINR for 2017–2023 in its major sections, presented by JINR Acting Vice-Director and VBLHEP Director V. Kekelidze (NICA project), by JINR Vice-Director R. Lednický (particle physics), by JINR Vice-Director M. Itkis (nuclear physics), and by JINR Vice-Director B. Sharkov (condensed matter physics, radiation biology).

The recommendations of the Programme Advisory Committees were reported by I. Tserruya (PAC for Particle Physics), M. Lewitowicz (PAC for Nuclear Physics), and D. L. Nagy (PAC for Condensed Matter Physics).

The Scientific Council heard the scientific report "International Year of Basic Sciences for Development in 2022: Status and Prospect" presented by M. Spiro (France).

The Scientific Council approved the recommendations of the juries on the award of the N. Bogoliubov Prize and of the B. Pontecorvo Prize, also on the award of the JINR annual prizes for best papers in the fields of scientific research, methodology, research and technology, and applied research.

Election of the Director of FLNR and endorsement of the appointment of Deputy Directors of LRB were held at the session. The vacancies of positions of Deputy Directors of FLNR were announced.

General Considerations of the Resolution. Following the report by JINR Director V. Matveev, the Scientific Council congratulated JINR on its active participation in the key events of the International Year of the Periodic Table of Chemical Elements, which ended with the IYPT Closing Ceremony in Tokyo on 5 December 2019. The achievements presented by JINR within the IYPT emphasized the leading role of this Institute in the synthesis and study of properties of new superheavy elements.

The Scientific Council noted with satisfaction the commissioning and the successful technological start-up of the Booster of the NICA complex, which took place on 23 December 2019, and the ongoing work on the installation of the superconducting MPD magnet in the NICA collider hall.

The Scientific Council welcomed the new agreements on joint activities on the NICA project signed with five Polish and five Mexican research centres and universities as well as the updated JINR–GSI Cooperation Agreement on German participation in the NICA project signed by the partners during the Helmholtz Winter Readings in Moscow on 6 February 2020.

The Scientific Council congratulated the leaders of the NICA project: I. Meshkov on his election as Full Member of the Russian Academy of Sciences (RAS) and V. Kekelidze on his election as Corresponding Member of RAS.

The Scientific Council appreciated the commissioning, in 2019, of five photodetector clusters within the Baikal-GVD project — the largest deep-water neutrino telescope in the Northern Hemisphere with an effective volume of 0.25 km^3 as well as the plans for installing two additional clusters with 576 optical modules in 2020. The Scientific Council welcomed the coordination, by the Russian Ministry of Science and Higher Education, of the cooperation within the Baikal-GVD project between JINR and the Institute for Nuclear Research of the Russian Academy of Sciences.

The Scientific Council recognized the significant progress achieved in developing the concept of a new neutron source at JINR as well as FLNP's activities on continued upgrade and development of the IBR-2 facility, its cryogenic moderators and spectrometers. It also noted the successful implementation of the FLNP User Programme at the IBR-2 spectrometer complex, which provides a wide range of options for research in condensed matter physics and related fields.

The Scientific Council endorsed the agreement signed between JINR and the Rosatom State Atomic Energy Corporation on partnership interactions in some aspects of implementing large projects, including development of the NICA collider complex and of the Factory of Superheavy Elements, exploitation of the IBR-2 reactor, and development of JINR's new neutron source.

The Scientific Council appreciated the constant attention being paid by the JINR Directorate to human resources training and staff qualification raising: the beginning of operation of new dissertation councils at JINR on the basis of its right to independently confer academic degrees and the defence of three PhD theses, the beginning of operation of the JINR Distinguished Postdoctoral Research Fellowship Programme and one year of operation of the Dubna School of Engineering on the basis of the Cooperation Agreement between JINR, Dubna State University and Bauman Moscow State Technological University with support of the Moscow Region Government.

The Scientific Council welcomed the efforts being made by the JINR Directorate towards ensuring a competitive level of salaries for JINR's qualified scientists, engineers and specialists.

The Scientific Council noted the recent achievements in strengthening JINR's international cooperation. These include the ongoing process of restoration of the full membership of the Republic of Uzbekistan in JINR, the signing of the JINR–Serbia Roadmap for Cooperation, the ongoing implementation of the JINR–BMBF Joint Declaration of Intent, the negotiations held with JINR's participation within two recent meetings of the Group of Senior Officials on Global Research Infrastructures and on BRICS Research Infrastructures.

Implementation of the Seven-Year Plan for the Development of JINR for 2017–2023 and Proposals of Updates to the Plan. The Scientific Council took note of the reports concerning progress in implementing the Seven-Year Plan for the Development of JINR for 2017–2023. The speakers also presented their proposals for updates to the Plan which concern, in particular:

— the schedules for completion and start of operation of the main elements of the NICA complex;

— the Neutrino Programme (challenge of increasing the effective volume of the Baikal-GVD detector to 0.45 km^3);

— R&D for a new experimental hall (1st class) for chemistry of superheavy elements and a project for a new separator;

— the topics "Neutron and optical methods of research" related to the Plan's section "Condensed Matter Physics";

— work on the project "Precision laser metrology for accelerators and detector complexes";

— further development of the Multifunctional Information and Computing Complex.

The Scientific Council endorsed these proposals. At its future sessions, it looks forward to being informed about further progress in implementing the Seven-Year Plan and its updates, suggesting that the format of these presentations should be modified in the future to leave more room for discussion.

Draft Strategic Plan for the Long-Term Development of JINR. The Scientific Council took note of the report of the International Working Group on the draft of the Strategic Plan for the Development of JINR presented by

JINR Director V. Matveev and JINR Vice-Director B. Sharkov. The Scientific Council expressed gratitude to the Working Group for the preparation of a single, integrated document based on the deep analysis of materials presented by the thematic subgroups describing the overall strategy with its flagship projects and partnership priorities. The Scientific Council suggested that the Working Group should take into account the comments and proposals made during the discussion at this session.

The Scientific Council recommended that the JINR Committee of Plenipotentiaries consider the presented draft as a basis and asked the JINR Directorate to continue work on strategic planning towards developing the Seven-Year Plan for 2024–2030 taking into account the opinion of the Member States and defining precisely their participation in major research projects and the required human and material resources.

Initiative of IUPAP. The Scientific Council took note with interest of the report "International Year of Basic Sciences for Development in 2022: Status and Prospect" presented by M. Spiro, President of the International Union of Pure and Applied Physics (IUPAP) and member of the JINR Scientific Council.

The proposal for the International Year was developed by IUPAP, with the encouragement and support of UNESCO, the International Science Council and its many members and partner institutions, including the International Union of Pure and Applied Chemistry. The Scientific Council recommended that JINR actively support this initiative.

Recommendations in Connection with the PACs. The Scientific Council supported the recommendations made by the PACs at their meetings in January–February 2020, as reported at this session by I. Tserruya, Chair of the PAC for Particle Physics, M. Lewitowicz, Chair of the PAC for Nuclear Physics, and D. L. Nagy, Chair of the PAC for Condensed Matter Physics. The Scientific Council requested the JINR Directorate to consider these recommendations while preparing the JINR Topical Plan of Research and International Cooperation for the year 2021.

Particle Physics. Noting with satisfaction the installation of the magnets of the Booster synchrotron in the ring and the beginning of commissioning work, the Scientific Council supported the active preparatory work for starting the collider assembly: test of the RF1 system and progress in the serial production of the collider magnets. It appreciated the openness of the report on the infrastructure developments at VBLHEP, pointing out sources of delay in civil construction and suggesting the need to revise procurement procedures.

The Scientific Council welcomed the efforts of the MPD collaboration to develop the detector elements with a view to completing the first stage of the detector construction and commissioning by 2021. It appreciated the ongoing efforts of the BM@N team toward completion of the experimental set-up for the heavy-ion run in 2021.

The Scientific Council appreciated the progress made by the JINR group in fulfilling its obligations in the ATLAS upgrade project, in particular, the continuation of mass production of the MicroMegas chambers for the New Small Wheel of the Muon spectrometer. It joined the PAC in reiterating its recommendation to the JINR Directorate to consider unifying the two projects, one devoted to physics analysis and operation and the other focused on detector upgrade and R&D, into a single one. The Scientific Council endorsed the PAC's recommendation on continuation of the ATLAS project for the period 2021–2023 with first priority.

The Scientific Council appreciated the efforts of the JINR team in the ALICE experiment in physics analysis concerning the photoproduction of light vector mesons in ultraperipheral Pb–Pb collisions and, for the first time, the identical charged kaon femtoscopic correlations in p–Pb collisions at the energy of $\sqrt{s_{NN}} = 5.02$ TeV. Noting the group's contribution to the maintenance and development of the GRID-ALICE analysis at JINR and to the photon spectrometer upgrade, the Scientific Council encouraged further increase of these efforts and supported the PAC's request that the group submit at the next PAC meeting a detailed plan of its future activities with milestones.

The Scientific Council took note of the contribution of the JINR group in the CMS experiment to the search for extra gauge bosons and extra dimensions in the dimuon channel as well as the recent results on searches for extra Higgs bosons decaying into pairs of b-quarks and muons. It commended the work carried out by the group in the Phase 1 upgrade project, in the operation of the Tier1 and Tier2 computer centres as well as in the CMS Regional Operation Centre.

The Scientific Council noted with pleasure that the action plan previously requested from the participants of the NA64 experiment to improve the ratio of FTE to participants, to attract students and to get involved in data analysis, was satisfactorily addressed in their revised proposal. The Scientific Council endorsed the PAC's recommendation to continue JINR's participation in the NA64 project for 2021–2023 with first priority.

The Scientific Council noted that the revised proposal of the FASA experiment had not answered the criticism raised at the previous PAC meeting. The authors have not convinced the PAC that FASA is a detector capable of resolving the open questions of the multifragmentation process. Furthermore, the FASA detector has limited capability in measuring the full event in 4π geometry. The Scientific Council seconded the PAC's recommendation to reject the FASA project.

Recognizing the scientific merit of the charged-lepton flavor violation processes as probes for new physics, the Scientific Council appreciated JINR contributions to the experiments Mu2e, MEG-II and COMET. The Scientific Council concurred with the PAC that participation in three different experiments with very similar scientific goals and competing with each other was not fully justified. It supported the PAC's proposal to focus effort and resources on one single experiment and recommended approval of the project with the three experiments for only one year.

Nuclear Physics. The Scientific Council noted that the Frank Laboratory of Neutron Physics has good prospects for further development of scientific work in the following areas: research of quantum-mechanic phenomena with ultracold and cold neutrons, study of properties of the neutron, study of nuclear reactions induced by neutrons, and applied research using nuclear physics methods under the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron". The Scientific Council recommended that the priorities of this theme be better focused. In particular, special attention should be given to the development of key technologies for the new neutron source.

The Scientific Council appreciated the development of activities related to IREN and encouraged an active use of the extracted beams for both basic and applied research in order to make more efficient use of the facility's operating time.

The Scientific Council concurred with the PAC that work on modernization of the EG-5 accelerator at FLNP is important. In preparing a full proposal for this project, expected accelerator specifications should be clearly identified in accordance with the priorities of expanding the research programme. Also, two options should be carefully compared: modernization of the present EG-5 accelerator or purchase of a new accelerator, taking into account the risk associated with the proposed upgrade.

The main goal of the FLNR Factory of Superheavy Elements in 2019 was to commission the DC-280 cyclotron, including obtaining all necessary permits for work and the production of heavy-ion beams within the design parameters. The operation of the DC-280 cyclotron was officially started on 25 March 2019. Beams of ^{12}C, ^{40}Ar, ^{48}Ca, and ^{84}Kr with intensities of a few particle microamperes (pμA) were extracted. In particular, the intensity of accelerated ^{48}Ca ions exceeded 5 pμA. The acceleration efficiency reached 51%.

The installation and commissioning of the new gas-filled separator GFS-2 was completed; test experiments were conducted with beams of ^{40}Ar and ^{48}Ca which were delivered to GFS-2 situated in the experimental hall. The experiments showed excellent background event suppression. Experiments with ^{48}Ca beams and targets of ^{nat}Yb, ^{174}Yb, ^{170}Er, and ^{206}Pb were carried out; the main goal was to determine the separator's transmission and target stability when irradiated with high-intensity heavy-ion beams. Synthesis of Mc isotopes in the ^{48}Ca + ^{243}Am reaction will be the first test reaction for the production of superheavy nuclei. The Scientific Council recommended that the FLNR Directorate complete the test experiments as soon as possible and start implementation of the experimental programme at the SHE Factory.

The observation of nuclei produced in multinucleon transfer (MNT) reactions with proton numbers up to $Z = 102$ at the separators SHIP (GSI) and SHELS (FLNR, JINR) showed that these reactions could be considered as an alternative pathway to extend the nuclear chart towards the heaviest neutron-rich nuclei. The Scientific Council expects that investigations of MNT reactions will highly benefit from the upgrade of the U400 cyclotron complex, where it is planned to produce also a uranium beam of sufficient intensity.

Condensed Matter Physics. The Scientific Council was pleased with the progress in developing the concept of DNS-IV — the future neutron source for JINR. Two alternative concepts of DNS-IV were considered in detail by the PAC for Condensed Matter Physics: a pulsed neutron reactor IBR-3 with ^{237}Np core and an accelerator-driven spallation neutron source with PuO_2 core providing a neutron multiplication factor of about 20–50. Both options had been the subject of a feasibility study at the N. A. Dollezhal Research and Development Institute of Power Engineering (Moscow). The final recommendation made within this study and based on such criteria as achievable neutron characteristics, nuclear safety, engineering complexity, timeline and estimated costs is to choose the option of the pulsed neutron reactor IBR-3 with NpN fuel. This option was selected as the working concept for further development of DNS-IV, and a detailed roadmap was developed by FLNP to implement DNS-IV.

At the same time, the Scientific Council shared the PAC's concern about the background levels of the new facility and drew attention to the crucial importance of achieving background values at IBR-3 and its instruments corresponding to the world-best practice.

The Scientific Council also took note of the beginning of JINR's cooperation with the A. A. Bochvar High-Technology Research Institute of Inorganic Materials (Moscow) aimed at developing a roadmap for fabrication of NpN reactor fuel.

The Scientific Council appreciated the wealth of scientific results and new instrumentation developments in the field of condensed matter physics at IBR-2 in 2019. It concurred with the PAC that the activities focused on the upgrade of the IBR-2 instruments were important for providing competitive opportunities for realization of the FLNP scientific programme to the external users and for expanding the research areas.

The Scientific Council welcomed the regular follow-up by the PAC of the inelastic neutron scattering research at IBR-2, also the presentation of analytical reports to the PAC on the current trends in neutron spectroscopy worldwide and on the status of inelastic neutron scattering spectroscopy at FLNP. The Scientific Council took note of the PAC's conclusion that the two reviewed spectrometers no longer satisfy the requirements of some users. In this regard, the Scientific Council supported the preparatory work towards opening the new project of developing a new inelastic neutron scattering spectrometer and expects that a detailed proposal for this new project will be presented at a future PAC meeting.

The Scientific Council took note of the information about the development of a neutron radiography and tomography facility at the WWR-K reactor of the Institute of Nuclear Physics in Almaty (Kazakhstan) in collaboration with FLNP, and the results of this activity. It shared the PAC's recommendation on the beginning of implementation of the proposed research programme.

Noting the successful completion of the project "Development of an open information and educational environment to support research priorities in material science and structure of matter", the Scientific Council supported the PAC's recommendation on the opening of a new project "Open information and educational environment for supporting fundamental and applied multidisciplinary research at JINR" for 2021–2023 within the theme "Organization, Support and Development of the JINR Human Resources Programme". Given the potential of the new project, the Scientific Council believes that its implementation will help attract a new generation of scientists to the JINR research teams.

Common Issues. The Scientific Council strongly supported the recommendation of the PAC for Nuclear Physics that all proposals for new projects and requests for extension of themes or projects contain full information on required financial and human resources and a SWOT analysis.

Reports by Young Scientists. The Scientific Council followed with interest the reports by young scientists, selected by the PACs for presentation at this session: "Real-time detection of supernova neutrino signal", "Study of No isotopes with the GABRIELA array", and "Neutron activation analysis as a tool for tracing the accumulation of silver nanoparticles in tissues of female mice and their offspring", and thanked the respective speakers: A. Sheshukov (DLNP), A. Kuznetsova (FLNR), and I. Zinicovscaia (FLNP). The Scientific Council welcomes such selected reports in future.

Awards. The Scientific Council supported the proposal by JINR Director V. Matveev to nominate the team of staff of the Flerov Laboratory of Nuclear Reactions under the leadership of Yu. Oganessian for the Prize of the JINR Committee of Plenipotentiaries for the idea, development and successful realization of the project of the accelerator complex of the Factory of Superheavy Elements as a major achievement in building JINR's world-class research infrastructure, which opens unique opportunities for promoting one of the main areas of the JINR research programme — the synthesis and study of properties of new superheavy elements.

The Scientific Council approved the Jury's recommendations presented by JINR Director

V. Matveev on the award of the N. Bogoliubov Prize:

— to D. Kazakov (JINR) for his outstanding contributions to the development of quantum field theory, renormalization theory and renormalization group revealing the renormalization properties of supersymmetric field theories; for his pioneering papers on multiloop calculations in quantum field theory;

— to Dam Thanh Son (Kadanoff Center for Theoretical Physics, University of Chicago, USA) for his achievements in the fields of quantum chromodynamics, applications of string theory and gauge/gravity duality addressing basic questions in strongly interacting many-body systems; for his pioneering papers on transport coefficients, such as viscosity and conductivity, and on strongly coupled three-dimensional gauge theories.

The Scientific Council approved the recommendations of the Jury presented by its Chair, A. Olshevskiy, on the award of the B. Pontecorvo Prize to F. Gianotti (CERN) for her leading contributions to the experimental studies of fundamental interactions and to the discovery of the Higgs boson.

The Scientific Council approved the Jury's recommendations presented by JINR Vice-Director B. Sharkov on the award of JINR annual prizes for best papers in the fields of scientific research, methodology, research and technology, and applied research.

The Scientific Council congratulated Ts. Tsogtsaikhan, staff member of FLNP from Mongolia, on his successful defence of his PhD thesis in physics and mathematics at JINR and on the award of the first PhD Diploma issued on the basis of JINR's right to independently confer academic degrees.

Election, Endorsement, and Announcement of Vacancies in the Directorates of JINR Laboratories. The Scientific Council elected S. Sidorchuk as Director of the Flerov Laboratory of Nuclear Reactions (FLNR) for a term of five years. The Scientific Council thanked S. Dmitriev for his successful tenure as Director of this Laboratory.

The Scientific Council announced the vacancies of positions of FLNR Deputy Directors. The endorsement of appointments will take place at the next session of the Scientific Council in September 2020.

The Scientific Council endorsed the appointment of A. Boreyko and A. Chizhov as Deputy Directors of the Laboratory of Radiation Biology (LRB), until the completion of the term of office of LRB Director A. Bugay.

Rules of Procedure of the Scientific Council. The Scientific Council discussed the amendments proposed by the Working Group of its members, R. Tsenov, M. Waligórski, and I. Wilhelm, to the Regulations for the Election of Directors and for the Endorsement of Appointments of Deputy Directors of JINR Laboratories, which are part of the Rules of Procedure of the JINR Scientific Council, and decided to continue the consideration of the Draft Regulations together with the JINR Directorate at the next session.

The 128th session of the JINR Scientific Council took place by videoconference on 17 September. It was chaired by JINR Director V. Matveev and Professor C. Borcea of the H. Hulubei National Institute of Physics and Nuclear Engineering (Bucharest, Romania).

V. Matveev delivered a comprehensive report covering information about JINR's operation during the COVID-19 pandemic, the decisions of the latest session of the JINR Committee of Plenipotentiaries held by videoconference in June 2020, recent achievements in science and technology in the main areas of JINR activities as well as recent events in JINR's cooperation with its partner institutions and organizations.

The recommendations of the Programme Advisory Committees were reported by I. Tserruya (PAC for Particle Physics), M. Lewitowicz (PAC for Nuclear Physics), and D. L. Nagy (PAC for Condensed Matter Physics).

The Scientific Council approved the Jury's recommendation on the award of the V. Dzhelepov Prize.

The endorsement of appointments of FLNR Deputy Directors was held at the session.

General Considerations of the Resolution. Following the report by JINR Director V. Matveev, the Scientific Council appreciated the efforts being made by the JINR Directorate to ensure the stable operation of JINR under conditions of the COVID-19 pandemic and of health protection measures for the staff and visitors.

The Scientific Council recognized recent achievements in implementing and developing JINR's major facilities, in particular:

— the progress achieved in constructing the NICA megascience complex including a unique technological accomplishment accompanied by obtaining the first scientific results, the regular functioning of the Supervisory Board of the

NICA Complex Project and its Cost and Schedule Review Committee, the signing of several dedicated agreements on cooperation between JINR and the Helmholtz Centre for Heavy Ion Research (GSI, Germany), the Federal Ministry of Education and Research (BMBF, Germany), and the Ministry of Science and Technology of the People's Republic of China;

— the full readiness of the DC-280 accelerator for the start of Day-1 experiment, including preparing the americium-243 target, obtaining a calcium-48 beam of high intensity, and performing a series of test experiments as well as launching a new cross-laboratory project of FLNR, LIT and BLTP entitled "Superheavy nuclei and atoms: Limits of nuclear mass and boundaries of the Periodic Table" and supported by the Russian Ministry of Science and Higher Education within a grant competition for realizing large-scale research projects in the priority fields of scientific and technological development;

— the increased effective volume of the Baikal-GVD detector, which reached 0.35 km^3 after the installation of two new clusters in February–April 2020, and the continuous development of the entire Neutrino Programme of JINR with its new results obtained in the experiments with JINR's participation;

— the further development of the User Programme for the IBR-2 spectrometers and the efforts being made by FLNP to meet the user needs by updating the IBR-2 working schedule, which was shifted due to the COVID-19 lockdown period;

— the progress in development of the Multifunctional Information and Computing Complex, including the recent integration, through the DIRAC Interware, of JINR's major computing resources: Tier1 and Tier2 grid components, the "Govorun" supercomputer, the NICA cluster, the cluster of the National Autonomous University of Mexico, and JINR storage resources.

The Scientific Council welcomed the new initiatives in the cooperation format between JINR and BMBF, which will focus on three key fields, each regulated by its steering committee: Heisenberg–Landau Programme, Neutron Programme, and Young Scientists Programme. The Scientific Council also noted a series of events and meetings held within cooperation with Azerbaijan, France, Russia, Serbia, South Africa as well as with CERN.

The Scientific Council commended the efforts being made by JINR Directorate to ensure the competitive level of remuneration for JINR's highly qualified staff by establishing an Incentive Fund and developing the corresponding Regulations for its use.

The Scientific Council welcomed the preparation by the JINR Directorate of a plan of activities for the year 2021 dedicated to the celebration of the 65th anniversary of JINR (26 March 2021) both at JINR and in Member States.

Recommendations in Connection with the PACs. The Scientific Council took note of the recommendations made by the PACs at their meetings in June–July 2020, as reported at this session by I. Tserruya, Chair of the PAC for Particle Physics, M. Lewitowicz, Chair of the PAC for Nuclear Physics, and D. L. Nagy, Chair of the PAC for Condensed Matter Physics. The Scientific Council requested the JINR Directorate to consider these recommendations while preparing the JINR Topical Plan of Research and International Cooperation for the year 2021.

Particle Physics. The Scientific Council was pleased to note that despite the difficult pandemic situation, the Nuclotron–NICA project including the VBLHEP infrastructure developments advanced well and, basically, at the necessary pace. In particular, in spite of a two-month delay, the tests of the main Booster systems were completed and preparation work for launching the Booster synchrotron was started. The Scientific Council seconded the concern of the PAC for Particle Physics with the lack of sufficient manpower for the collider magnet construction and tests, and urged the JINR management to take the necessary steps to address this issue that otherwise could seriously impact the overall schedule of the NICA project. The Scientific Council endorsed the PAC's request that the Nuclotron maximum energy of 4.5 GeV/nucleon should be available as soon as possible.

The Scientific Council appreciated the efforts of the BM@N team on upgrading the detector for the heavy-ion physics runs planned for 2021 and beyond and on completion of the analysis of short-range correlations of nucleon pairs in inverse kinematic reactions measured at the Nuclotron.

The Scientific Council welcomed the steady progress in the assembly and production of most of the MPD detector components foreseen in the first-stage configuration as well as in the production of the Inner Tracking System. At the same time, the Scientific Council shared the PAC's concern regarding the delay in the ECAL construction and the resulting impact on the physics programme, with only half of the coverage foreseen now at the first stage while the second half is expected at a later stage. The Scientific Council appreciated the ongoing Monte Carlo simulations of the detector and physics processes in preparation for the first beams in MPD and welcomed the plans to intensify these efforts. The Scientific Council supported the PAC's recommendation on extension of the MPD project until the end of 2025 with first priority.

The Scientific Council encouraged the JINR team in the COMPASS experiment to enhance its participation in the data analysis and develop collaborative work for the physics exploitation of the data in order to secure scientific recognition of the group's two-decade-long work in COMPASS. By the project completion in 2022, the group should explore new opportunities like, e.g., MPD and SPD where its experience is certainly very much needed. The Scientific Council endorsed the PAC's recommendation concerning extension of the COMPASS-II project until the end of 2022 with first priority.

The Scientific Council recognized that the TAIGA project has a solid in-house component with significant international participation. The JINR group is playing an important role in the TAIGA collaboration for the design and production of the IACTs, but its participation in the data analysis should be strengthened. Publication of the methodological results obtained by the group should be carried out more actively. The Scientific Council endorsed the PAC's recommendation on extension of the TAIGA project until the end of 2023 with first priority.

The Scientific Council appreciated the high quality of the work performed by the JINR group in the Daya Bay and JUNO experiments. The contributions of the JINR group to both experiments made in many important systems of the detectors are acknowledged and imprinted in the structure of the collaboration management. The Scientific Council supported the plans of the JINR team in the data analysis of the Daya Bay experiment and in the development, construction and commissioning of the JUNO project. The Scientific Council endorsed the PAC's recommendation to continue the participation in the JUNO project until the end of 2023 with first priority.

The Scientific Council, taking into account the visible role of the JINR group in the NOvA experiment and its solid plans for further advances in forefront neutrino physics research with the DUNE experiment, supported the PAC's recommendation on continuation of NOvA and approval of the group's participation in DUNE, both until 2023 with first priority. It also supported the PAC's proposal to the JINR Directorate to provide the necessary resources to the DUNE project in order to guarantee visible participation of the JINR group and to encourage the group to play the role of bridgehead for the future joining of more groups associated with JINR.

Nuclear Physics. The Scientific Council commended the progress of work on the Factory of Superheavy Elements (SHE Factory) reviewed by the PAC for Nuclear Physics. At present, the "flat-top" system at the DC-280 cyclotron has been tested, leading to further increase in the efficiency of production of heavy-ion beams. A differential pumping system is being constructed at the GFS-2 gas-filled separator to accept the highest possible ion current produced by DC-280. All previously scheduled test experiments have been completed. The first experiment to produce moscovium isotopes in the $^{48}Ca + ^{243}Am$ reaction at the SHE Factory has been prepared. The americium target has been installed and tested.

The Scientific Council supported the PAC's recommendations on the concluding theme "Improvement of the JINR Phasotron and Design of Cyclotrons for Fundamental and Applied Research". As a result of the upgrade of the Phasotron and its beam lines, a stable operation of the accelerator was ensured for an average of 1000 hours per year, of which about 80% was used for medical research. Research under the theme was focused mostly on developing and improving cyclotrons used in hadron therapy. The most important activities were carried out in collaboration with the Institute of Nuclear Physics, Polish Academy of Sciences (Kraków, Poland) on the modernization of the conventional IAC-144 cyclotron and with the Institute of Plasma Physics of the Chinese Academy of Sciences (Hefei, PRC) on the design and manufacture of the SC200 superconducting isochronous cyclotron for proton therapy. A design of the SC230 compact superconducting cyclotron with smaller dimensions and the required magnetic field level was developed by the team.

The Scientific Council concurred with the PAC's recommendation that the DLNP Directorate should consider continuing the studies planned by the team in the field of development, construction and upgrade of cyclotrons under one of the themes of this Laboratory. The Scientific Council recommended that the JINR Directorate make soon a decision on the Biomedical Research Centre with dedicated proton accelerator and JINR contribution to the future medical complex for proton therapy.

The Scientific Council noted the importance of the EG-5 accelerator for JINR and its Member States, which requires a modernization of the existing accelerator or a purchase of a new one with similar design parameters. In the opinion of the PAC, the most cost-effective solution is the modernization of this accelerator. The Scientific Council supported the PAC's recommendation on the preparation and opening of a project to modernize the existing accelerator and associated experimental infrastructure activities under the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron" with financing from the budget of the current Seven-Year Plan for the Development of JINR, starting in 2021.

The Scientific Council supported the recommendation on the opening of the new project "Measurement of ordinary muon capture for testing nuclear matrix elements of 2β decays (project MONUMENT)" for 2021–2023 with first priority. This project is aimed at carrying out experimental measurements of muon capture at several daughter candidates for 2β decay nuclei. Obtained results would have high importance for checking the accuracy of theoretical calculations of nuclear matrix elements. The measurements of muon capture will be carried out at the meson factory of the Paul Scherrer Institute (PSI) in Switzerland.

Condensed Matter Physics. The Scientific Council noted the results achieved in the technical design of the IBR-3 reactor to be a new neutron source of JINR as well as the beginning of JINR's cooperation with the potential fuel manufacturer. Presently, the technical requirements for the next stage of designing the new neutron source — development of the Technical Proposal — have been identified and the contract for this work is being prepared.

The Scientific Council welcomed the continuous efforts in experimental studying and modelling of the neutron background at the spectrometers of the IBR-2 reactor as well as in search for means of suppressing the backgrounds at its extracted beams. The Scientific Council supported the recommendation of the PAC for Condensed Matter Physics towards deeper elaboration of the IBR-3 technical proposal and continuation of the FLNP activities on studying and suppressing neutron background at the IBR-2 spectrometers.

The Scientific Council took note of the recent developments regarding the joint facility for structural research using synchrotron X-rays at the SOLARIS National Synchrotron Radiation Centre and agreed with the PAC that these JINR–SOLARIS collaborative efforts in building the SOLCRYS laboratory would extend the range of condensed matter research approaches at JINR. The Scientific Council shared the PAC's opinion that close attention should be paid to the design details of the SOLCRYS laboratory.

The Scientific Council supported the PAC's recommendations on themes and projects previously approved for completion in 2020 as well as on new themes and projects. These recommendations concern:

— closure of the theme "Investigations of Condensed Matter by Modern Neutron Scattering Methods" and opening of a new theme "Investigations of Functional Materials and Nanosystems Using Neutron Scattering" for 2021–2025 with a new project "Development of inverse geometry inelastic neutron scattering spectrometer at the IBR-2 reactor" for 2021–2023;

— closure of the theme "Development of Experimental Facilities for Condensed Matter Investigations with Beams of the IBR-2 Facility" and opening of a new theme "Scientific and Methodological Research and Developments for Condensed Matter Investigations with IBR-2 Neutron Beams" for 2021–2025; closure of the BSD and PTH projects and opening of a new project of this theme "Construction of a wide-aperture backscattering detector (BSD) for the HRFD diffractometer" for 2021–2023;

— closure of the project "A system for neutron operando monitoring and diagnostics of materials and interfaces for electrochemical energy storage devices at the IBR-2 reactor";

— extension of the theme "Modern Trends and Developments in Raman Microspectroscopy and Photoluminescence for Condensed Matter Studies" for 2021–2023; closure of the Nanobiophotonics project and opening of the Biophotonics project for 2021–2023;

— extension of the theme and project "Novel Semiconductor Detectors for Fundamental and Applied Research" for 2021–2023 and of the PAS project for 2021–2023;

— opening of the new project "Study of the radioprotective properties of the Damage Suppressor (Dsup) protein on a model organism *D. melanogaster* and human cell culture HEK293T" for 2021–2022 within the theme "Biomedical and Radiation-Genetic Studies Using Different Types of Ionizing Radiation";

— extension of the theme and project "Research on the Biological Effect of Heavy Charged Particles with Different Energies" for 2021–2023.

The Scientific Council welcomed further continuation of activities within the theme "Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data" which was positively reviewed by the PAC.

Endorsement of Appointments of FLNR Deputy Directors. The Scientific Council endorsed the appointment of G. Kamiński and A. Yeremin as Deputy Directors of the Flerov Laboratory of Nuclear Reactions (FLNR), until the completion of the term of office of FLNR Director S. Sidorchuk.

Awards and Prizes. The Scientific Council approved the proposal by JINR Director V. Matveev to award the title "Honorary Doctor of JINR" to M. Spiro (France), I. Tserruya (Israel), and I. Wilhelm (Czech Republic), in recognition of their outstanding contributions to the advancement of science and the education of young scientists.

The Scientific Council approved the recommendation of the Jury presented by its member, V. Shvetsov, on the award of the V. Dzhelepov Prize to E. Shabalin (FLNP, JINR) for the development and construction of the world's unique heterogeneous cryogenic neutron moderator at IBR-2.

MEETING OF THE JINR FINANCE COMMITTEE

A regular meeting of the Finance Committee was held on 19 November in the format of a videoconference under the chairmanship of the representative of Georgia A. Khvedelidze.

The Finance Committee heard the report of the Director of the Institute V. Matveev and recommended that the CP note the successful implementation of the recommendations of the JINR Scientific Council on scientific tasks of the Institute and activities in development and upgrading of JINR basic facilities; support the activities of the JINR Directorate in provision of implementation of tasks of the current Seven-Year Plan of JINR Development; highly evaluate scientific and scientific-technical achievements of the Institute in the main trends of research; note and endorse the amendments in the Regulations of the Supervisory Board of the project "The NICA Complex for superconducting rings at heavy-ion colliding beams" on establishing the strength of the Supervisory Board, determination of the status and authority of an observer, the order of holding meetings and voting; note the development of a new format of cooperation of JINR with BMBF (Germany) in the framework of three autonomous directions: the Heisenberg–Landau Programme in theoretical physics, Neutron Programme and Young Scientists Programme; take note of the activities of JINR Directorate in drafting the plan of events on the 65th anniversary of the Institute (26 March 2021), at JINR and in Member States.

Concerning the report of the JINR Chief Scientific Secretary A. Sorin "Progress of implementation of the Seven-Year Plan for the Development of JINR for 2017–2023 and proposals for updating the Plan", the Finance Committee recommended the CP that it highly evaluate the prepared Brief Report on the progress in accomplishment of the current plan of JINR development in 2017–2020 and proposals on its upgrading in 2021–2023, as well as endorse the efforts of the JINR Directorate in implementation of tasks of the current seven-year period in development of large parts of scientific research infrastructure and note a great number of outstanding scientific results and scientific-technical elaborations in 2017–2020.

Taking into account the development of the NICA project in accordance with the recommendations of the scientific advisory committees (MAC, DAC, PAC, Scientific Council) and the decisions of the Supervisory Board of the megaproject "NICA Complex", the new regulations on construction that required a significant change in the building design to accommodate the NICA heavy-ion collider and the corresponding infrastructure complications as well as taking into account the adverse external circumstances associated with COVID-19, which affected the cost and timing of the project, the Finance Committee recommended that the CP note the calculated enlargement of the total cost of the NICA project by US$ 61.7 million.

The Finance Committee recommended that the CP endorse the proposed directions of upgrading of the Seven-Year Plan and recommended the JINR Directorate that it present the final variant of the upgraded Seven-Year Plan of the JINR development at the CP session in March 2021.

Regarding the report "Draft budget of JINR for the year 2021, provisional contributions of the Member States for the years 2022, 2023, and 2024" presented by M. Vasilyev, Acting Head of the JINR Finance and Economy Office, the Finance Committee recommended that the CP approve the JINR budget for the year 2021 with the total income and expenditure amounting to US$ 223 811.4 thousand, approve the scale of contributions of the JINR Member States for the year 2021, the contributions of the Member States and the repayment of contribution arrears of Member States in 2021 in payment of contributions to JINR budget, as well as agree with the inclusion in the JINR budget for 2021 of the amounts of contributions of the Member States, with respect to which the decision on suspension of memberships has been taken, in order to preserve the established proportions of contributions of the Member States. The Finance Committee recommended that the CP determine the provisional volumes of the JINR budget in income and expenditure for the year 2022 amounting to US$ 217.4 million, for the year 2023 amounting to US$ 222.8 million, for the year 2024 amounting to US$ 228.4 million, as well as the provisional amounts of the Member States' contributions for the years 2022, 2023, and 2024.

The Finance Committee recommended that the CP compensate JINR's budget deficit in 2021, arising from the unpaid contribution by the Democratic People's Republic of Korea and the Republic of Uzbekistan, at the expense of other incomes and receipts of the JINR budget.

The Finance Committee recommended that the CP approve the budget for the use of the special-purpose funds of the Russian Federation, allocated in accordance with the Agreement between the Government of the Russian Federation and JINR on the construction and exploitation of the NICA complex of superconducting rings for heavy-ion colliding beams, for the year 2021 in the amount of 3 787 442.7 thousand rubles.

The Finance Committee recommended that the CP approve the consolidated adjustment of the JINR budget for the year 2020 over 9 months.

The Finance Committee recommended that the CP allow the JINR Director to index the salary and tariff parts of the compensation package of the staff members, taking into account the possibilities afforded by the JINR budget in 2021, in accordance with the JINR Collective Bargaining Agreement for 2020–2023 and approve the directions for using the Incentive Fund in 2021, proposed by the JINR Directorate.

Regarding the report "Results of the meeting of the Working Group under the CP Chair for JINR Financial Issues held on 29 October 2020" presented by A. Khvedelidze, Plenipotentiary of the Government of Georgia to JINR, the Finance Committee recommended that the CP agree with the proposal of the Government of the Republic of Uzbekistan and discuss a possibility to resume its full participation in 2021 on the following conditions:

— the Republic of Uzbekistan pays a part of arrear to the JINR budget in the amount of US$ 30.0 thousand before the CP session in November 2020;

— the CP writes off the current arrears of contributions of the Republic of Uzbekistan to the JINR budget for the period from 1 January 2004 to 30 September 2020 in the amount of US$ 3 271.1 thousand (60% of the current arrears);

— the Republic of Uzbekistan pays the remaining part of the current arrears of the Republic of Uzbekistan to the JINR budget in the amount of US$ 2 180.8 thousand in 20 years according to the schedule endorsed at the CP session in November 2020;

— after assuming the full participation to JINR, the Republic of Uzbekistan will pay the annual contribution to the JINR budget in amount approved by the CP.

The Finance Committee recommended that the CP discuss the issue of repayment of the restructured arrears of the Republic of Uzbekistan that arose before 1 January 2002 in the amount of US$ 1 051.7 thousand and the arrears that arose for 2002–2003 in the amount of US$ 1 081.8 thousand, after the full participation of the Republic of Uzbekistan to JINR.

Regarding the report "Results of the audit of JINR's financial activities performed for the year 2019 and analysis of implementation by the Directorate of the Institute of the Plan of Activities on the results of the audit of financial activities of JINR in 2018" presented by D. Korsakov, Director of the audit company "Korsakov and Partners", the Finance Committee recommended that the CP approve the auditors' report and the Accounting Report of JINR for the year 2019.

MEETINGS OF THE JINR PROGRAMME ADVISORY COMMITTEES

The 51st meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 20–21 January. It was chaired by Professor D. L. Nagy.

The Chair of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting. JINR Vice-Director B. Sharkov informed the PAC about the Resolution of the 126th session of the JINR Scientific Council (September 2019) and about the decisions of the JINR Committee of Plenipotentiaries (November 2019).

The PAC heard a progress report on developing the concept of a new neutron source at FLNP presented by V. Shvetsov. The PAC noted the results of consideration of two alternative concepts of DNS-IV: a pulsed neutron reactor IBR-3 with ^{237}Np core and an accelerator-driven spallation neutron source with PuO_2 core providing a neutron multiplication factor of about 20–50. Both options had been under a feasibility study at the N. A. Dollezhal Research and Development Institute of Power Engineering (Moscow). The final recommendation made within this study was based on such criteria as achievable neutron characteristics, nuclear safety, engineering complexity, timeline and estimated costs. According to this recommendation, the pulsed neutron reactor IBR-3 with NpN fuel was selected as the working concept for development of DNS-IV. The PAC congratulated the FLNP Directorate on determining the working concept of the new neutron source and recommended its deeper elaboration.

The PAC noted the beginning of JINR's cooperation with the A. A. Bochvar High-Technology Research Institute of Inorganic Materials (Moscow) aimed at developing a roadmap for fabrication of NpN reactor fuel as well as welcomed the detailed roadmap for the DNS-IV implementation presented at the meeting.

The PAC was informed by D. Kozlenko about the main results of instrumentation developments and scientific research in the field of condensed matter physics at the IBR-2 reactor in 2019. The PAC considered the activities focused on the upgrade of the IBR-2 instruments to be important for providing competitive research opportunities to the external users and for expanding the research areas. The PAC appreciated the demonstrated examples of the new scientific results and instrumentation developments at IBR-2 achieved in 2019.

The PAC recommended that the authors of future reports on new instrumentation developments at IBR-2 be explicit on possible threats and difficulties of the development or upgrade of each particular facility under consideration. The demands of the respective user community for a particular instrument should be clearly justified and the relevance to corresponding tasks of the current Seven-Year Plan for the Development of JINR should be reflected in presentations.

The PAC heard information presented by D. Chudoba on the statistics of the FLNP User Programme at the IBR-2 spectrometers. It supported further developing the FLNP User Programme, including the neutron activation analysis facility, and recommended considering a possibility of changing the application submitting period for the second round.

The PAC heard reports presented by W. Zając and D. Chudoba on the current trends in neutron spectroscopy and on the status of inelastic neutron scattering spectroscopy at FLNP. It noted that the two spectrometers mentioned in the reports no longer satisfied the requirements of users. The PAC took note of the progress of work for opening the new project of developing a new inelastic neutron scattering spectrometer for 2021–2023 and supported this intention. The PAC expects a detailed proposal for this new project to be presented at the next meeting.

The PAC heard a report presented by K. Nazarov on developing a neutron radiography and tomography facility at the WWR-K reactor of the Institute of Nuclear Physics in Almaty (Kazakhstan) in collaboration with FLNP. The PAC took note of the description of the main components of the experimental set-up and of the results of the first test experiments, and recommended following up with the implementation of the proposed research programme.

The PAC considered the report presented by Yu. Panebrattsev on the completed project "Development of an open information and educational environment to support research priorities in material science and structure of matter" and the proposal for opening a new project "Open information and educational environment for supporting fundamental and applied multidisciplinary research at JINR". The PAC noted the results of the completed project which include, in particular, the creation of a system of online courses in the main fields of JINR research and the implementation of the megascience projects. Given the potential of the new project, the PAC considered that it could attract a new generation of scientists to the JINR research teams. In view of the successful implementation of the concluded project, the PAC recommended its closing and opening the new one for implementation in 2021–2023.

The PAC heard with interest the following scientific reports: “Microscopic mechanism of the spontaneous polarization in strontium hexaferrites”, “Ultrasensitive detection of analyte molecules at attomolar concentration by Raman spectroscopy”, “Superconductor spintronics based on Josephson nanostructures”, “TEM examination of the ceramics irradiated with heavy ions of fission fragment energies” and “Structural modification of carbon materials by swift heavy ions” and thanked the speakers V. Turchenko, G. Arzumanyan, Yu. Shukrinov, V. Skuratov, and A. Olejniczak for their excellent presentations.

The PAC took note of the information about the international conference “Radiobiological Basis of Radiation Therapy” (17–18 October 2019, Dubna) presented by I. Koshlan.

The PAC reviewed 15 poster presentations made by young scientists in condensed matter physics and related fields. The poster “Neutron activation analysis as a tool for tracing the accumulation of silver nanoparticles in tissues of female mice and their offspring” by I. Zinicovscaia was selected as the best poster at the session. The PAC noted two other high-quality posters: “Synthesis and research of magnetic nanoparticles of the “core-shell” type for bioapplications” by A. Nazarova and “Investigation of the internal structure and atomic dynamics of pharmaceutical compounds under the influence of high pressure” by N. Belozerova.

The 51st meeting of the Programme Advisory Committee for Nuclear Physics was held on 30–31 January. It was chaired by Professor M. Lewitowicz.

The Chair of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting. JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 126th session of the Scientific Council (September 2019) and about the decisions of the Committee of Plenipotentiaries (November 2019).

The PAC heard a report on the theme “Investigations of Neutron Nuclear Interactions and Properties of the Neutron” presented by E. Lychagin. This report covered the results obtained in recent months and the prospects for further development of scientific work in the various areas: research of quantum-mechanical phenomena with ultracold and cold neutrons, study of properties of the neutron, study of nuclear reactions induced by neutrons, and applied research using nuclear physics methods. The PAC noted that the research areas within the framework of this theme were developing successfully, and the scientific programme for the period 2020–2022 is broad and relevant. At the same time, the PAC recommended that priorities of this theme be better focused, with particular emphasis on the development of key technologies for a new neutron source. The PAC encouraged an active use of the IREN extracted beams for both basic and applied research.

The PAC heard a report on the plans for modernization of the EG-5 accelerator, presented by A. Doroshkevich. The PAC considered the work on the modernization of the accelerator to be very important for maintaining and developing the scientific potential of FLNP as well as for expanding the field of scientific investigations. The PAC recommended presenting a full proposal of the project for EG-5, comparing carefully two options: modernization of the present EG-5 accelerator or purchase of a new accelerator taking into account the risk associated with the proposed upgrade.

The PAC heard a proposal for opening a new project BECQUEREL presented by P. Zarubin. Despite the fact that studies of nuclear fragmentation using nuclear emulsions have a very long history, this method still keeps promising opportunities. After a lengthy discussion the PAC recommended that a renewed project proposal be presented at the PAC meeting in January 2021.

The PAC heard reports on the status and plans for the Factory of Superheavy Elements (SHE Factory) presented by V. Semin (DC-280 cyclotron) and V. Utyonkov (GFS-2 separator).

The main goal in 2019 was to commission the DC-280 cyclotron, including the approval of all necessary permits for work and the production of heavy-ion beams within the design parameters. To date, beams of ^{12}C, ^{40}Ar, ^{48}Ca, and ^{84}Kr with intensities of a few particle microamperes (pμA) have been extracted. The installation and commissioning of the new gas-filled separator (GFS-2) was completed. A series of test experiments for the optimization of the parameters of the separator was conducted with alpha particles and the $^{\rm nat}$Yb(^{40}Ar, xn)$^{207-212}$Ra reaction products. The experiments showed excellent background event suppression, and experiments with ^{48}Ca beams and targets of $^{\rm nat}$Yb, ^{174}Yb, ^{170}Er, and ^{206}Pb were carried out. The synthesis of Mc isotopes in the ^{48}Ca + ^{243}Am reaction will be the first test reaction for the production of superheavy nuclei.

The PAC recommended that FLNR complete the test experiments as soon as possible and start implementing the experimental programme at the SHE Factory.

The PAC heard the report “Prospects of investigation of multinucleon transfer reactions” presented by A. Yeremin, concerning the current status and prospects of studying the structure of heavy nuclei produced in multinucleon transfer (MNT) reactions. Observation of isotopes with proton numbers up to $Z = 102$ at the SHIP (GSI) and SHELS (FLNR, JINR) separators have shown that MNT reactions can be considered as an alternative pathway to extend the nuclear chart towards the heaviest neutron-rich nuclei. The PAC noted that, along with the study of new isotopes, the exploration of the MNT-reaction mechanism is of great importance, and strongly supported the development of a specialized set-up dedicated to a comprehensive study of such a mechanism. The PAC recommended presenting as soon as possible a detailed project of a new set-up aimed at measuring features of the MNT reactions and their heavy products.

The PAC heard the scientific reports “Fusion reactions in nuclear astrophysics” presented by V. Sargsyan and “Investigation of prompt neutrons from fission induced by resonance neutrons” presented by Sh. Zeynalov.

The PAC reviewed 13 poster presentations in the field of nuclear physics research by young scientists from FLNR. The best posters selected were “Study of No isotopes with the GABRIELA array” presented by A. Kuznetsova, “Effective method of excitation function measurement for (α, n) reactions at low energies” presented by E. Gazeeva, and “Data acquisition and control systems developed for the synthesis of superheavy elements at the experimental set-up GFS-2” presented by L. Schlattauer. The poster “Study of No isotopes with the GABRIELA array” was recommended for presentation at the session of the Scientific Council in February 2020.

The 52nd meeting of the Programme Advisory Committee for Particle Physics took place on 3–4 February. It was chaired by Professor I. Tserruya.

The Chair of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting. JINR Vice-Director R. Lednický informed the PAC about the Resolution of the 126th session of the JINR Scientific Council and about the decisions of the JINR Committee of Plenipotentiaries.

The PAC took note of the reports concerning the current preparation of the draft of the Strategic Plan for the long-term development of JINR in its major sections, and in particular those related to particle physics, heavy-ion physics and spin physics, presented by B. Sharkov and D. Naumov. The PAC looks forward to being informed about the final version of the Strategic Plan.

The PAC heard with interest the report on the progress towards realization of the Nuclotron–NICA project presented by A. Sidorin. The PAC was pleased to note that all the magnets of the Booster synchrotron had been installed in the ring, that commissioning work had started, and active preparatory work was underway for starting the collider assembly.

The PAC appreciated the openness of the report on the infrastructure developments at VBLHEP presented by N. Agapov, pointing out at sources of delay in civil construction and suggesting the need to revise procurement procedures.

The PAC took note of the reports on the progress towards realization of the BM@N and MPD projects presented by M. Kapishin and A. Kisiel, and welcomed the collaborations' efforts to develop the detector elements and complete construction of the detectors.

The PAC took note of the upgrade plans of the ATLAS detector presented by A. Cheplakov. The PAC appreciated the progress made by the JINR group in continuation of mass production of the MicroMegas chambers for the New Small Wheel of the Muon spectrometer and the contribution to the development of readout electronics for the liquid argon hadronic calorimeter. At the same time, the PAC is concerned that the JINR ATLAS team is split into two groups, a hardware group and an analysis team. The PAC recommended continuation of JINR's participation in the ATLAS upgrade project for the period 2021–2023 with first priority, reiterating its recommendation made at its previous meeting to consider unifying the two JINR ATLAS projects, one devoted to physics analysis and operations and the other focused on detector upgrade and R&D, into a single one.

The PAC heard with interest the revised proposal of the NA64 experiment presented by D. Peshekhonov and recommended continuation of JINR's participation in the NA64 project for the period 2021–2023 with first priority. The PAC was pleased to note that the action plan previously requested from the authors to improve the ratio of FTE to participants, to attract students and to get involved in data analysis, was satisfactorily addressed.

The PAC took note of the proposal for the FASA experiment presented by S. Avdeev and adjusted for the criticism expressed at the previous meeting. The PAC recommended rejection of the FASA project since the authors had not provided convincing arguments that FASA was a detector capable of resolving the open question of the multifragmentation process.

The PAC heard with interest the proposal of a new project "Search for new physics in the charged lepton sector" which includes three experiments: Mu2e and MEG-II presented by V. Glagolev and COMET presented by Z. Tsamalaidze. The PAC recognized the scientific merit of the charged-lepton flavor violation processes as probes for new physics; however, it considers that participation in three different experiments with very similar scientific goals and competing with each other is not fully justified. The PAC proposed that effort and resources be focused on one single experiment, thus providing better conditions for the JINR team to achieve stronger impact, visibility and leadership in that experiment. Realizing the complexity associated with such a decision, the PAC recommended approval of the project with the three experiments for only one year. This should allow enough time for the proponents, in coordination with the DLNP Director and JINR management, to decide on the long-term involvement in this interesting physics project.

The PAC took note of the report on the results obtained by the JINR group in the ALICE experiment at the LHC presented by E. Rogochaya. These concern the photoproduction of light vector mesons in ultraperipheral Pb–Pb collisions at 5.02 TeV and, for the first time, the identical charged kaon femtoscopic correlations in p–Pb collisions at the energy of $\sqrt{s_{NN}} = 5.02$ TeV which showed consistency with the predictions of hydrodynamic models. The PAC appreciated the effort of the JINR team in physics analyses and requested it to submit at the next PAC meeting a detailed plan of its future activities with milestones.

The PAC took note of the report on the physics results obtained by the JINR group in the ATLAS experiment at the LHC presented by E. Khramov. The group's members have continued their analyses in defining the structure of the proton at ultrahigh energies, in searches for $Z\gamma$, $W\gamma$ and $H\gamma$ resonances in boosted jet plus photon final states and Supersymmetry processes, and in the search for a valence-like nonperturbative component of heavy quarks in the proton. The JINR group received an ATLAS Software Development Grant to participate in the development of the event triggers indexing infrastructure and implementation of the new configurations mechanism for the AthenaMT framework. The PAC appreciated the group's plans to continue the above-mentioned analyses and expand its participation in the ATLAS software development.

The PAC took note of the new results and current activities of the JINR group in the CMS experiment at the LHC presented by V. Aleksakhin. The PAC appreciated the contribution of this group to the search for extra gauge bosons and extra dimensions in the dimuon channel, the recent results on searches for extra Higgs bosons decaying into a pair of b-quarks and muons, and the cross-section measurements of Drell–Yan lepton pair production. It also commended the operation and service work carried out by the group in the Phase 1 upgrade project, in the operation of the Tier1 and Tier2 computer centres, as well as the CMS Regional Operation Centre.

The PAC reviewed 18 poster presentations in particle physics by young scientists from DLNP, BLTP and VBLHEP, and selected the poster "Real-time detection of supernova neutrino signal" presented by A. Sheshukov to be reported at the session of the Scientific Council in February 2020.

The 52nd meeting of the Programme Advisory Committee for Nuclear Physics was held on 25 June by videoconference. It was chaired by Professor M. Lewitowicz.

The Chairman of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting. JINR Vice-Director S. Dmitriev informed the PAC about the Resolution of the 127th session of the Scientific Council (February 2020) and about the decisions of the Committee of Plenipotentiaries (June 2020).

The PAC was informed about the appointments of G. Trubnikov as First Vice-Director of JINR, S. Dmitriev as Vice-Director of JINR, B. Sharkov as Vice-Director of JINR, and S. Sidorchuk as Director of FLNR. The PAC wished them a bright future in these new positions. The Committee also acknowledged the excellent work accomplished by the former FLNR Director S. Dmitriev and the former JINR Vice-Director M. Itkis who had made invaluable contributions to the progress of JINR and FLNR.

The PAC was informed about the status of the Factory of Superheavy Elements (SHE Factory) at FLNR. At present, installation of the "flat-top" system has been completed at the DC-280 cyclotron and is being tested. A differential pumping system is being constructed at the GFS-2 gas-filled separator; if used in combination with the "flat-top" system, it will allow experiments with the highest possible intensity of ion beams produced by DC-280. All previously scheduled test experiments have been completed. The first experiment to produce moscovium isotopes in the $^{48}Ca + {}^{243}Am$ reaction has been prepared.

The PAC heard a report on the results of work under the theme "Improvement of the JINR Phasotron and Design of Cyclotrons for Fundamental and Applied Research", presented by G. Karamysheva.

Due to the upgrade of the Phasotron and its beam lines carried out between 2016 and 2020, a stable operation of the accelerator was ensured for an average of 1000 hours per year; of these, about 80% was used for medical research. Research under the theme was focused mostly on developing and improving cyclotrons used in hadron therapy.

The most important activities were carried out in collaboration with the Institute of Nuclear Physics, Polish Academy of Sciences, on the modernization of the IAC-144 cyclotron in Kraków and with the Institute of Plasma Physics of the Chinese Academy of Sciences (Hefei) on the design and manufacture of the superconducting isochronous SC200 cyclotron for proton therapy. Design of the SC230 compact superconducting cyclotron with smaller dimensions and a required magnetic field level was developed by the project's group members. The SC230 accelerator may become a candidate for further realization of the biomedical research programme at JINR.

The PAC noted that for choosing the direction towards the realization of a modern proton therapy facility at JINR clear criteria needed to be formulated according to which the choice of the dedicated medical accelerator could be made, in particular, to present more details on how many patients and fractions for proton therapy would be planned.

The PAC recommended continuing the studies planned by the team in the field of development, construction and upgrade of cyclotrons, including cooperation in the field of medical cyclotrons within the framework of one of the DLNP themes. It also recommended that the JINR Directorate make soon a decision on this direction and support the realization of an optimized facility for proton therapy.

The PAC heard a report on the plans for the development of the EG-5 accelerator and its experimental infrastructure at FLNP, presented by A. Doroshkevich. The PAC noted the utmost importance of EG-5 for JINR and its Member States. The authors compared in detail two technical solutions: modernization of the existing EG-5 accelerator and purchase of a new accelerator with similar design parameters. The choice of the most cost-effective solution is modernization of the EG-5 accelerator.

The PAC recommended that the FLNP Directorate prepare and open a project to modernize the existing accelerator and associated experimental infrastructure activities under the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron" with financing from the budget of the current Seven-Year Plan for the Development of JINR, starting in 2021.

The PAC heard a proposal to open a new project "Measurement of ordinary muon capture for testing nuclear matrix elements of 2β decays (project MONUMENT)" presented by D. Zinatulina. This project is aimed at carrying out experimental measurements of muon capture at several daughter candidates on 2β-decay nuclei. Obtained results would be of high importance for checking the accuracy of theoretical calculations of nuclear matrix elements. The measurements of muon capture will be carried out at the meson factory of the Paul Scherrer Institute (PSI) in Switzerland. This application was reviewed and approved by the PSI User Committee in 2020; the beam time was officially granted for a preliminary study of ^{136}Ba with a further experimental programme for three years. This project continues and extends the previous ordinary muon decay programme proposed and implemented under the leadership of JINR researchers from 1998 to 2006. The participants of the project have the required expertise and experience in the field of high-precision nuclear spectroscopy and its implementation to study not only rare processes but also muon capture. The PAC recommended opening the MONUMENT project for 2021–2023 with first priority and providing the project with full requested funding.

The 53rd meeting of the Programme Advisory Committee for Particle Physics took place on 29 June by videoconference. It was chaired by Professor I. Tserruya.

The Chair of the PAC presented an overview of the implementation of the recommendations taken at the previous meeting and highlighted the Resolution of the 127th session of the JINR Scientific Council relevant to the PAC for Particle Physics.

The PAC heard a report on the progress towards realization of the Nuclotron–NICA project presented by A. Sidorin. The tests of the main Booster systems were completed. The PAC welcomed the active preparations for launching the Booster synchrotron with beam in August 2020 but expressed its concern with the lack of manpower sufficient for the collider magnet construction and tests that could seriously impact the overall schedule of the NICA project.

The PAC welcomed the progress in the infrastructure developments at VBLHEP presented by N. Agapov. Despite the difficult pandemic situation, all areas of infrastructure development are advancing without downtime and basically at the necessary pace.

The PAC appreciated the progress towards upgrade of the BM@N detector for the heavy-ion physics runs planned for 2021, presented by M. Kapishin. It encouraged the BM@N team to publish the results obtained with the C and Ar beams as soon as possible.

The PAC took note of the report on the progress towards realization of the MPD project presented by A. Kisiel and recommended extension of the project until the end of 2025 with first priority. The PAC welcomed the steady progress in the assembly and production of most MPD detector components foreseen in the first stage configuration. The PAC expressed its concern with the delay in the ECAL construction and the resulting impact on the physics programme, with only half of the coverage foreseen now at the first stage while the second half is expected at a later stage. The PAC appreciated the ongoing Monte Carlo simulations of the detector and physics processes while preparing the first beams in MPD and welcomed the plans to intensify this effort.

The PAC took note of the report on the project "Studies of the nucleon and hadron structure at CERN — Project COMPASS-II" presented by A. Nagaytsev. The PAC encouraged the JINR team to enhance its participation in the data analysis and develop collaborative work for the physics exploitation of the data to secure scientific recognition of the group's two-decade-long work in COMPASS. By the project completion in 2022, the group should explore its possible participation in MPD and SPD where its expertise is certainly very much needed. The PAC recommended extension of the COMPASS-II project until the end of 2022 with first priority.

The PAC took note of the report on the project "Astrophysical studies in the TAIGA experiment" presented by L. Tkatchev and recommended extension of the TAIGA project until the end of 2023 with first priority. The main responsibility of the JINR group is the design of Imaging Atmospheric Cherenkov Telescope (IACT), mechanics manufacturing and tests. The third telescope was sent to Siberia in April 2020, the fourth IACT will be built during 2021–2023. The PAC encouraged the team, in particular its young researchers, to strengthen their participation in the data analysis and to publish the methodological results obtained more actively.

The PAC appreciated the report presented by D. Naumov on JINR's participation in the Daya Bay and JUNO experiments. The JINR team will continue the neutrino oscillation analysis and searches for sterile neutrinos in the Daya Bay experiment and will contribute to the development, construction and commissioning of various parts of the JUNO project: high-voltage units, Top Tracker detector, new test station for the large detector PMTs, TAO near detector, software packages for data processing and Global Neutrino Analysis. The JINR data centre is expected to be one of the three European centres managing JUNO data. The PAC noted the high quality of the work performed by the JINR group and recommended continuation of the JUNO project with first priority until the end of 2023.

The PAC heard with interest the report on JINR's participation in the NOvA experiment and on the new results in the study of neutrino oscillations, presented by A. Olshevskiy. Since 2014 the JINR group has made significant contributions to the experiment, the team members are well involved in the ongoing neutrino oscillation analyses and the studies of supernova and atmospheric neutrinos, as well as in Dirac monopole searches. JINR employees also act in various leading roles, such as Detector Simulation Convener, offline and DAQ software release managers, DAQ, DDT and ROC experts.

The JINR group also presented its plans for the future LBNF/DUNE neutrino project at Fermilab/SURF, with a gradual increase of their participation in this large-scale international experiment expected to start after completion of NOvA. The PAC recommended continuation of NOvA and approval of the group's participation in DUNE, both until 2023 with first priority. The PAC encouraged the JINR Directorate to provide the necessary resources to the DUNE project in order to guarantee visible participation of the group. The JINR group should play the role of bridgehead for the future joining of more groups associated with JINR.

The 52nd meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 2 July by videoconference. It was chaired by Professor D. L. Nagy.

The PAC took note of the report on the development of a new neutron source at FLNP presented by V. Shvetsov. The PAC noted the results achieved in the technical design of the IBR-3 reactor as well as the beginning of JINR's cooperation with the potential fuel manufacturer. The technical requirements for the development of the Technical Proposal of the new neutron source were prepared in cooperation with the N. A. Dollezhal Research and Development Institute of Power Engineering (Moscow). A collaborative workgroup from FLNP's Department of Spectrometer Complex and Department of Neutron Investigations of Condensed Matter continued activities on the experimental determination, modeling and search for means of suppressing the backgrounds at the extracted beams of the IBR-2 reactor. The PAC recommended deeper elaboration of the IBR-3 Technical Proposal and continuation of the activities on studying and suppressing neutron background at the IBR-2 instruments.

The PAC took note of the information about developments regarding the joint facility for structural research using synchrotron X-rays at the SOLARIS National Synchrotron Radiation Centre, presented by N. Kučerka. The JINR–SOLARIS collaborative efforts towards building the SOLCRYS laboratory will extend the suite of condensed matter research approaches at JINR. The PAC welcomed the progress in constructing the SOLCRYS laboratory, while recommending paying close attention to the design details.

The PAC took note of the report on the concluding theme "Investigations of Condensed Matter by Modern Neutron Scattering Methods" presented by D. Kozlenko and recommended opening a new theme "Investigations of Functional Materials and Nanosystems Using Neutron Scattering" for 2021–2025.

The PAC supported the proposal for opening a new project "Development of inverse geometry inelastic neutron scattering spectrometer at the IBR-2 reactor" for 2021–2023, presented by D. Chudoba. The estimated parameters of the new spectrometer are up to two orders of magnitude better than those of the NERA spectrometer. The new spectrometer with the proposed parameters is expected to be competitive to similar devices already existing in leading European neutron laboratories.

The PAC recommended closure of the theme "Development of Experimental Facilities for Condensed Matter Investigations with Beams of the IBR-2 Facility" as reported by S. Kulikov and opening the new theme "Scientific and Methodological Research and Developments for Condensed Matter Investigations with IBR-2 Neutron Beams" for 2021–2025. The PAC noted with satisfaction that all work planned under the concluding theme had been successfully completed. The PAC recommended closure of the completed BSD and PTH projects, as reported by V. Kruglov and A. Chernikov, respectively, and opening the new project "Construction of a wide-aperture backscattering detector (BSD) for the HRFD diffractometer" for implementation in 2021–2023.

The PAC considered the written report presented by M. Avdeev on the concluding project "A system for neutron *operando* monitoring and diagnostics of materials and interfaces for electrochemical energy storage devices at the IBR-2 reactor". The PAC was pleased to note that the project objectives on wide adaptation of neutron scattering methods and sample environment systems for studying the evolution of the structure of electrochemical interfaces and electrode materials in *operando* mode had been fully achieved and recommended closure of the project.

The PAC recommended extension of the theme "Modern Trends and Developments in Raman Microspectroscopy and Photoluminescence for Condensed Matter Studies" for 2021–2023 reported by G. Arzumanyan. Given the successful realization, the PAC recommended closure of the Nanobiophotonics project and supported opening the Biophotonics project for implementation in 2021–2023.

The PAC took note of the report on the concluding theme and project "Novel Semiconductor Detectors for Fundamental and Applied Research" and of the proposal for their extension presented by G. Shelkov. The PAC recommended extension of these theme and project for 2021–2023.

The PAC recommended extension for 2021–2023 of the PAS project as reported by K. Siemek. It noted with satisfaction the progress in developing the PAS method at DLNP including construction of a reactive ion etching system and development of a system of positron ordered flux based on the Cryogenic Source of Monochromatic Positrons (CSMP).

The PAC recommended opening the new project "Study of the radioprotective properties of the Damage Suppressor (Dsup) protein on a model organism *D. melanogaster* and human cell culture HEK293T" presented by E. Kravchenko for its implementation at DLNP in 2021–2022. The PAC noted the novelty of the research proposed and the high methodological level of the planned experiments.

The PAC recommended extension of the theme and project "Research on the Biological Effect of Heavy Charged Particles with Different Energies", as reported by A. Bugay, for 2021–2023.

The PAC took note of the written progress report on the theme "Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data" for the period of 2019–2020, prepared by G. Adam, and welcomed further continuation of the reviewed activities within this theme.

As a general recommendation, the PAC suggested that the JINR Directorate consider the possibility of encouraging young scientists to apply for additional projects to develop their own ideas in the field of science and instrumentation.

PRIZES AND GRANTS

The Bruno Pontecorvo Prize for 2020 was awarded to Professor K. Niwa (Nagoya University, Japan) for the development of the high-resolution nuclear emulsion technique, which led to identification of the tau neutrino and direct observation of tau neutrino oscillations.

JINR PRIZES FOR 2020

I. Theoretical Physics Research

First Prizes

1. "Graphene-based planar tunnel electronics".
Authors: V. Katkov, V. Osipov.

2. "Scalar solitons, boson stars and hairy black holes".
Authors: J. Kunz, I. Perapechka, Ya. Shnir.

Second Prize

"Neutrino mass, double beta decay and nuclear structure".
Authors: F. Šimkovic, A. Babič, R. Dvornický, H. Ejiri, S. Kovalenko, M. Krivoruchenko, A. Smetana, D. Štefánik, P. Vogel, J. Vergados.

II. Experimental Physics Research

First Prizes

1. "Investigation of probabilities of formation and decay of superheavy systems in dependence on the Coulomb factor Z_1Z_2 at energies near the Coulomb barrier".
Authors: E. Kozulin, A. Bogachev, I. Vorobiev, M. Itkis, J. Itkis, G. Knyazheva, D. Kumar, K. Novikov, A. Pan, I. Pchelincev.

2. "Background-free search for neutrinoless double-β decay of ^{76}Ge with GERDA".
Authors: K. Gusev, I. Zhitnikov, D. Zinatulina, A. Klimenko, A. Lubashevskiy, N. Rumyantseva, A. Smolnikov, M. Fomina, E. Shevchik, M. Shirchenko.

III. Physics Instruments and Methods

First Prize

"Measurement of analyzing powers for nucleon-nucleus scattering at momentum range from 1.75 to 5.4 GeV/c".
Authors: O. Gavrishchuk, D. Kirillov, J. Mušinský, C. Perdrisat, N. Piskunov, V. Punjabi, P. Rukoyatkin, I. Sitnik, E. Tomasi-Gustafsson, R. Shindin.

Second Prizes

1. "Development and software implementation of effective methods for modeling, reconstruction and analysis of events in the MPD/NICA setup".
Authors: V. Vasendina, V. Voronyuk, A. Zinchenko, D. Zinchenko, V. Kireev, V. Kolesnikov, A. Mudrokh, J. Aichelin, E. Bratkovskaya.

2. "Development and application of new experimental methods at ACCULINNA-2 fragment separator".
Authors: A. Bezbakh, M. Golovkov, A. Gorshkov, S. Krupko, I. Muzalevskii, E. Nikolskii, G. Ter-Akopian, A. Fomichev, V. Chudoba, G. Kaminski.

IV. Applied Physics Research

First Prize

"Experimental study and multiscale modeling of latent tracks structure in radiation resistant dielectrics".

Authors: V. Skuratov, R. Rymzhanov, A. Volkov, A. Ibraeva, N. Kirilkin, N. Medvedev, J. O'Connell, A. Janse van Vuuren, J. Neethling, M. Zdorovets.

Second Prize

"Nanoscale structure of planar and developed electrochemical interfaces for lithium power sources by neutron scattering".
Authors: M. Avdeev, V. Petrenko, I. Gapon, A. Ivankov, E. Ushakova, Ye. Kosiachkin, D. Itkis, L. Yashina, A. Rulev, T. Zakharchenko.

V. Encouraging Prizes

1. "Three-body soft dipole mode and astrophysical applications".
Authors: L. Grigorenko, Yu. Parfenova, N. Shulgina, M. Zhukov.

2. "Development and creation of coordinate detectors based on thin-walled drift tubes for the NA64 at CERN".
Authors: E. Vasilieva, P. Volkov, Yu. Gusakov, T. Enik, I. Zhukov, G. Kekelidze, V. Kramarenko, V. Lysan, D. Peshekhonov, A. Solin.

3. "High-resolution magnetic analyzer MAVR for studying characteristics of nuclear reactions".
Authors: V. Maslov, Yu. Penionzhkevich, D. Aznabayev, S. Lukyanov, N. Skobelev, Yu. Sobolev, I. Kolesov, S. Pashchenko, G. Gulbekian, M. Khabarov.

GRANTS

In 2020, for the implementation of a number of scientific projects, the staff members of the Joint Institute for Nuclear Research received financial support of the Russian Foundation for Basic Research (RFBR), the Russian Scientific Foundation (RSF), the Ministry of Science and Higher Education of RF, and the Foundation for the Advancement of Theoretical Physics and Mathematics "BASIS".

RFBR financed JINR projects in the framework of the following competitions: "Competition of Projects of Fundamental Scientific Research" (19 projects); "Competition of Projects Accomplished by Young Scientists ("My First Grant")" (8 projects); "Competition of the Best Scientific Projects Accomplished by Young Scientists under the Guidance of Candidates and Doctors of Science in RF Scientific Organizations ("Mobility")" (3 projects); "Competition of the Best Projects Implemented by Young Scientists ("Eureka! There is an idea") held jointly by RFBR and the Foundation of Support of Scientific-Design Activities of Students, Postgraduates and Young Scientists ("National intellectual development")" (1 project); "Competition of the Best Projects in the Topic "Fundamental Properties and Phase Transformations of Hadron and Quark–Gluon Matter: Facility of the Megascience Class Complex NICA" (Megascience-NICA)" (10 projects); "Competition of the Best Projects of Interdisciplinary Fundamental Research" (2 projects); "Competition of Oriented Fundamental Research in Urgent Interdisciplinary Topics" (1 project); "Competition for the Best Projects on Fundamental Research in the Topic "Heavy ions with ultrarelativistic energies", together with the National Centre of Scientific Research of France" (1 project); "Competition for the Best Projects on Fundamental Research Carried out on the Basis of the Laboratory "Joint laboratory 'underground' in Europe", together with the National Centre of Scientific Research of France" (1 project); "Competition for Financial Support for Preparation and Publication of Scientific Review Papers" (2 projects); "Competition for the Best Projects on Fundamental Research Carried out by Leading Teams of Young Specialists" (1 project).

RFBR financed a number of JINR scientific projects in the framework of international contests: together with the State Committee of Science of the Ministry of Education and Science of the Republic of Armenia (1 project); together with the Belarussian Republican Foundation for Basic Research (2 projects); together with the National Scientific Foundation of Bulgaria (1 project); together with the Department of Science and Technology of the Government of India (3 projects); together with the State Foundation of Natural Sciences of China (2 projects); together with the Ministry of Science, Technology and Environment of the Republic of Cuba (1 project); together with the Ministry of Education, Culture, Science and Sport of Mongolia (2 projects); together with the German Scientific-Research Community (2 projects); together with the National Centre of Scientific Research of France (4 projects).

RSF rendered financial support to scientific projects of JINR in the framework of the competitions "Holding of Fundamental Scientific Research and Scientific Research in Separate Scientific Groups" (4 projects), "Holding of Fundamental Scientific Research and Scientific Research by International Scientific Communities" (2 projects), "Holding of Initiative Research by Young Scientists" (3 projects), "Holding of Research by Scientific Groups under the Guidance of Young Scientists" (1 project); "Holding of Research on the Basis of Existing Scientific Infrastructure of the World Level" (5 projects).

The RF Ministry of Science and Higher Education financed 2 projects: "Creation of a pilot order of modules for the Electromagnetic Calorimeter as part of the Multi-Purpose Detector (MPD) experimental facility at the NICA collider complex" and "Superheavy nuclei and atoms: Limits of nuclear mass and boundaries of the Periodic Table".

The Foundation for the Advancement of Theoretical Physics and Mathematics "BASIS" financed one project in the competition "Visitor" ("Invited Scientist") under the programme "Scientific Mobility".

2020

INTERNATIONAL RELATIONS AND SCIENTIFIC COLLABORATION

COLLABORATION IN SCIENCE AND TECHNOLOGY

The main results of the international cooperation in science and technology of the Joint Institute for Nuclear Research in 2020 are reflected by the following data:

— joint research was conducted with scientific centres in the Member States, as well as with international and national organizations in other countries, on 44 topics of first priority and one topic of second priority;

— to solve cooperation issues and questions of participation in scientific meetings and conferences, the Joint Institute sent 655 specialists;

— for joint work and consultations, as well as for participation in meetings, conferences, and schools held at JINR, 240 specialists were received;

— 16 international scientific conferences and schools, 12 workshops, and 7 meetings were organized and held.

The international cooperation of JINR is presented in agreements and treaties. Its development comprises joint experiments at basic facilities of physics centres, the acquisition of research data, the preparation of joint publications of the joint research results, the supply of equipment and techniques for the interested sides, etc.

From 9 to 30 January, the second JINR–RSA School was held in iThemba LABS (the RSA) with the participation of the Institute representatives. The School was organized by the South African Institute for Nuclear Technology and Sciences and supervised by Professor R. Newman.

The participants of the School were 32 students and postgraduates from 13 South African universities. Head of the JINR International Cooperation Department D. Kamanin addressed the participants with a brief welcoming speech. BLTP Director D. Kazakov delivered a lecture on modern particle physics. BLTP staff member T. Shneidman told students about theoretical models of atomic nuclei. Yu. Panebrattsev delivered a lecture course "Detectors and processing of signals in nuclear research". VBLHEP staff members P. Semchukov and K. Klygina organized a workshop on processing signals in nuclear and physical experiments and the virtual laboratory of nuclear fission. N. Sidorov read a lecture on colliders and the NICA complex being constructed at JINR. V. Belaga and P. Semchukov held workshops on the analysis of experimental data with the use of ROOT. DLNP staff member and UC Deputy Director A. Zhemchugov delivered a lecture course on Monte Carlo modelling of processes in experiments on particle physics and organized workshops on the GEANT software complex. The lecture programme of the School was concluded with the lecture by UC Director S. Pakuliak about JINR and the UC educational programmes for students.

At the end of January, staff members of the Dzhelepov Laboratory of Nuclear Problems of JINR M. Lyablin and A. Artikov visited Tashkent on the invitation of President of the Academy of Sciences of Uzbekistan B. Yuldashev to present the Precision Laser Inclinometer (PLI).

The seminar presentation of the PLI took place in the G. A. Mavlyanov Institute of Seismology of the Academy of Sciences of Uzbekistan. During the seminar, M. Lyablin made the report "New methods for registration of microseismic oscillations". A unique sensitivity of the PLI and its ability to register low-frequency angular movements of surface of the earth were noted. The crucial importance of using the device together with well-known methods of earthquake prediction was highlighted.

After the seminar, there was a meeting with B. Yuldashev. During the meeting, it was decided to send two employees to JINR for training in using the PLI and its further maintenance in seismic laboratories of Uzbekistan.

On 29 January, Chairman of the Presidium of the Far Eastern Branch of the Russian Academy of Sciences Academician V. Sergienko visited the Joint Institute on the invitation of the JINR Directorate. He met with JINR Director Academician V. Matveev and discussed the issues of the development of cooperation between scientific centres in the Far Eastern region with the Joint Institute for Nuclear Research.

V. Sergienko was acquainted with research conducted at the Flerov Laboratory of Nuclear Reactions and the accelerator complex of the Factory of Superheavy Elements. He was welcomed at the Laboratory by FLNR Scientific Leader Yu. Oganessian, FLNR Director S. Dmitriev, Deputy Director A. Popeko and Head of the DC-280 facility K. Gikal.

On 5 February, Counsellor of the Embassy of the Republic of India in Russia Dr. Sh. Shrotriya, accompanied by staff member of the Political Division of the Embassy V. Singh, visited the Joint Institute for Nuclear Research.

The guests visited the Factory of Superheavy Elements and the Nanocentre of FLNR. At the Frank Laboratory of Neutron Physics, the guests saw the IBR-2 research reactor, and the REGATA and IREN facilities.

At the Directorate, JINR Vice-Director R. Lednický received the guests. Head of the International Cooperation Department D. Kamanin, UC Director S. Pakuliak, Advisor to the JINR Director M. Tumanova, and Head of the BLTP Sector S. Nedelko, as well as Indian employees of the Institute, took part in the meeting.

At the meeting, the parties noted a high level of the existing cooperation between India and JINR, expressed their interest in its further broadening, discussed opportunities in development of contacts in scientific and educational spheres, and stressed the importance of informing the scientific community and official representatives of India on modern status of JINR and possibilities for cooperation.

On 14 February, a regular meeting of the JINR Science and Technology Council (STC) was held, chaired by Professor R. Jolos.

In his report on the NICA status, V. Kekelidze spoke about the plans for major objects: the accelerating complex with the booster cyclotron and the collider, the MPD and BM@N experimental facilities, the computer information complex, channels and facilities for applied innovative research, as well as the programme of scientific studies. The plans are constantly adjusted in accordance with the work progress. The speaker then informed in detail the STC members about the progress of the development, assembling and adjusting of elements of all the systems, the construction of new buildings, the creation of scientific-engineering and research infrastructure.

Speaking about participants of the project, V. Kekelidze noted that the programme of scientific research was being actively developed by theoreticians from numerous scientific centres of the world, coauthors of the NICA White Paper, Russian scientists in the framework of the RFBR projects, participants of established international collaborations of the BM@N, MPD and SPD experiments. Agreements with five Mexican universities and the memorandum of participation of Polish organizations in MPD were signed; the GSI–JINR agreement was activated. The GSI Helmholtz Centre for Heavy Ion Research coordinates the participation of Germany in the NICA project. The contribution of the country to the project is about 20 million euros. R. Jolos and V. Matveev made comments on the report.

The report on the elaboration of the JINR development strategy was made by B. Sharkov, a JINR Vice-Director, Coordinator of the International Working Group established in 2016 and chaired by V. Matveev, with participation of leading world experts and leaders of the main scientific trends at JINR. He noted that the strategic aim of the JINR development until 2030 as of a world-level scientific centre was to ensure its leading positions in the fields of high-energy physics, nuclear physics and heavy-ion physics, neutrino physics and astrophysics, condensed matter physics, radiation biology, information technologies and high-performance computing. B. Sharkov also noted the importance of work conducted in the fields of interdisciplinary research and innovation technologies. The strategic plan for the JINR development should be the basis for drafting the next Seven-Year Plan and adoption of decisions leading JINR to new scientific achievements in a longer term. All materials are available on the website Indico.jinr.ru. S. Nedelko, D. Peshekhonov, D. Naumov, I. Meshkov, R. Jolos, and

V. Matveev took part in the discussion of the report.

A. Verkheev, Chairman of the Association of Young Scientists and Specialists (AYSS) of JINR, presented the report on the AYSS activities. He based his report on the sociological survey, a survey on scientific indicators and written report on AYSS grants compiled in recent years. In particular, the speaker proposed some corrective amendments in the system of grant support and discussed a number of general issues vital to the majority of young scientists and specialists: opportunities in career, financial status, lodging conditions, organization and conditions of labour. A. Verkheev stressed that attracting employees and retaining talented and active staff members should be given the highest priority in the Institute. S. Nedelko, M. Hnatič, B. Sharkov, D. Peshekhonov, Yu. Potrebenikov, I. Meshkov, G. Shirkov, A. Tamonov, A. Sorin, and R. Jolos commented on the report. V. Matveev thanked the speaker for the informative speech and expressed the readiness of the Directorate to help in solving the problems considered in the report.

On 24–26 February, the first meeting of the NICA Cost and Schedule Review Committee (CSRC) was held. The Committee emerged on the decision of the CP of JINR and the Supervisory Council for the project "NICA Complex".

The Committee was created to consult the Supervisory Council and the CP on issues related to cost estimate and work progress towards the implementation of the project "NICA Complex". The Committee, which is headed by F. Ferroni (INFN, Italy), consists of recognized specialists in the fields of high-energy physics and accelerator physics: I. Mnikh (DESY, Germany), L. Cifarelli (University of Bologna, Italy), F. Bordri (CERN), L. Kostov (Agency for Nuclear Regulation, Bulgaria), E. Rabinovici (Israel), and L. Kravchuk (INR RAS, Russia). The meetings of the Committee were attended by JINR Director V. Matveev, Head of the project "NICA Complex" V. Kekelidze and Co-Head of the theme "NICA Complex" A. Sorin. First Deputy Minister of Science and Higher Education of Russia G. Trubnikov, Head of the project's directorate R. Lednický and Deputy Head of the project office Yu. Potrebenikov, JINR Chief Accountant S. Dotsenko and Deputy Head of the Finance & Economy Office of JINR M. Vasilyev participated in the work of the Committee.

On the first day of the Committee meeting, the participants had an excursion to the objects of the NICA complex. During the meeting, detailed presentations made by heads of major subsystems and objects of the complex were heard and discussed whose development is planned in the framework of the basic configuration of the project according to the JINR Topical Plan and requirements of the Russian national project "Nauka" till the end of 2022. Special attention was paid to the estimate of the base cost and the cost effectiveness of the project, the estimate of the implementation plans and efficiency of their realization, the estimate of the efficiency of instruments and methods used by managers and executors of the project to monitor the costs and work planning, the main issues of financing, as well as issues related to them and risks caused by technical problems in the implementation of the project.

The Committee noted considerable progress in the implementation of basic elements of the complex achieved over the past two years. The CSRC members also noted great efforts made by the management of the project and the administration of the Institute to provide financial and technical support, as well as the high quality of reports presented at the meeting.

The Committee paid special attention to the necessity to establish the project office with clearly defined personal duties of its members in the fields of development and monitoring of the adhering to the project's implementation schedule, logistics, budget, safety and quality control of purchased equipment and work done, determining critical objects of the basic configuration of the complex, the development of the minimization plan and the risk reduction at its critical objects. The Committee highlighted that the estimate of the implementation progress should be conducted at least three times a month. On 26 February, at a closed session of the Committee, decisions and recommendations were formulated to the Supervisory Council for the project "NICA Complex" and the CP of JINR.

On 25–27 February, Vice-Chancellor and Principal of the University of Pretoria (the RSA) T. Kupe visited JINR with an RSA delegation that included Head of International Cooperation S. Mokoduwe, Head of Research Capacity Development Department R. Ramoutar-Prieschl, Head of the Department of Physics Ch. Theron, as well as Professors of the Department of Physics Th. Hltshwayo and S. Rakityanski.

The visit of the delegation coincided with the 15th International training programme for decision-makers in science and international scientific cooperation JEMS — "JINR Expertise for Member States and Partner Countries" (JEMS-15). The guests used the opportunities of the training programme for in-depth acquaintance with the Joint Institute, the development of its scientific infrastructure and current scientific research.

On 27 February, a meeting of the delegation with the JINR Directorate took place. Vice-Directors M. Itkis and R. Lednický, and Chief Scientific Secretary A. Sorin represented JINR at the event. Executive of the contacts with the RSA, Head of the International Cooperation Department D. Kamanin, Deputy Director of the University Centre A. Zhemchugov and Coordinator of RSA scientists in JINR Arnaud Rossow also took part in the meeting on behalf of JINR.

During the meeting, the parties noted a dynamic development of scientific contacts between JINR and scientific centres and universities of the RSA. They also discussed practical steps towards the cooperation enhancement between the University of Pretoria and the Joint Institute. The meeting at the JINR Directorate was concluded with a singing of the cooperation agreement on carrying out scientific research and training scientific and technical staff.

On 2 March, an opening ceremony of the workshop "Prospects of Cooperation with Eurasian Countries — Members of JINR" took place in the Presidium of the Azerbaijan National Academy of Sciences.

The delegation of the Joint Institute headed by JINR Director Academician V. Matveev consisted of FLNP Director V. Shvetsov, DLNP Deputy Director D. Naumov, Head of Sector of the LIT Division of Computational Physics V. Gerdt, Deputy Head of the Finance & Economy Office M. Vasilyev, and Deputy Head of the International Cooperation Department A. Kotova. Moreover, Plenipotentiary of the Government of the Republic of Kazakhstan to JINR A. Kenzhin and Head of the National Group of the Republic of Uzbekistan in JINR, DLNP Chief Researcher A. Inoyatov took part in the event on behalf of JINR.

President of the Azerbaijan National Academy of Sciences (ANAS) Academician R. Mehdiyev headed the party of the Republic of Azerbaijan. ANAS First Vice-President I. Guliyev, Plenipotentiary of the Government of Azerbaijan to JINR N. Mamedov, and representatives of various scientific organizations of Azerbaijan also took part in the event.

The meeting was attended by representatives of ministries as well: First Deputy Minister of Science and Higher Education G. Trubnikov represented the Russian Federation and Deputy Minister of Education F. Gurbanov represented the Republic of Azerbaijan.

The participants discussed the status of cooperation of the Joint Institute and the Republic of Azerbaijan and ways and opportunities to develop it. One of the milestones of the meeting was the signing of a four-lateral agreement on cooperation among the Institute of Physics of ANAS, Baku State University, the Joint Institute for Nuclear Research and the Institute of Nuclear Physics of the Ministry of Energy of the Republic of Kazakhstan.

On 20–21 April, the 5th Collaboration Meeting of the BM@N Experiment at the NICA Facility was held via videoconference at VBLHEP.

At the meeting, the recent results obtained with C and Ar beams were discussed. The main focus was on the data collected in carbon–nucleus interactions for preparation for publication in a refereed journal, and the status of the results obtained in the data analyses of argon–nucleus interactions was discussed. The plans for research in the field of heavy-ion physics were reviewed. Organizational issues of the BM@N collaboration were discussed at a separate meeting on 20 April.

On 23–24 April, the 5th Collaboration Meeting of the MPD Experiment at the NICA Facility was held at VBLHEP in the format of an online conference. The main purpose of the meeting was to assess the level of detector readiness, including software development, discussion of physics tasks and results obtained by the collaboration, as well as consideration of current organizational issues of MPD.

The meeting included sessions on physics and detector readiness open for all MPD collaborators, as well as a closed meeting of the MPD collaboration leadership.

On 27 April, the 42nd meeting of the Committee Russia–CERN was held as a videoconference — it was the first meeting after the new Agreement between the RF Government and CERN on scientific-technical cooperation came into force. CERN Director General F. Gianotti headed the delegation from CERN; Co-Chairman of the Committee on the side of Russia was Deputy Minister of Science and Higher Education of the Russian Federation S. Lyulin. JINR was represented by JINR Director Academician V. Matveev, JINR Vice-Director Academician B. Sharkov and JINR Vice-Director, VBLHEP Director RAS Corresponding Member V. Kekelidze.

At the meeting, the parties discussed in detail the participation of the Russian Federation in the second phase of modernization of the Large Hadron Collider (LHC) and establishment of the High-Luminosity LHC, joint maintenance and usage of the LHC detectors, and other practical issues.

CERN delegation presented further steps to form a European Strategy for Particle Physics. For its part, members of the Russian delegation presented information on the implementation of the Russian Federation's initiatives for the fulfilment of projects in the fields of megascience research infrastructure within the national project "Science", in particular, the NICA project. Academician B. Sharkov presented the strategy of JINR development until 2030 and beyond to the Committee.

On 27–29 May, the 11th session of the NICA Machine Advisory Committee (MAC) was held in the format of videoconference. Despite the fact that MAC members are specialists from Japan, Europe, and the USA, the time of broadcast was chosen acceptable for the Committee members.

All meetings of the Committee were attended by JINR Director V. Matveev, First Vice-Director G. Trubnikov, Vice-Director B. Sharkov, Head of the project "NICA Complex" V. Kekelidze and Co-Head of the theme "NICA Complex" A. Sorin.

Thirteen reports were presented. V. Kekelidze described organizational structure of the NICA project and informed the MAC members about the results of the first meeting of the NICA Cost and Schedule Review Committee (CSRC) held at JINR on 24–26 February 2020. Progress on the NICA Booster commissioning was reported by Head of the VBLHEP Accelerator Division A. Butenko. Other reports presented by JINR specialists as well as their colleagues from the Budker INP were dedicated to each of the main systems and elements of the accelerator facility. Specially for the MAC session, a few videos were prepared under support of the JINR Scientific Information Department.

In June, issue 1 of the newsletter "NICA Bulletin" was published. The availability of periodic information on the JINR flagship international project "NICA Complex" is in demand by the JINR Member States, international collaborations of the project, and the scientific community. Most important events in implementation of the project "NICA Complex" will be discussed in the bulletin. Head of the directorate of the NICA project is G. Trubnikov, Head of the NICA project is V. Kekelidze.

Issue 1 was prepared with active participation of A. Butenko, N. Molokanova, D. Peshekhonov, Yu. Potrebenikov, A. Rassadova and A. Sidorin. The next issue of the "NICA Bulletin" was scheduled for October 2020.

On 15 June, an extended meeting of the national groups was held as a videoconference, in which the representatives of the JINR Directorate, the Member States, heads of national groups and divisions of the Institute took part.

JINR Director V. Matveev addressed the participants with a welcoming speech. He thanked those present for their active work and stressed that the leadership of the Institute was making every effort to create an atmosphere that would help the representatives of the participating countries feel comfortable away from home.

G. Stiforov made a summary presentation about the progress in the implementation of the MC^2 Club project. Members of the JINR Directorate, representatives of several divisions and heads of national groups took part in the discussion of the presented results of this work.

The results of a survey carried out among members of national groups on the issues of stay of non-Russian staff members in JINR were presented by the Assistant to Head of the JINR SO&IC Office W. Chmielowski. 125 staff members were sent a questionnaire of 25 questions. Each question was related to a particular area of activities: information about JINR in your country, procedures of leaving your country to work at JINR, checkpoints, workplace, research facilities, canteens, relations with other employees, salary, professional development, use of grants, place of living, organizations for children, medical care, pension insurance and taxes, cultural life and sports, etc. More than 2.5 thousand reviews were received which are to be analyzed.

D. Kamanin presented information of the Directorate of the Institute about the celebration of the 65th anniversary of JINR and the upcoming CP session. The issue of filling the JINR news website was also raised here. JINR Chief Scientific Secretary A. Sorin called the Institute community to contribute to the scope and strengthening the information field about the activities of the Institute.

On 27 June, the festival of technology and science GEEK PICNIC started in a new online format. The main topic of the event was devoted to the theme "Multi-Universe": other dimensions, parallel realities and other worlds.

JINR continued the tradition of its participation in the festival, presenting various events at its virtual stand. The work of the stand was organized by the group of social communications of the JINR UC. Deputy Director of DLNP D. Naumov, Doctor of Physics and Mathematics, who is responsible for the Neutrino Programme at JINR, made a lecture about neutrino as a key to study secrets of nature. The audience heard not only about peculiarities of the ghost particle but also the latest news about the development of the deep underwater neutrino telescope in Lake Baikal.

Senior Engineer of VBLHEP D. Ponkin gave an on-line master class for the guests on designing a printed circuit board and programming electronics similar to that used for charged particle accelerators.

Senior Researcher of BLTP A. Golubtsova made an informative lecture on holographic duality and black holes at the virtual stand of JINR.

Researcher of the Sector of Radiation Physiology of LRB Yu. Severyukhin held a video excursion around the Laboratory of Radiation Biology. He showed how behavioral experiments on small laboratory animals are conducted and how the influence of space radiation on mice and rats is studied. After the excursion he answered questions of the audience online.

"Multi-Universe" of the festival GEEK PICNIC Online united many visitors among whom were physicists and fans of computer games, scientific popular bloggers and experts in game industry. For JINR it was a good opportunity to demonstrate a wide range of scientific research and its achievements.

On 1 July, the 26th meeting of the Coordination Committee on the implementation of the Agreement between the German Federal Ministry of Education and Research (BMBF) and JINR was held as a videoconference.

JINR Director V. Matveev, who headed a JINR delegation, noted in his welcoming speech special importance and rich history of the cooperation with BMBF, as well as the importance of the joint training of staff.

The German delegation, headed by BMBF Coordinator for cooperation with JINR J. Kroseberg representing the BMBF Department "Universe and Matter", included cospeakers G. Röpke (University of Rostock), F. Schilling (Karlsruhe Institute of Technology), F. Schreiber (University of Tübingen), K.-D. Gross (GSI), P. Senger (GSI), O. Kühnholz (DESY), T. Ueltzhöffer (DESY) and A. Verma (German Aerospace Centre — DLR).

In his introductory report on the strategic view of the future cooperation, JINR First Vice-Director G. Trubnikov highlighted the main priorities and expectations of JINR: the development of the formal status of Germany in JINR, search for new ways of cooperation, tools for attracting and supporting the scientific youth, as well as deepening of cooperation in the framework of the megascience project NICA. He also proposed to German colleagues to consider the full membership in JINR in the future as a format corresponding in practice to the current state of the cooperation and noted other opportunities for joint consideration: information centres, programmes for improving qualification for leaders of science and higher education, etc.

Leader of the NICA project V. Kekelidze devoted his report to the state of the cooperation of the NICA and FAIR projects and its further prospects.

J. Kroseberg presented a report about a new format of bilateral interactions in three main directions, each with its managing committee. The first field is the continuation of the Heisenberg–Landau Programme. BLTP Deputy Director N. Antonenko and G. Röpke of the University of Rostock reported on it in detail. F. Schilling (Karlsruhe Institute of Technology) and FLNP Director V. Shvetsov presented information on joint research in the field of neutron physics. They also suggested to expand the scope of joint research. The third one is the most extensive cooperation field in the framework of the new format, namely, the attraction and support of young scientists under joint research projects on a wide scope of joint work (programmes of the JINR University Centre, AYSS schools for young scientists, the JEMS programme, and some other scientific events for young specialists).

The agenda of the meeting included presentations by the JINR scientific laboratories. DLNP Deputy Director D. Naumov told participants about cooperation in the framework of the Baikal Neutrino Telescope. LRB Director A. Bugay shared ideas for cooperation with the Laboratory of Radiation Biology. FLNR Deputy Director A. Popeko reported on the opportunities for young scientists at the Flerov Laboratory of Nuclear Reactions. LIT Director V. Korenkov represented the Laboratory of Information Technologies.

The meeting of the BMBF–JINR Committee was preceded by a set of bilateral online discussions in a round-table format. Their participants worked out prospects for cooperation development on a wide scope of issues: attraction of young scientists, organization of the JINR–GSI/FAIR school, expansion of the programme of neutron research, search for ways of cooperation in astroparticle physics and in the framework of one of the key JINR projects, namely, Baikal-GVD. Some strategic issues of the cooperation and JINR initiatives were reported on by the JINR delegation at the meeting of the Russian–German joint commission on scientific and technical cooperation on 25 June. In fact, these discussions were continued during the present BMBF–JINR Committee meeting.

On 8 July, staff members of the Flerov Laboratory of Nuclear Reactions and the JINR University Centre held an online meeting with a video excursion to the FLNR experimental facilities with 125 students of the Governor's School for the Sciences and Engineering (GSSE) of the University of Tennessee (USA).

The meeting was encouraged by the Administrator of the summer school J. Moody. The UC Social Communication Group created a video tour a part of which featured FLNR scientists talking about and demonstrating their work and then they answered questions from the audience.

On 9 July, a regular meeting of the JINR Directorate took place in the International Conference Hall which was partially held via videoconference. JINR Director V. Matveev spoke about important results of the first half of 2020, including work on the strategy of JINR development up to 2030, the successful transition to the new system of defending theses, improvement of the procedure of accepting specialists from Member States, progress in repair work at the hostel in Moskovskaya street 2, and mentioned plans for the near future. Summing up the main results of the CP session that approved the full budget for 2020, the Director mentioned the importance of work with staff; in particular, he approved of the questionnaire for staff members of JINR Member States that was organized by AYSS and the council of national group leaders.

JINR Vice-Director R. Lednický analyzed the questioning of staff from JINR Member States; remote co-speakers were Assistant to Head of the JINR Science Organization & International Cooperation Office W. Chmielowski and Head of the International Cooperation Department D. Kamanin. Comments and remarks on questioning results were made by A. Ruzaev, A. Kotova, D. Kazakov, V. Kekelidze, A. Tamonov, M. Vasilyev and representatives of the Hotel & Restaurant Complex Management Office, the Administration Services Office, the Transport Department, and the Security Office.

JINR First Vice-Director G. Trubnikov informed the participants of the meeting about the results of the work of the BMBF–JINR Coordination Committee. In particular, he discussed the issue of enhancing the status of Germany in the project "NICA Complex" as an associate member of the supervisory committee with prospects to make the status of a full member at JINR that would allow implementing the cooperation potential to the full extent. V. Shvetsov, B. Sharkov and R. Jolos made their comments.

JINR Vice-Director S. Dmitriev spoke about the start of preparations for the 65th anniversary of JINR establishment and the first meeting of the working group on the jubilee preparations. V. Matveev, Yu. Oganessian, G. Trubnikov, B. Sharkov and V. Korenkov expressed their points of view.

The congratulations were read sent by RF Minister of Science and Higher Education V. Falkov and JINR Directorate to the community of staff members of the Flerov Laboratory of Nuclear Reactions headed by Yu. Oganessian for the idea, work-out and successful implementation of the project of the Factory of Superheavy Elements (SHE Factory). The leaders promoted by the Directorate are Yu. Oganessian, FLNR Scientific Leader and Scientific Leader of the project, V. Matveev, JINR Director, Chairman of the Coordinating Committee for the creation of the SHE Factory, S. Dmitriev, FLNR Director (at the time of nomination), Leader of the project, Chairman of the Coordination Council for the creation of the SHE Factory, and G. Gulbekian, FLNR Chief Engineer, Technical Leader of the project. The leading developers of the project are B. Gikal, Technical Leader of the DC-280 cyclotron creation, N. Osipov, Head of the Group for development of design documentation for the DC-280 systems, I. Kalagin, Head of the Group for assembling and launch of the DC-280 cyclotron, S. Bogomolov, Head of the Group for the creation and launch of the ECR source of the DC-280 accelerator complex, and S. Pashchenko, Head of the Group for the creation and launch of the control system of the DC-280 cyclotron complex.

JINR Chief Scientific Secretary A. Sorin, JINR Vice-Directors R. Lednický, S. Dmitriev and B. Sharkov informed the participants about the results of the CP session and summer PACs. Closing statements were made by JINR Director V. Matveev.

On 15 July, Vice-Rector of Moscow Institute of Physics and Technology (MIPT) and Acting Director of the Landau Phystech School A. Voronov visited JINR with the aim of discussing the issues of training scientific and engineering employees at MIPT for the implementation of the JINR large-scale scientific projects.

During the meeting at the Directorate, the parties discussed prospects for cooperation, as well as further steps in the fields of the staff training and attracting MIPT students to work at JINR. The participants paid special attention to work with junior-year students of MIPT.

A. Voronov was acquainted with the objects of the JINR scientific infrastructure: the NICA accelerator complex under construction and the site for the production of superconducting magnets at VBLHEP, the SHE Factory and the DC-280 cyclotron at FLNR, as well as the site for assembling detectors of the deep underwater neutrino telescope Baikal-GVD and the laboratory of X-ray microtomography at DLNP. The guest was accompanied by Head of the MIPT Department of Fundamental and Applied Problems of Microworld, RAS Corresponding Member D. Kazakov, Deputy Heads of the Department S. Pakuliak and G. Shelkov.

On 20 July, Director of the Institute V. Matveev presented JINR diplomas on conferring academic degrees on three applicants who defended their theses: D. Sumkhuu (Mongolia), A. Rutkauskas (Russia) and M. Omelyanenko (Russia).

The awarding ceremony was also attended by JINR First Vice-Director G. Trubnikov, JINR Vice-Director V. Kekelidze, Chief Scientific Secretary of the Institute A. Sorin, Scientific Secretary of the Qualification Committee O. Belov, and Scientific Secretary of the JINR Dissertation Council for Particle Physics V. Arefiev.

Congratulating the recipients of diplomas, the Director of the Institute noted an important role of the system of academic degrees conferring for the personnel support of the physical facilities under construction and planned for construction at JINR, as well as the role of supervisors of applicants for the preparation and defence of theses.

On 29 July, the 5th meeting of the Supervisory Board of the NICA Complex project was held as a videoconference. The meeting was attended by representatives of the Directorate of JINR headed by JINR Director V. Matveev and JINR First Vice-Director G. Trubnikov, Chairman of the Bulgarian Nuclear Regulatory Agency, Plenipotentiary of the Government of the Republic of Bulgaria to JINR L. Kostov, President of RAS A. Sergeev, and Deputy Director General of Rosatom State Corporation Yu. Olenin.

During the meeting, members of the Supervisory Board evaluated the progress of the project and discussed further development, scientific programme, and staffing support of the collider complex, as well as took decisions on changes in the membership of the Supervisory Board.

The Leader of the NICA project V. Kekelidze presented to participants of the meeting a report on the progress in the NICA project, the results of the meeting of the NICA Cost and Schedule Review Committee (March 2020), and the detailed plan for the operation of the basic configuration of the NICA project scheduled for December 2022. The Supervisory Board supported the implementation of the programme of the 1st Day Experiment at the collider of the NICA complex, as well as emphasized the importance of the staffing support of the project and assigned to the JINR Directorate the task of intensifying this activity.

The co-reports were made by Leader of the NICA Project Directorate G. Trubnikov and Leader of the NICA project V. Kekelidze on the development of the basic configuration of the "NICA Complex" project and preparation of the report for 1 January 2021 on the implementation of Order No. 783-p of 27 April 2016 of the Government of the Russian Federation.

At the suggestion of G. Trubnikov, the Supervisory Board decided to invite Director for Large Facilities and Basic Research Department of the Federal Ministry of Education and Research of Germany Dr. V. Dietz and Scientific Managing Director of GSI and FAIR Professor P. Giubellino to join the Supervisory Board as observers.

On 26 August, a JINR delegation took part in a solemn opening ceremony of the Year of Russian–Chinese Cooperation in Science, Technology, and Innovation scheduled for 2021. JINR First Vice-Director G. Trubnikov represented JINR at the official ceremony held as a videoconference. JINR Director V. Matveev, Leader of the NICA megascience project and JINR Vice-Director V. Kekelidze, as well as Head of the International Cooperation Department D. Kamanin were present in the videoconference hall at the JINR Directorate as observers of the event.

An Agreement between the Ministry of Science and Technology of the People's Republic of China and the Joint Institute for Nuclear Research was signed at the event on the participation of China in the construction and operation of the complex of superconducting rings for heavy-ion colliding beams NICA. The parties agreed to establish a Bilateral Coordinating Committee (BCC) with an equal number of representatives of the parties. The BCC shall be responsible for the resolution of technical and financial issues related to the participation of Chinese scientific organizations in the construction and operation of the NICA complex.

The Agreement was signed in the presence of high-ranking participants of the solemn opening ceremony of the Year at which Deputy Prime Minister of the Russian Government T. Golikova headed the Russian party and Vice-Premier of the State Council of China Sun Chunlan headed the Chinese party. On behalf of the Russian Federation and the People's Republic of China, the event was also attended by representatives of the cabinets, governments, administrative bodies, heads of academies of sciences, public and scientific organizations, agencies and foundations, as well as diplomatic representatives of the two countries.

During the opening ceremony of the Year, a Roadmap for Russian–Chinese cooperation in science, technology, and innovation for 2020–2025 was also signed. The document was signed by Minister of Science and Higher Education of the Russian Federation V. Falkov and by Minister of Science and Technology of the People's Republic of China Wang Zhigang. The intention of the parties to support JINR–China cooperation is also reflected in this document.

On 15 September, the ceremony of hybrid format was held for concluding the Russian–German Scientific and Educational Partnership Year 2018–2020 where the JINR First Vice-Director G. Trubnikov took part. An exposition of JINR was displayed at the virtual innovation exhibition of leading scientific and educational organizations and funds from Russia and Germany dedicated to this event.

A videoconference "Russian–German dialogue in education and science: Creating future together" was organized in the framework of the event. The plenary discussion session "Dialogue in science and education: Prospects for the Russian–German cooperation" was attended by President of the German Academic Exchange Service J. Mukherjee, President of the Goethe-University Frankfurt/Main B. Wolff, Vice-President of the Helmholtz Association of German Research Centres H. Dosch, President of the Technische Universität Berlin Ch. Thomsen, as well as Russian colleagues: Vice-President of the Russian Academy of Sciences Yu. Balega, Chairman of the Council of the Russian Foundation for Basic Research V. Panchenko, and NUST MISIS Acting Rector S. Salikhov. G. Trubnikov spoke about the INTErnational REmote Student Training (INTEREST) programme worked out at JINR to maintain the process of intense exchange of knowledge and experience with talented students and postgraduates beyond geographical borders, and invited young scientists to join this programme.

Among long-standing directions of Russian–German cooperation, joint research of ocean, near-Earth space and establishment of the research infrastructure were mentioned.

The winners of the competition "Russia and Germany: Scientific and educational bridges" were awarded at the Closing Ceremony of the Year. The project "The TAIGA Observatory — Russia and Germany open a new window to the Universe" was recognized as one of the winners of the competition in the category "Advanced Research" for successful long-term scientific cooperation. JINR actively participates in the TAIGA international experiment, which is one of the priority projects of JINR in the field of astrophysical research.

On 15 September, the opening of SPD Days in Dubna took place at JINR in a videoconference format to present to a wide world scientific community the Spin Physics Detector (SPD) project, the second-largest experimental facility at the NICA complex, as well as to encourage the establishment of international scientific collaboration around the project. On that day, the first event of the cycle, namely, the international meeting "NICA SPD Experiment at JINR", took place in a mixed format combining a videoconference with personal attendance.

Representatives of scientific centres and universities from Bulgaria, Brazil, Croatia, the Czech Republic, Egypt, France, India, Italy, Poland, Russia, Serbia, Slovakia, and the RSA participated in the meeting. Representatives of government agencies of some countries also took part in the event.

JINR Vice-Director Academician B. Sharkov opened the meeting, after which some reports on the project were presented. Head of the project's working group A. Guskov (DLNP) made a report on the general concept of the SPD project and plans for the construction and launch of the physical facility of the experiment. V. Ladygin (VBLHEP) presented a detailed description of physical characteristics and subsystems of the SPD detector, as well as major tasks of the physical programme of the experiment. The report by A. Baldin (VBLHEP) presented existing developments on the miniSPD stand, the present state and plans for the construction of the SPD test zone at extracted and secondary beams of the Nuclotron for testing the detectors and data acquisition systems. The JINR report by A. Zhemchugov (DLNP) was devoted to the development of the data acquisition system, the development of software and computing for the SPD experiment.

After the general discussion in a round-table format, the discussion of participation in the project took place. Vice-President for Culture and Scientific Communication of the Academy of Scientific Research and Technology of Egypt (ASRT) G. El-Feky expressed the interest of Egypt to become a participant of the SPD project, as well as announced the intention to launch a corresponding competition on cooperation projects within the framework of the Roadmap for JINR–Egypt cooperation development signed in December 2018. The interest of Chilean researchers in the participation in the project on the creation of detectors, electronics and heterogeneous computing was expressed by representatives of the Universidad A. Bello (UNAB). B. Mellado from the University of the Witwatersrand (RSA), who represented iThemba LABS as well, informed the audience that the development of data acquisition systems and machine learning is the area of potential interest for RSA scientific organizations in the SPD project. I. Gorbunov (VBLHEP) made proposals for using capabilities of machine learning. Answering the questions of participants about the involvement of students in the project, A. Zhemhugov suggested using opportunities of the JINR remote scientific and educational platform INTEREST.

A more detailed discussion of the scientific component of the project was continued at the next events of the SPD Days in Dubna, namely, in the framework of remote workshops "Gluon Content of Proton and Deuteron at SPD" (30 September – 1 October) and "Physics Programme for the First Stage of the NICA SPD Experiment" (5–6 October).

On 18 September, a JINR delegation took part in the 24th meeting of the Russian–Chinese sub-commission for scientific and technical cooperation that was held in a video-conference format. The Russian delegation was headed by Deputy Minister of Science and Higher Education of the Russian Federation S. Lyulin, and Vice-Minister of Science and Technology of the People's Republic of China Huang Wei headed the Chinese delegation. JINR was represented by First Vice-Director G. Trubnikov, Leader of the NICA megascience project and Vice-Director V. Kekelidze, VBLHEP Deputy Director H. Khodzhibagiyan, Head of the International Cooperation Department D. Kamanin, and Head of the MPD project at NICA V. Golovatyuk.

The parties shared information and made decisions on a number of aspects of bilateral cooperation between Russia and China, including a discussion of issues of the cooperation in the framework of the megaproject NICA. The parties highly evaluated the Agreement on China's participation in the construction and operation of the NICA complex signed the day before. The Chinese party announced that according to the State Plan for priority scientific research, funds necessary for the implementation of bilateral projects in the framework of NICA had been allocated. The Russian party in its turn confirmed the intention to provide further support of the cooperation in these projects. Representatives of responsible organizations, namely, Deputy Director of the Institute of Modern Physics of the Chinese Academy of Sciences Zhao Hongwei and Deputy Director of the JINR Veksler and Baldin Laboratory of High Energy Physics H. Khodzhibagiyan, elucidated the status of these projects and the progress in their implementation.

On 21–25 September, the Samara Region was one of the central regional sites of the 15th All-Russian Festival of Science NAUKA 0+, and JINR became the official representative of the topical week "Nuclear Physics". Within its framework, scientists from JINR held online scientific popular events for Samara National Research University named after Academician S. Korolev. Visitors of the exposition could interactively get acquainted with large-scale scientific tasks and future experiments, the online competition on nuclear research, etc.

The main theme of the Festival 2020 was "Physics of Future" — in connection with the celebration of the 75th jubilee of atomic industry of Russia. The key tasks of the Festival were also common — to attract young people to science, to arouse interest in scientific research through interactive scientific process, and to establish dialogue between science and society.

The Festival was continued on 10–11 October in the Expocentre in the Moscow site of NAUKA 0+, where a stand of JINR was displayed with mock-up models of almost all operational facilities, lectures and presentations were made by scientists, master classes were given in physics, chemistry, robotic science, and popular scientific shows were organized for children.

On 22–23 September, Representatives of the Rosatom State Corporation Yu. Olenin, Deputy Director General for Science and Strategy, V. Ilgisonis, Director for Scientific and Technical Research and Development, as well as representatives of the Rosatom's JSC "Nauka i innovatsii" A. Dub, First Deputy Director General, and R. Afanasiev, Managing Director, visited JINR.

The delegation visited the Frank Laboratory of Neutron Physics where they were welcomed by FLNP Director V. Shvetsov and his colleagues. The guests visited the IBR-2 research reactor and learnt about the research fields of the Laboratory. At the Flerov Laboratory of Nuclear Reactions, the delegation, accompanied by JINR Vice-Director S. Dmitriev and FLNR Director S. Sidorchuk, was acquainted with the Factory of Superheavy Elements and the Laboratory's research in the field of the synthesis of superheavy elements. The excursion to the Veksler and Baldin Laboratory of High Energy Physics was conducted by VBLHEP Director, Leader of the NICA megascience project V. Kekelidze. The guests learnt about the implementation of the complex of superconducting rings at colliding heavy-ion beams NICA, visited the construction site of the project, as well as the factory of superconducting magnets.

At the end of the visit, the delegation had a meeting with representatives of the JINR Directorate at which the guests were welcomed by JINR Director Academician V. Matveev. The Institute's party was also represented by First Vice-Director G. Trubnikov, Vice-Directors S. Dmitriev, V. Kekelidze and B. Sharkov, Adviser to Director G. Kozlov and FLNR Scientific Leader Yu. Oganessian. The sides discussed wide opportunities to develop cooperation and confirmed their readiness to increase interactions in the framework of the agreement between JINR and Rosatom signed in December 2019.

On 25 September, First Deputy Chairman of the State Duma Committee on Health Protection of the Federal Assembly of the Russian Federation N. Sanina visited JINR.

At the JINR Directorate, N. Sanina was welcomed by JINR Director V. Matveev. The meeting was also attended by JINR First Vice-Director G. Trubnikov, JINR Director Assistant for radiation medicine G. Shirkov, VBLHEP Deputy Director Yu. Potrebenikov, Social Infrastructure Management Office Director A. Tamonov, and JINR Chief Engineer Assistant E. Uglov. During the meeting the sides discussed measures for intensifying the cooperation between JINR and the Federal Biomedical Agency based on the agreement signed in 2016, and plans for the development of proton therapy for cancer based on the extensive JINR experience and the construction of a specialized medical centre for proton therapy in Dubna.

At the end of the visit to JINR, N. Sanina had meetings with Acting Head of Dubna S. Kulikov, as well as with heads of the Dubna City Hospital. The participants discussed the issues of the creation of a cardiovascular department in the City Hospital, sanitary and epidemiological safety in educational organizations of the city, preventive examinations at enterprises, aid to the City Hospital, as well as an opportunity to renovate the children's polyclinic in the right-bank part of the city.

On 29 September, a meeting of the College of the Ministry of Science and Higher Education of the Russian Federation was held by Minister of Science and Higher Education of the Russian Federation V. Falkov. The meeting was attended by JINR First Vice-Director Academician G. Trubnikov. Members of the College, representatives of the scientific community and executive authorities of regions discussed the progress in the implementation of the national projects "Nauka" (Science) and "Obrazovanie" (Education) in the framework of responsibilities of the Ministry of Science and Higher Education of Russia.

Four federal projects will be included in the single national project: "Development of integrated processes in the fields of science, higher education and industry" ("Integration"), "Development of large-scale scientific and technological projects on priority research fields" ("Research leadership"), "Development of the infrastructure for scientific research and staff training" ("Infrastructure"), "Development of human resources for regions, various fields and the sector of research and developments" ("Staff").

On 30 September, the 33rd meeting of the Council of the International Association of the

Academies of Sciences (IAAS) was held as a videoconference. JINR Director Academician V. Matveev and Head of the International Cooperation Department D. Kamanin took part in the meeting on behalf of the Joint Institute for Nuclear Research.

As a result of the meeting, the IAAS Council decided to confer on the Joint Institute for Nuclear Research the status of a Full Member of the IAAS, taking into account great achievements of the Institute in the fields of science and education, as well as the active JINR participation in the Council's activities. Moreover, at the meeting, JINR Director V. Matveev was unanimously elected Full Member of the IAAS.

In his speech, V. Matveev highlighted the importance of tasks set by the IAAS and their relevance to the tasks of JINR. He noted in his report on the JINR activities the following: "In 2021, the Joint Institute will celebrate its 65th anniversary. One of the milestones of the upcoming year will be the adoption of the Institute's Long-Term Development Strategic Plan until 2030. One of its important chapters considers a further development of international cooperation. So, strengthened contacts between the IAAS and JINR will definitely contribute to integration processes in the CIS countries and beyond".

Before attaining the status of a full member, the Joint Institute for Nuclear Research has been an associate member of the IAAS since 1997. Full-fledged IAAS sessions were twice held on the JINR invitations: in 2000 in Dubna, and in 2002 in the JINR Hotel "Dubna" in Alushta.

On 22 October, a regular meeting of the JINR Science and Technology Council (STC) was held; due to the difficult epidemiological situation, the meeting had a hybrid format.

JINR Director V. Matveev noted that a draft of the Long-Term Development Strategic Plan of the Institute until 2030 would be presented at the coming CP session. The second constituent of the strategy document was to be discussed, namely, the plan of the development of the Institute as the international intergovernmental scientific and research organization.

The results of the work of an expert and analytical Working Group established under the Directorate to discuss these issues were reported by its chair G. Trubnikov, JINR First Vice-Director. He illustrated the main issues of the strategy of the Institute development and mechanisms to implement them, and suggested that a Working Group on strategic development issues be established under the CP Chair. I. Meshkov, V. Kekelidze, D. Peshekhonov, B. Sharkov, N. Russakovich, S. Nedelko, and R. Jolos took part in the discussion of the report.

According to the discussion results, V. Matveev noted that the presented document gave a clear and full idea on the strategy and prospects of the Institute development. STC indorsed the Strategic Plan of the Long-Term Development of JINR until 2030 presented by G. Trubnikov.

On 22–23 October, the Federation Council Committee on Science, Education and Culture held a guest meeting in Dubna on the topic "Main fields of and prospects for the development of international scientific and technical cooperation in the framework of the implementation of the Strategy of the Scientific and Technological Development of the Russian Federation". Among the participants were members of the Federation Council, leaders of JINR, governors of Tomsk and Novosibirsk regions, representatives of RF ministries and departments, leaders of RF constituent entities, heads of science cities, members of the Russian Academy of Sciences, rectors, and representatives of the SEZ "Dubna".

As part of the guest meeting, a number of introductory excursions to scientific laboratories of the Institute were organized on 22 October for the FC Committee members and participants of the meeting: the guests could acquaint themselves with the status of implementation of the megascience project NICA at VBLHEP, the Factory of Superheavy Elements at FLNR and the project of the deep-water neutrino telescope Baikal-GVD at DLNP, and met with young scientists.

The agenda of the meeting included issues of development and efficient use of scientific-technical potential of science cities of Russia. Chairperson of the FC Committee L. Gumerova opened the meeting. She noted that one of the tasks set by the leaders of the country is provision of the international leadership in spheres of science and technology and development of international scientific-technological cooperation and international integration in science and technology. L. Gumerova underlined that the choice of the place for the guest meeting was determined by the status of JINR as an international science centre that has no borders, countries, religions and is united only with the idea of service for science for the sake of peace and progress.

In his greeting, JINR Director V. Matveev thanked the speaker for the honour to receive such a representative delegation at the Institute and for the support of the international scientific centre in Dubna and attention to its activities rendered by the leaders of the country.

JINR First Vice-Director G. Trubnikov in his turn addressed the colleagues at the meeting — governors, vice-governors, heads of science cities, leaders of universities — and asked them to regard the Institute as a consulting coordinating platform from the point of view of development of international scientific technical cooperation in Russian regions, cities, universities and scientific research institutions.

Deputy Head of the Science Organization and International Cooperation Office D. Kamanin made a report about the international structure of the Institute, JINR Member States and cooperation with world scientific and educational centres.

RF Deputy Minister of Science and Higher Education S. Lyulin informed the participants of the meeting about financing of scientific research, the importance of participation in international collaborations, implementation of projects of the "megascience" class in Russia. The talk of the Governor of the Novosibirsk Region, A. Travnikov, was devoted to the implementation of the national project "Science and Universities", support for young scientists and the development of Akademgorodok in Novosibirsk. Head of Administration of International Cooperation of RAS S. Malenko presented the strategy of RAS for the development of international scientific and scientific-technical activities. A. Afanasiev, Director General of the SEZ "Dubna", spoke about the activities of the zone since its establishment in 2005. RF Deputy Minister for Economic Development O. Tarasenko made a report on establishment of innovative scientific-technological centres that unite organizations of scientific-technological character. Other speakers were the following: Chairman of the Council of Rectors of Southern Russian Universities, President of the Southern Federal University M. Borovskaya, Head of the science city Koltsovo N. Krasnikov, Head of the city district Pushchino A. Vorobyev, Head of the municipal district of Chernogolovka O. Egorov, Deputy Director of the Centre for system analysis and advanced elaborations in education and science V. Kiselev, Rector of the North Ossetian University A. Ogoev, Prorector in scientific activities of the Moscow Aviation Institute Yu. Ravikovich, Acting Head of the city district Dubna S. Kulikov and others.

The following persons took part in discussions: Deputy Head of Administration of RF President in scientific-educational policy E. Nechaeva, Deputy Chairman of the FC Committee V. Smirnov, members of the FC Committee E. Greshnyakova, N. Kosikhina, O. Khokhlova, V. Beketov, and S. Mikhailov.

On 28 October, the 19th meeting of the RSA–JINR Joint Coordination Committee started in a videoconference format. The JINR party was headed by Head of the JINR International Cooperation Department D. Kamanin. Co-chairman on behalf of the RSA party was D. Adams, Acting Deputy Director General for Research Development and Support at the Department of Science and Innovation of the Government of the RSA.

FLNR Deputy Scientific Leader M. Itkis made a report on the topical issues of the Institute's development. UC Director S. Pakuliak told the audience about a recently launched JINR distant educational programme INTEREST. At the end of discussions, the parties expressed a common opinion that this programme is a promising platform for the development of bilateral cooperation in the educational field. D. Kamanin presented proposals on the launch of strategic cooperation projects developed together with partners from the RSA. These projects relate to the RSA's participation in the NICA/SPD collaboration, technological issues of cooperation in the fields of heavy-ion accelerators, the regional cloud infrastructure on the DIRAC platform for the SKA project, underground laboratories and the construction of the future neutron source IBR-3.

On 30 October, the 27th meeting of the Coordination Committee on the implementation of the Agreement between the German Federal Ministry of Education and Research (BMBF) and JINR was held in a videoconference format. The German delegation was headed by BMBF Coordinator for cooperation with JINR J. Kroseberg representing the department "Universe and Matter". Vice-Director B. Sharkov co-chaired the meeting on behalf of JINR.

The previous meeting, as the current one, and a number of working meetings held this year focused on the in-depth discussion of the new format aimed, first of all, at attracting scientific youth. As a result, the scientific programme of cooperation will be formed in the framework of three programmes: the Heisenberg–Landau Programme in the field of theoretical physics, the Neutron Programme and Programme of Young Scientists. Both parties will make special efforts to attract young scientists and to promote their scientific careers in the framework of the implementation of joint scientific projects in the priority areas of cooperation between JINR and German scientific organizations and universities. A steering committee will be formed for each programme.

The Coordination Committee discussed the financing issues of the programmes, peculiarities of work during a two-year period of transition to a new cooperation format, formation of the management committees, the results of current joint activities and the procedure for reviewing applications for joint projects up to the end of 2020. It is expected to finish applications processing, including for new projects, by mid-December.

The key event of the meeting of the Coordination Committee was the signing of an agreement between JINR and FAIR/GSI on the establishment of a series of DD (Dubna–Darmstadt) joint international schools. B. Sharkov and FAIR/GSI Science Director P. Giubellino signed the document. In the framework of an 8-day programme of the school, young scientists from JINR and FAIR/GSI Member States will have opportunities to listen to lectures on the most relevant and most important areas of modern science. Both the experiment and the theory are presented covering, in particular, the topics of hadron and nuclear physics, atomic physics, plasma physics, materials science, biophysics and radiation medicine, accelerator physics, detector studies and developments, micro/nanoelectronics, information technologies and high-performance computing, etc. An important component of the work of the school will be practical classes, in which students will solve real problems under the guidance of lecturers. The document provides financing of the school by both parties.

On 6 November, the transportation of the superconducting magnet for the MPD detector to the site of the NICA project in Dubna was successfully finished. Before arriving at Dubna, the case with the magnet was transported by sea from Genoa (Italy) to St. Petersburg. The cryostat with superconducting winding of the magnet for the MPD detector was designed by Russian scientists (specialists of JINR and the "Neva-Magnit" SDPC) and produced in Italy at the enterprise "ASG superconductors", one of few manufacturers of unique equipment for large-scale scientific research projects in the world, in particular, for the Large Hadron Collider at CERN.

The height of the case with the transportation platform was 7.6 m, the total weight was 120 t. The distance of 2.8 km from the Dubna port to the MPD pavilion at VBLHEP was covered in 3 hours as the transportation of the cryostat demanded absolute accuracy of the schedule and scrupulous attitude to smallest wavering of the case. Parts of the city communications were temporally dismounted for the smooth and safe delivery.

On 11 November, the Joint Institute for Nuclear Research took part in the second Russian–German scientific and educational exhibition at which Russian and German universities, scientific organizations and scientific funds presented their joint programmes.

The exhibition was organized in the framework of the Russian–German Scientific and Educational Partnership Year 2018–2020 held under the patronage of the Minister of Foreign Affairs of the Russian Federation and the Federal Minister for Foreign Affairs of the Federal Republic of Germany, as well as with the support of the Ministry of Science and Higher Education of Russia, coordinators of the Year, namely, NUST MISIS, the German Academic Exchange Service (DAAD), and the German House for Research and Innovations (DWIH) in Moscow.

JINR was one of the pioneers of a new format for the organization of international exhibition space and successfully presented a wide range of tools for the development of scientific and educational cooperation, from the international programme for students INTEREST to cooperation in the framework of the NICA megaproject.

On 17 November, Dr. V. Soare, Ambassador Extraordinary and Plenipotentiary of Romania to the Russian Federation, and L. Constantiniu, Counsellor on Education and Science, visited the Joint Institute for Nuclear Research. They met with representatives of the national group of JINR Romanian staff members in the conference hall of the JINR Club of Scientists.

At the Directorate, they were received by JINR Director V. Matveev, First Vice-Director G. Trubnikov, Vice-Director R. Lednický, LIT Director V. Korenkov, Deputy Scientific Leader of FLNR M. Itkis, Head of the International Cooperation Department D. Kamanin, Head of the Romanian staff members group G. Adam, and Deputy Director of FLNP O. Culicov.

The guests were informed about the achievements of the Institute and future plans of its development; the contribution of Romanian scientists and specialists to the activities of JINR was highly evaluated. In their turn, V. Soare and L. Constantiniu stressed the important role of the Joint Institute in training scientific staff and development of physics in Romania, and expressed their hope for even more fruitful co-operation in future.

On 20 November, during a working visit to Dubna, Prime Minister of the Russian Federation M. Mishustin put one of the main blocks of the megascience project "NICA Complex" — the superconducting booster synchrotron (booster) — into operation.

The Prime Minister was accompanied by Deputy Prime Minister D. Chernyshenko, Minister of Science and Higher Education of the Russian Federation V. Falkov, and Governor of the Moscow Region A. Vorobyev.

The Head of the Russian Government gave start to the operation of the superconducting accelerator by pressing a symbolic button. Young scientists participating in the project's implementation also took part in the ceremony.

On 16 December, VBLHEP Director, JINR Vice-Director RAS Corresponding Member V. Kekelidze gave a talk in the Federation Council of the Russian Federation in the framework of the "Expert Time" project, a regular meeting of senators with world-renowned scientists, politicians, directors, and artists.

In his report, V. Kekelidze spoke about scientific tasks of the NICA project, its key experimental facilities, as well as plans for the launch of the complex the construction of which is scheduled to be completed in 2021. The speaker presented to senators the experience of passing expert examinations by the project, including European commissions for science. V. Kekelidze also presented JINR practices on the creation and work organization of international scientific collaborations in the framework of the MPD and SPD experiments at the NICA complex.

V. Kekelidze paid special attention to the potential of applied research on the basis of the NICA complex. In particular, he noted that compact superconducting magnets, whose technology was worked out at JINR and which are the basis of the complex, are most advanced for development of cost-efficient accelerators at modern centres of ray therapy. Moreover, the speaker noted the capabilities of one of the largest and the most efficient cryogenic complex in Russia, which allows conducting large-scale scientific developments using temperatures close to absolute zero. For example, it is used for the creation of storage facilities and transportation systems for liquid gases. According to V. Kekelidze, in the framework of the project "NICA Complex", a megawatt energy storage is being created that has no analogues in the world. It is being developed on the basis of the superconducting cable created in Dubna, which is at the heart of the entire cryogenic complex of VBLHEP. Besides, it is possible to reproduce the entire range of particles of ionizing radiation at the NICA accelerator complex. This allows developing the JINR research into effects of space radiation on living organisms, including during long-distance flights into space. It also gives an opportunity to develop radiation-resistant electronics.

The speaker also presented to the members of the Federation Council proposals based on the milestones of the meeting. It was proposed to take into account the experience of the science city of Dubna where a unique model of interaction had formed between federal, regional, and municipal levels of the government, advanced science and production, the Special Economic Zone, and the international scientific organization — JINR.

Speaker of the Federation Council V. Matvienko noted the necessity to create legal conditions for successful development of megaprojects. The Speaker of the Federation Council instructed Chairman of the Federation Council Committee on Science, Education and Culture L. Gumerova to continue working jointly with scientists on drafting a roadmap for updating the legislative framework of the Russian Federation for the areas of science and scientific and technological development of Russia.

On 16 December, the JINR Directorate congratulated the national group of the Republic of Kazakhstan on the Independence Day of the Republic of Kazakhstan via videoconference.

In his congratulatory speech, JINR Vice-Director G. Trubnikov noted successes of the co-operation of JINR with scientific centres of Kazakhstan, as well as highly evaluated work of a young and dynamically developing national group of the Republic of Kazakhstan at the Institute. The group not only demonstrates high scientific results but also plays an active role in JINR social life.

Head of the national group of the Republic of Kazakhstan D. Aznabayev and his deputy A. Issadykov spoke about the development of the scientific infrastructure at the Institute of Nuclear Physics in Almaty. A number of proposals were also voiced for the cultural programme of the 65th JINR anniversary: in particular, to organize an online seminar due to the 15th anniversary of the DC-60 accelerator, built in Kazakhstan with the participation of JINR specialists.

At the end of December, an online opening ceremony of the Information Centre of JINR on the platform of the Academy of Scientific Research and Technology (ASRT) of the Arab Republic of Egypt (ARE) was held. The event took place with the participation of representatives of the ARE Government, leaders of JINR, ASRT, and the North Ossetian State University (NOSU), as well as some honorary guests from the Member States and partner countries of JINR. A representative international seminar dedicated to the concept of JINR Information Centres was organized on the eve of the opening ceremony.

ASRT Vice-President for Culture and Scientific Communication G. El-Feky and JINR Director V. Matveev welcomed participants of the meeting. Chief Scientific Secretary A. Sorin, Head of the International Cooperation Department D. Kamanin, Director of the University Centre S. Pakuliak, and W. Badawy, Head of the National Group of Egypt at JINR and the Coordinator of the cooperation with Egypt, took part in the ceremony as well on behalf of the Joint Institute.

The event was continued with key presentations on the JINR scientific infrastructure and opportunities for increasing the cooperation on the basis of the newly opened Information Centre. JINR Vice-Director B. Sharkov spoke about the concept of the JINR development until 2030. ASRT President M. Sakr presented the main results of the Egypt–JINR cooperation, which included 100 scientific projects and more than 120 final publications.

Minister of Higher Education and Scientific Research of Egypt Kh. Abdul Ghaffar congratulated the audience on the opening of the Information Centre in Cairo. A. Ogoev, Rector of the North Ossetian State University on the basis of which the JINR Information Centre was opened, passed a symbolic key of the new JINR Information Centre to ASRT.

During the live broadcast from ASRT, Minister Kh. Abdul Ghaffar and ASRT President M. Sakr cut the symbolic red ribbon and solemnly opened the plaque of the JINR Information Centre, which marked the official start of operation of the first JINR Information Centre on the African continent.

JINR Vice-Director and Co-Chairman of the Joint Coordination Committee on the ARE–JINR Cooperation R. Lednický congratulated colleagues from ASRT. Honorary guests of the event made speeches in the final part of the opening ceremony. Among them were Deputy Director of the Institute of Experimental and Applied Physics of the Czech Technical University I. Štekl, Director General of the Institute of Atomic Physics (IFA) and Plenipotentiary of the Government of Romania to JINR F.-D. Buzatu, Director General of the Arab Atomic Energy Agency (AAEA) located in Tunis S. Hamdi, and others.

On 30 December, the extended meeting of the JINR Directorate was held, at which milestones of the Institute's activities in 2020 were summed up.

The key issue of the meeting's agenda was the report by JINR Director Academician V. Matveev, in which he noted the main results achieved in the laboratories and offices of the Institute. V. Matveev noted that, in spite of difficult working conditions caused by the pandemic, the JINR staff acted as a team, managed to implement most of the plans and achieve bright results in the flagship projects, such as the launch of the Booster of the NICA collider and the first experiment at the Factory of Superheavy Elements. On the occasion of the expiration of the term of office of the JINR Director, V. Matveev expressed deep gratitude to all members of the Directorate and leaders of the Institute.

JINR Director-elect Academician G. Trubnikov, taking the office from 1 January 2021, noted personal merit of Academician V. Matveev that the Institute is currently in the excellent state. G. Trubnikov conveyed greetings from Prime Minister of Russia M. Mishustin and Minister of Science and Higher Education V. Falkov to the audience on the occasion of the first beam at the NICA Booster. The elected Director highlighted that the changes in the Institute's management structure necessary for the implementation of these plans should not be revolutionary but evolutionary instead.

Participants of the meeting, among which there were members of the Directorate, heads of offices and laboratories of JINR, warmly thanked V. Matveev for work done as the JINR Director and expressed hope to continue joint work in the future with V. Matveev as JINR Scientific Leader.

Summary information was traditionally provided by heads of JINR laboratories and departments as well. W. Chmielowski, S. Dmitriev, S. Dotsenko, M. Itkis, D. Kamanin, D. Kazakov, V. Kekelidze, R. Lednický, B. Sharkov, V. Shvetsov, A. Sorin, and A. Tamonov spoke at the concluding meeting of the JINR Directorate.

CONFERENCES AND MEETINGS HELD BY JINR

Seven conferences were the largest among the scientific conferences and workshops held at JINR in 2020.

From 27 January to 1 February, the 27th International Conference ***"Mathematics. Computing. Education" (MCE-2020)***, organized by Moscow State University, the Joint Institute for Nuclear Research, Dubna State University, the Keldysh Institute of Applied Mathematics of RAS, the interregional public organization "Women in Science and Education" and other leading scientific centres, was held at Dubna State University.

At the opening of the scientific forum, JINR Director RAS Academician V. Matveev acquainted the conference participants with the JINR scientific programme, Rector of Dubna State University D. Fursaev spoke about the latest discoveries in cosmology and astrophysics, and Director of the Institute of System Analysis and Management of Dubna State University Eu. Cheremisina described the innovative principles of IT education for preparing specialists at ISAM of Dubna University.

Since the MCE conference is interdisciplinary, the programme was intensive and comprised plenary sessions, oral and poster presentations, round tables, lectures, tutorials, etc. The following reports are noteworthy: Director of LIT V. Korenkov introduced a digital platform for megascience projects, Director of VBLHEP V. Kekelidze devoted his report to the NICA megascience project, Director of LRB A. Bugay dwelt upon the issues of modeling in modern approaches to improving the efficiency of radiation therapy of tumors, and Scientific Leader of FLNR Yu. Oganessian reported on the prospects for the synthesis of new superheavy elements.

The scientific forum brought together a large number of participants from different regions of Russia and European countries. Next year the traditional conference will take place in Pushchino.

On 20–21 April, ***the 5th Collaboration Meeting of the BM@N Experiment at the NICA Facility*** was held via videoconference at the Veksler and Baldin Laboratory of High Energy Physics.

At the meeting, the recent results obtained with C and Ar beams were discussed. The main focus was on the data collected in carbon–nucleus interactions for preparation for publication in a refereed journal; the status of the results obtained in the data analysis of argon–nucleus interactions was also discussed. The plans for research in the field of heavy-ion physics were reviewed. Organizational issues of the BM@N collaboration were discussed at a separate meeting on 20 April.

On 23–24 April, ***the 5th Collaboration Meeting of the MPD Experiment at the NICA Facility*** was held at VBLHEP as an online conference. The main purpose of the meeting was to assess the level of detector readiness, including software development, discussion of physics tasks and results obtained by the collaboration, as well as consideration of current organizational issues of MPD.

The meeting included sessions on physics and detector readiness open for all MPD collaborators, as well as a closed meeting of the MPD collaboration leadership.

On 20–23 October, the international conference ***"RFBR Grants for NICA"*** was held at VBLHEP. It was attended by representatives of the Russian Foundation for Basic Research, Leaders of the NICA project, employees of the Institute and the JINR Member States, responsible for the implementation of works supported by the RFBR. The meetings were held via videoconferencing. The conference was of a summary nature and was aimed at discussing the results of the performed work and confirming the practicability of further grant support from the RFBR.

Ninety-seven applications were submitted for the competition on the topic "Fundamental properties and phase transitions of hadron and quark–gluon matter: Megascience facility NICA Complex", which was announced in 2018. Thirty-six projects were supported within the competition; that is, 37% of the applications were approved by the expert groups of the foundation.

The conference was opened by JINR Director V. Matveev, wishing the participants successful and fruitful work. Head of the Directorate of the NICA project, JINR First Vice-Director G. Trubnikov noted, in particular, that the RFBR supports several dozen projects at JINR, mainly on the NICA accelerator complex under construction, and that several hundred scientists from all over the world had joined the collaboration, partly owing to the RFBR support.

At the opening of the conference, Deputy Chairman of the RFBR Board V. Kvardakov conveyed greetings to participants of the meeting from Chairman of the RFBR Board V. Panchenko. V. Kvardakov acquainted the participants with the activities of the foundation, created in 1992. The foundation unites and supports today 90 thousand researchers in 66 regions of the Russian Federation, including 10 thousand young scientists and specialists. With the support of the foundation, more than 300 scientific events have been held, more than 250 books and monographs have been published. The Joint Institute for Nuclear Research has received grants for 266 projects, and in some years, they reached almost a hundred. In total, in 2020, the RFBR supported 43 projects of the Institute. In the list of regions for grants, Dubna ranks second after Moscow, in the list of JINR scientific centres it is in the first place.

JINR Vice-Director V. Kekelidze, Leader of the NICA project, also welcomed the participants of the conference and expressed gratitude to the leadership of the RFBR and active participants of cooperation.

The plenary part of the conference was opened by the reports of Leaders of the NICA project. The structure of the project and the progress of its implementation were presented in the report of G. Trubnikov, A. Kisiel spoke about the MPD collaboration, P. Senger reported on the physics programme and modernization of the BM@N facility, and O. Teryaev presented the contribution of JINR theorists to the NICA physics programme. Several reports were devoted to the development of the SPD concept. In total, 51 plenary reports and 52 in six parallel sections were heard, including reviews of the FAIR, LHC and RHIC accelerator complexes. Proceedings of the conference will be published in special issues of the journal “Physics of Elementary Particles and Atomic Nuclei” (PEPAN) in 2021.

On 26–27 October, ***the 6th Collaboration Meeting of the BM@N Experiment at the NICA Facility*** was held at VBLHEP. At the meeting, participants considered the issues of international cooperation connected with improving the BM@N experimental facility for future work at heavy-ion beams in the framework of the implementation of the NICA megascience project.

The event was opened by Leader of the NICA project, JINR Vice-Director V. Kekelidze. The meeting was held as a videoconference so that about 120 registered participants from different countries could take part in the event. There were traditionally three plenary sessions dedicated to detectors, software and experimental data processing.

At the plenary sessions on the BM@N experiment, the participants actively discussed the latest results of experimental data analysis acquired by using relativistic beams of carbon and argon ions. During the irradiation of the facility, about 150 million events have been registered, the analysis of which allowed obtaining information about the production of strange particles acquired in interactions of “medium” ion beams with various targets. The report by scientific partners of the BM@N experiment on the status of the SRC project evoked considerable interest. Studies on the search for short-range nucleon–nucleon correlations in the framework of the SRC are carried out using the BM@N detector subsystems. The participants paid much attention to the discussion of the status of the preparation for the SRC experimental programme in 2021. The issues related to the development of software for detector subsystems of the facility and the experimental data analysis were discussed in detail in parallel sections.

In general, the participants of the meeting noted obvious progress in both experimental data analysis and the preparation of the facility for future runs, the first of which is planned for the autumn of 2021.

The list of reports and presentations are available via the link https://indico.jinr.ru/event/1533/timetable/#20201026.

On 28–30 October, ***the 6th Collaboration Meeting of the MPD Experiment at the NICA Facility*** took place at VBLHEP by videoconference. Almost 150 scientists and specialists from Europe, Asia, and the Americas took part in the meeting, ensuring lively, interesting, and constructive discussions. At the beginning of the meeting, JINR Vice-Director, Leader of the NICA project V. Kekelidze welcomed participants of the meeting.

S. Kostromin presented a report on the progress in the creation of the NICA accelerator complex and described in detail the degree of completion of each of the numerous project elements. The speaker concluded that the works were in full swing to provide the first Run at the NICA collider at the end of 2022.

A detailed report on the status of the MPD project was presented by the Spokesperson of the MPD collaboration A. Kisiel. He noted the steady growth of the international collaboration and active participation of MPD members in the preparation for physics analysis in the framework of the MPD PWG (MPD Physics Working Groups).

The plan of activities was described in detail by the MPD Technical Coordinator V. Golovatyuk. Comprehensive reports were given on the status of major detectors, such as the Time Projection Chamber (TPC), the Time-of-Flight (TOF) and Electromagnetic Calorimeter (ECal). An important milestone is the start of production of ECal modules by the Chinese institutions, thanks to the recent agreement with the Chinese Ministry of Science and Technology and the allocation of dedicated funding.

On the second day, detailed reports were given on the development of MPD software and computing infrastructure located at VBLHEP as well as at the Laboratory of Information Technologies of JINR. The Institutional Board of MPD approved the allocation of the Common Fund for the Collaboration and other important organizational matters during the special session.

The last day of the meeting was devoted to in-depth reviews of activities in physics analysis planned for the initial operation of NICA. The convenors of the MPD Physics Working Groups, as well as several international collaborators, participated in the discussion.

From 9 to 13 November, ***the XXIV International Scientific Conference of Young Scientists and Specialists of JINR (AYSS-2020)*** took place in the online format. The number of participants reached 138, including 108 JINR employees and 30 colleagues from 23 universities and scientific centres of Germany, India, Kazakhstan, Poland, Romania, Russia, Serbia, Slovakia, Ukraine, and Vietnam.

A plenary lecture at the conference was given by JINR First Vice-Director G. Trubnikov. He devoted the lecture to the JINR long-term development plan. Moreover, the programme of the conference included 4 lectures on the topical issues of modern science. Professor of the Sternberg Astronomical Institute of MSU S. Popov spoke about the life of neutron stars with an evolving magnetic field. Professor R. Ospanov reported on the discovery of the Higgs boson and some results of the LHC operation on behalf of the ATLAS collaboration. Candidate of Physics and Mathematics of the Russian Institute of Radiology and Agroecology P. Volkova spoke about the importance of cosmic technologies in radiation biology. FLNP Director V. Shvetsov closed the plenary part of the conference with a report on the JINR Neutron Programme. Records of plenary lectures are available on the website of the conference and on the YouTube channel jinrtv.

The participants of the event in their turn presented 115 oral reports in 9 sections. The topics of reports covered theoretical physics, mathematical modelling and computational physics, high-energy physics, accelerators and nuclear reactors, experimental nuclear physics, applied research, information technologies, condensed matter physics, life sciences. The JINR researchers who supervised the sections evaluated and selected the best reports, and their authors received honorary diplomas.

Despite the online format, the conference was held in a friendly atmosphere, allowing the participants to meet colleagues from different countries and to discuss the results of their research.

PARTICIPATION OF JINR IN INTERNATIONAL CONFERENCES

In 2020, scientists and specialists of the Joint Institute for Nuclear Research took part in 183 international conferences and meetings.

The largest delegations representing JINR attended the following events: 15th JUNO Collaboration Meeting (Nanning, China); LHCOPN/LHCONE Workshop (Geneva, Switzerland); 33rd ICP Vegetation Task Force Meeting (Riga, Latvia); meeting (scientific conference) of the Paleontology Section of the Moscow Society Nature Investigators and the Moscow Branch of the RAS Paleontology Society "Paleostrat-2020" (Moscow, Russia); 4th EOS Workshop (Geneva, Switzerland); Workshop on Correlations in Patronic and Hadronic Interactions (CPHI-2020) (Geneva, Switzerland); 5th Topical Workshop on Modern Aspects in Nuclear Structure (Bormio, Italy); Meeting of Scientific Advisory Committee FAIR-CZ (Prague, Czech Republic); 3rd All-Russian Scientific and Educational Congress "Oncoradiology, X-Ray Diagnostics and Therapy" (Moscow, Russia); STS Module & Ladder

Assembly Retreat (Grasellenbach, Germany); CREMLINplus Kick-off Workshop (Hamburg, Germany); 21st Winter Youth School on Biophysics and Molecular Biology (Repino, Russia); 2nd Conference on Neutrino and Nuclear Physics (CNNP2020) (Kleinmond, RSA); NUSTAR Annual Meeting 2020 (Darmstadt, Germany); 38th HADES Collaboration Meeting (Dresden, Germany); session-conference of the Nuclear Physics Section of the Department of Physics of RAS (Novosibirsk, Russia); 24th International Symposium "Nanophysics and Nanoelectronics" (Nizhni Novgorod, Russia); 54th School on Condensed State Physics (St. Petersburg, Russia); 10th All-Russian Conference "Information and Telecommunication Technologies and Mathematical Modeling of High-Tech Systems" (ITTMM, online) (Moscow, Russia); 27th Scientific and Practical Conference of Students, Postgraduates and Young Specialists (at Dubna University) (Dubna, Russia); scientific conference "New Materials of the XXI Century: Development, Diagnostics, Usage" (Moscow, Russia); 16th JUNO International Collaboration Meeting (online) (Beijing, China); 40th International Conference on High Energy Physics (ICHEP 2020; online) (Prague, Czech Republic); Asia-Pacific Symposium for Lattice Field Theory (APLAT 2020; online) (Tsukuba, Japan); international conference "Nanotechnology and Nanomaterials" (NANO-2020; online) (Lviv, Ukraine); conference "Computer Algebra in Scientific Computing" (CASC 2020; online) (Linz, Austria); 7th International Congress on Energy Fluxes and Radiation Effects (EFRE 2020) (Tomsk, Russia); 21st International Conference "Physical-Chemical and Petrophysical Studies in the Earth Sciences" (Moscow, Russia); scientific conference "Supercomputer Days in Russia" (online) (Moscow, Russia); 2nd International Conference on Molecular Modeling and Spectroscopy (ICMMS2; online) (Cairo, Egypt); 5th International Conference on Particle Physics and Astrophysics (ICPPA-2020; online) (Moscow, Russia); 1st National Congress on Cognitive Research, Artificial Intelligence and Neuroinformatics (CAICS 2020; online) (Moscow, Russia); All-Russian Festival of Science NAUKA 0+ (Moscow, Russia); 70th International Conference "Nucleus-2020. Nuclear Physics and Elementary Particle Physics. Nuclear Physics Technologies" (1st part; online) (St. Petersburg, Russia); International Conference on Computer Simulation in Physics and Beyond (CSP 2020) (Moscow, Russia); conference "Polynomial Computer Algebra" (St. Petersburg, Russia); 36th CBM Collaboration Meeting (Darmstadt, Germany); Conference and School for Young Scientists "Thermorentgenography of Nanomaterials" (online) (St. Petersburg, Russia); 3rd International Conference and Exhibition "Modern Network Technologies" (online) (Moscow, Russia); 12th International Conference "Carbon: Fundamental Problems of Science, Material Science, Technology" (CFPMST 2020) (Troitsk, Russia); 32nd International Workshop on High Energy Physics "Hot Problems of Strong Interactions" (online) (Protvino, Russia); International Conference of Students, Postgraduates and Young Scientists "Lomonosov-2020" (online) (Moscow, Russia); 2nd International Turkic World Congress on Science and Engineering (TURK-COSE 2020; online) (Nursultan, Kazakhstan); 2nd School for Young Scientists "High-Performance Platforms for Digital Economy and MegaScience Projects" (Moscow, Russia); All-Russian Scientific and Practical Conference "Nature. Society. Man" (Dubna, Russia); 10th Tastes of Nuclear Physics (online) (Bellville, RSA); scientific conference "50 Years of the RAS Institute for Nuclear Reasearch" (online) (Troitsk, Russia); workshop "New Achievements in Mathematical Physics" (online) (Bonn, Dubna, Tbilisii, Yerevan); EUROASIA Congress on Scientific Researches and Recent Trends-VII (online) (Baku, Azerbaijan); conference "Cosmic Rays and Neutrinos in the Multi-Messenger Era" (online) (Paris, France); 32nd Daya Bay Collaboration Meeting (online) (Beijing, China); International Conference in Memory of M. K. Polivanov "Polivanov — 90" (online) (Moscow, Russia); SAINTS @ tlabs Physics Summer School (2nd RSA–JINR School at iThemba LABS) (Somerset West, RSA); RSA–JINR Workshop on the Roadmap for Collaboration in Theoretical Physics (1st RSA–JINR Workshop on Theoretical Physics) (Franschhoek, RSA); RSA–JINR Round Table Meeting "Experimental Study with Light RIB at ACCULINNA-2" (Pretoria, RSA); 30th Meeting of the Joint Committee on the Collaboration IN2P3–JINR (Paris, France); workshop "Prospects of Cooperation with Eurasian Countries — Members of JINR" (Baku, Azerbaijan); Open Days in Serbia (Belgrade, Serbia); 9th Annual Scientific Conference of Young Scientists and Specialists of JINR (ALUSHTA 2020) (Alushta, Russia); 20th JINR–ISU Baikal Summer School on Physics of Elementary Particles and Astrophysics (online) (Bolshiye Koty, Russia).

DEVELOPMENT OF THE JINR INTERNATIONAL COLLABORATION AND RELATIONS OF THE YEAR 2020

1.	Number of short-term visits to JINR by specialists from the Member States (not counting Russian specialists)	113
2.	Number of visits of specialists from other countries,	127
	including visits of specialists from the Associate Members	63
3.	Number of visits by JINR specialists to the Member States (not counting missions within Russia)	256
4.	Number of visits by JINR specialists to other countries,	399
	including visits of specialists to the Associate Members	127
5.	Number of conferences, schools, and meetings held by JINR	40
6.	New cooperation agreements (memoranda of understanding), addenda to existing ones	180

LIST OF CONFERENCES, SCHOOLS, AND MEETINGS HELD BY JINR IN 2020 *

No.	Name	Place	Date	Number of participants
1.	SAINTS@tlabs Physics Summer School 2020 (2nd JINR–RSA School at iThemba LABS)	Somerset West, RSA	9–30 January	61
2.	51st meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	20–21 January	71
3.	Meeting of the Working Subgroup WSG-5 of the International Working Group for Preparation of the JINR Strategy Plan	Dubna	21 January	20
4.	RSA–JINR Woprkshop on the Roadmap for the Collaboration in Theoretical Physics (1st RSA–JINR Woprkshop on Theoretical Physics)	Fransch-hoek, RSA	26–28 January	40
5.	26th International Conference “Mathematics. Computer. Education”	Dubna	27 January – 1 February	225
6.	51st meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	30–31 January	24
7.	RSA–JINR Round Table Meeting “Experimental Study with Light RIB at ACCULINNA-2”	Pretoria, RSA	30–31 January	15
8.	52nd meeting of the Programme Advisory Committee for Particle Physics	Dubna	3–4 February	44
9.	30th meeting of the Joint Committee on the IN2P3–JINR Collaboration	Paris, France	11 February	10
10.	9th Open Robotic Tournament (CyberDubna 2020)	Dubna	14–16 Feb-ruary	67
11.	International symposium “Challenges and Trends in Strategic Development of Modern Physics”	Dubna	19 February	49
12.	127th session of the JINR Scientific Council	Dubna	20–21 Feb-ruary	73

* A number of conferences were held jointly with other organizations.

No.	Name	Place	Date	Number of participants
13.	Meeting of the Cost and Schedule Review Committee for the NICA Project	Dubna	24–26 February	17
14.	15th JINR Training Course "JINR Expertise for Member States and Partner Countries" (JEMS-15)	Dubna	25–28 February	13*
15.	Workshop "Prospects of Cooperation with Eurasian Countries — Members of JINR"	Baku, Azerbaijan	1–5 March	14
16.	Open Days of JINR in Serbia	Belgrade, Serbia	5–6 March	150
17.	5th Collaboration Meeting of the BM@N Experiment at the NICA Facility (online)	Dubna	20–21 April	108
18.	5th Collaboration Meeting of the MPD Experiment at the NICA Facility (online)	Dubna	22–23 April	157
19.	11th session of the Machine Advisory Committee for NICA	Dubna	27–29 May	28
20.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States (online)	Dubna	19 June	79
21.	Kick-off Meeting on the JINR–RSA Project "Nuclear Physics Methods in Ecological Research at the Southern Coast of Africa" (online)	Dubna	23 June	6
22.	52nd meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	25 June	70
23.	53rd meeting of the Programme Advisory Committee for Particle Physics	Dubna	29 June	51
24.	52nd meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	2 July	70
25.	32nd Summer International Computer School (online)	Dubna	20 July – 1 August	37
26.	Summer School of JINR Young Scientists and Specialists "Lipnya-2020"	Dubna	24–26 July	65
27.	128th session of the JINR Scientific Council (online)	Dubna	17 September	76
28.	9th Annual Scientific Conference of Young Scientists and Specialists of JINR in Alushta (Alushta-2020)	Resort Hotel "Dubna", Alushta, Russia	26 September – 3 October	64
29.	20th JINR–ISU Baikal Summer School on Physics of Elementary Particles and Astrophysics (online)	Bolshiye Koty, Russia	15–26 October	55
30.	International conference "RFBR Grants for NICA"	Dubna	20–23 October	184
31.	6th Collaboration Meeting of the BM@N Experiment at the NICA Facility (online)	Dubna	26–27 October	118
32.	6th Collaboration Meeting of the MPD Experiment at the NICA Facility (online)	Dubna	28–30 October	151

* Only trainees.

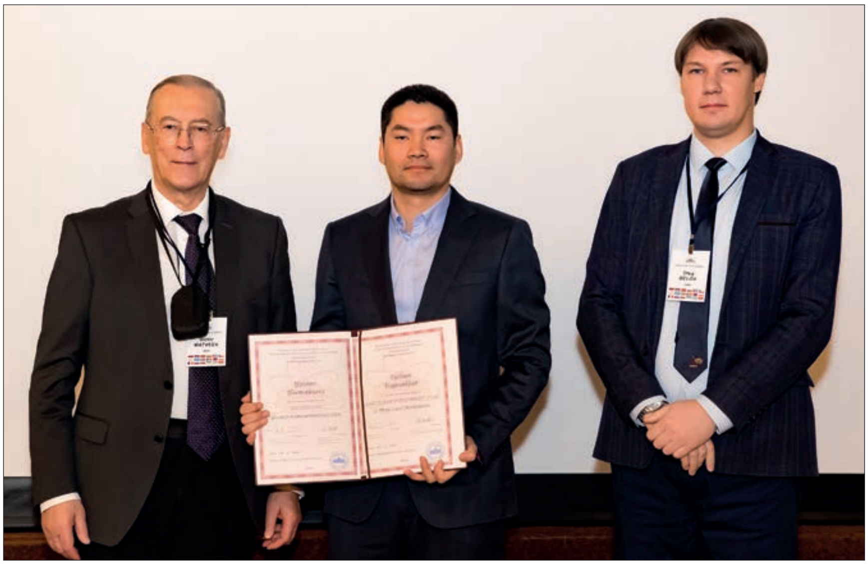
No.	Name	Place	Date	Number of participants
33.	Meeting of the Working Group under the Committee of Plenipotentiaries Chairman on Financial Issues of JINR (online)	Dubna	29 October	36
34.	24th International Scientific Conference of Young Scientists and Specialists of JINR (AYSS-2020; online)	Dubna	9–13 November	121
35.	Meeting of the JINR Finance Committee (online)	Dubna	19 November	59
36.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States	Dubna	23 November	83

Five meetings of the JINR Science and Technology Council were also held. Besides, JINR was one of the organizers of the 70th International Conference "Nucleus-2020. Nuclear Physics and Elementary Particle Physics. Nuclear Physics Technologies" (1st part, online) and the 27th International Seminar "Nonlinear Phenomena in Complex Systems".

The Joint Institute for Nuclear Research is an international intergovernmental scientific research organization, the activities of which are based on principles of openness for participation to all interested states and of their equal, mutually beneficial collaboration.

Dubna, 19 June. Participants of the JINR CP session

Dubna, 23 November. JINR CP session at which Academician G. Trubnikov (left) was elected as Director of the Institute



Dubna, 20–21 February. The 127th session of the JINR Scientific Council

Dubna, 17 September. The 128th session of the JINR Scientific Council held by videoconference

Dubna, 19 November. A meeting of the JINR Finance Committee

Dubna, 30–31 January. Participants of the 51st meeting of the PAC for Nuclear Physics

Dubna, 20–21 January. The 51st meeting of the PAC for Condensed Matter Physics

Dubna, 3–4 February. The 52nd meeting of the PAC for Particle Physics

Dubna, 25–27 February. A delegation of the University of Pretoria (RSA) headed by Vice-Chancellor and Principal T. Kupe on a visit to JINR

Baku, 2 March. The workshop “Prospects of Cooperation with Euroasian Countries — Members of JINR”

Belgrade (Serbia), 4–7 March. Open Days of JINR in Serbia

Dubna, 20 July. The JINR diplomas on conferring academic degrees were awarded. In the photo from right to left: G. Trubnikov, V. Kekelidze, V. Matveev, D. Sumkhuu, A. Rutkauskas, M. Omelyanenko, V. Arefiev, A. Sorin and O. Belov

Dubna, 26 August. The opening ceremony of the Year of Russian–Chinese Cooperation in Science, Technology and Innovation, assisted by the JINR delegation via videoconference

Dubna, 18 September. The memorial seminar and laying flowers dedicated to the 110th anniversary of the birth of M. Meshcheryakov

Dubna, 25 September. Visit to JINR by First Deputy Chairman of the State Duma Committee on Health Protection of the Federal Assembly of the Russian Federation N. Sanina (centre)

Dubna, 18 September. The JINR delegation participating in the 24th meeting of the Russian–Chinese subcommission for scientific and technical cooperation, held through videoconference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Dubna, 22–23 October. A visiting session of the Federation Council Committee on Science, Education and Culture

Moscow, 16 December. Speech of Director of VBLHEP, JINR Vice-Director Corresponding Member of RAS V. Kekelidze in the RF Federation Council (*courtesy: Federation Council*)

December. An online opening of the JINR Information Centre in the Academy of Scientific Research and Technology of the Arab Republic of Egypt. A welcoming speech by JINR Director V. Matveev via video link

2020

RESEARCH AND EDUCATIONAL PROGRAMMES OF JINR

BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

In 2020, at the Bogoliubov Laboratory of Theoretical Physics (BLTP) studies were carried out on the following four themes: Fundamental Interactions of Fields and Particles; Theory of Nuclear Systems; Theory of Complex Systems and Advanced Materials; Modern Mathematical Physics: Gravity, Supersymmetry and Strings. An important component of the BLTP activities is theoretical support of experimental research to be carried out within major international projects with the participation of JINR as well as Dubna-based experimental programs of JINR Laboratories. The research resulted in about 470 publications in peer-reviewed journals and proceedings of international conferences and one monograph. Most of the results were obtained in cooperation with scientists from the JINR Member States, Brazil, China, Egypt, Germany, India, Italy, France, South Africa, and other countries. Every year BLTP is a venue for scientific events of the highest level. In 2020, the Laboratory planned to organize 13 conferences and workshops and 3 schools for students and young scientists. However, due to the pandemic of the new coronavirus, all these events were postponed to the next year or canceled. At the same time, the BLTP researchers made over 110 reports at more than 60 conferences and workshops, both in person and at events held in an online format. The international collaboration was supported by the grants of the Plenipotentiaries of Bulgaria, the Czech Republic, Hungary, Poland, the Slovak Republic, Romania, and the JINR Directorate; the collaboration with German theorists was based on the Heisenberg–Landau Program; with Armenia, on the Smorodinsky–Ter-Martirosyan Program; with Polish theorists, on the Bogoliubov–Infeld Program; with Czech theorists, on the Blokhintsev–Votruba Program; and with Romanian theorists, on the Titeica–Markov Program. Collaboration with scientists from Western Europe was carried out in the framework of the JINR–INFN (Italy) and JINR–IN2P3 (France) agreements. The agreements for collaboration between the Bogoliubov Laboratory and APCTP (South Korea), ITP CAS (China) are functioning, as well as an active cooperation with theorists from CERN. Sixteen research projects were supported by the RFBR grants, three research projects, by the RSF. Traditionally, much attention was paid to recruiting young researchers, students, and postgraduate students to the Laboratory within the research and education project "Dubna International Advanced School of Theoretical Physics" (DIAS-TH); however, due to the coronavirus pandemic, the program for working with foreign young scientists was significantly reduced. The Laboratory plays the role of the training center for young scientists and students from many countries. Currently, about one third of the scientific staff are young scientists and PhD students. Within the JINR fellowship program for non-Member States, several researchers from China, Egypt, India, Iran, Japan, and Tajikistan have been working at BLTP on the long-term basis.

SCIENTIFIC RESEARCH

Fundamental Interactions of Fields and Particles. Theoretical investigations in 2020 were carried out in the framework of the following projects:

- Quantum field theory and physics beyond the Standard Model;
- QCD and spin/3D hadron structure;
- Strong interaction phenomenology and precision physics;

• Theory of hadronic matter under extreme conditions;

• Theory of electroweak interactions and neutrino physics.

Gauge covariance of the massless fermionic propagator was studied in three-dimensional quenched quantum electrodynamics (i.e., without internal fermion loops), within the framework of dimensional regularization. Assuming the finiteness of the coefficients of perturbative expansion and using the knowledge of the structure of the Landau–Khalatnikov–Fradkin transformation, it was obtained that exactly in three dimensions all odd perturbative coefficients, starting from the third, should be zero in any gauge [1].

The $U(1)$ extension of the Minimal Sypersymmetric Standard Model (MSSM) with nonuniversal charges was considered, and a possibility to account for flavor anomalies in $B \to K^*ll$ decays was analyzed. A scenario was proposed that not only solves the issue but also predicts certain hierarchy between two observables R_K and R_{K^*} that indicate lepton nonuniversality of possible New Physics. In addition, the angular observables for the $B \to K^*ll$ decay, which are sensitive to scalar operators, were studied in the context of Next-to-Minimal Sypersymmetric Standard Model (NMSSM) with light scalar bosons [2].

Nontrivial three-loop computations were carried out, which allows one to extract running strong coupling and quark masses from lattice results with high precision [3].

When the relic neutrino background was generated, it contained equal fractions of electron, muon, and tau neutrinos. It was shown that the gravitational field of our Galaxy and other nearby cosmic objects changes this composition near the Solar System, enriching it with tau and muon neutrinos. As a result, the relic electron neutrinos are the rarest for a terrestrial observer [4].

Measurements of the branching fractions of the semileptonic decays $B \to D^{(*)}\tau\overline{\nu}_\tau$ and $B_c \to J/\psi\,\tau\overline{\nu}_\tau$ systematically exceed the Standard Model (SM) predictions, pointing to possible signals of New Physics that can violate lepton flavor universality. The unknown origin of New Physics realized in these channels was investigated using a general effective Hamiltonian constructed from four-fermion operators and the corresponding Wilson coefficients. A fit of the Wilson coefficients was performed using all hadronic form factors from a covariant constituent quark model. Several new-physics scenarios were studied with the corresponding theoretical predictions provided, which are useful for future experimental studies [5].

The general properties of the B-meson decay form factors $F(q^2, q'^2)$, describing B-meson decays induced by two currents, e.g., B decays into four leptons in the final state, were investigated. The analytic properties of these complicated objects were studied, and those regions of q^2 and q'^2 were identified where perturbative QCD can be applied for obtaining predictions for the physical form factors [6].

For the first time, the energies of transitions in the molecular ion HD^+ were calculated with the highest precision of $\sim 10^{-11}$ in the framework of nonrelativistic quantum electrodynamics (QED). Measured rotational transition frequencies allow one to get the most accurate test of QED predictions in the three-body sector at the level of $5 \cdot 10^{-11}$, limited by the current uncertainties of the fundamental constants. The values of the fundamental constant combinations $R_\infty m_e(m_p^{-1} + m_d^{-1})$ and m_p/m_e were determined with fractional uncertainty of $2 \cdot 10^{-11}$. The results obtained provide a more than 20-fold stronger bound for a hypothetical fifth force between a proton and a deuteron [7].

A theorem was proven that generalizes the Naumov–Harrison–Scott identity to the case of neutrino propagation through absorbing medium. The derived identity sets up a direct connection between a combination of fundamental parameters of the lepton sector of the Standard Model (mixing angles, *CP*-violating phase, mass-squared splittings) in vacuum and its effective counterparts in matter which involves refractive indices, cross sections of inelastic interactions of neutrinos with matter and matter parameters. Of certain interest are studies of transformations of high-energy neutrino beams with a soft boundary spectrum in astrophysical media (relativistic jets, blast waves, AGNs, etc.), whose optical thickness along the neutrino beam is comparable to or larger than the neutrino mean free path [8].

Further development of the covariant quantum-field theory of neutrino oscillations was continued. A number of new results were obtained, in particular, a theorem was proven on the factorization of hadronic blocks of a connected macrodiagram at large spatial distances between its vertices; the properties of overlap tensors (determining the space-time regions of interaction of external wave packets) were studied in detail, and their explicit form was obtained for the major processes of the neutrino production and absorption, necessary for practical calculations of the decoherence effects. A number of effects potentially observable in terrestrial and astrophysical neutrino oscillation experiments were predicted and studied, e.g., a new oscillation regime on superlong (astronomical) baselines was investigated [9].

A phenomenological method was developed for calculating the differential cross sections for quasielastic interactions of (anti)neutrinos with nuclei, based on the standard relativistic Fermi gas model and introduction of a two-parameter function $M_A^{\rm run}(E_\nu)$ — the so-called "running" axial mass of the nucleon — into the axial (dipole) form factor. The parameters of this function were obtained from a thorough statistical analysis of available acceleration data [10].

The ξ-process implementation applied to the deeply virtual Compton scattering amplitude was demonstrated to ensure both the QCD and QED gauge invariance. The presented proof is very important for understanding the contour gauge used in different processes. In contrast to the standard axial-type gauge, the contour gauge, being a nonlocal kind of gauges, does not suffer from the residual gauge resulting in many technical difficulties for calculations [11].

The processes $\tau^- \to \pi^+\pi^-\nu_\tau$ and $e^+e^- \to \to \pi^+\pi^-$ were investigated beyond the $1/N_c$ approximation. It was shown that taking into account the pion interaction in the final state plays a very important role in these processes. The obtained results are in satisfactory agreement with the experimental data. The widths of the decays $\eta \to \pi^+\pi^-\gamma$ and $\eta' \to \pi^+\pi^-\gamma$ were calculated. The essential ambiguity related with the surface terms of anomalous triangle diagrams was used to satisfy the low-energy theorems for these processes. Besides, a new strategy for extracting the singlet–octet mixing angle from these processes was discovered [12].

It was found that the hydrodynamic properties of the relativistic medium associated with acceleration are determined by the phenomenon at the junction of quantum field theory and gravity — the Unruh effect. This conclusion was based on the calculation of quantum corrections associated with acceleration in the fourth order of the perturbation theory of quantum field theory at finite temperatures: they were shown to exactly satisfy the relations following from the Unruh effect. A wide range of field theories was considered: the theory of real and complex scalar fields in the framework of the usual and conformally symmetric formulations, the theory of Dirac fields, and the cases of massive and massless fields. In the case of massive scalar fields, the existence of infrared divergences was shown when calculating quantum field corrections with acceleration, and the summation of an infinite series of infrared diverging integrals was performed, which leads to a finite previously unknown nonperturbative contribution [13].

The paradox of a field of a moving locked charge (confined in a closed space) was solved with the use of the integral Maxwell equations. It was shown that the average electric field of locked charges does not depend on their Lorentz factors. The average electric field of protons moving in nuclei coincides with that of protons being at rest and having the same spatial distribution of the charge density. The electric field of a twisted electron is equivalent to the field of a centroid with immobile charges whose spatial distribution is defined by the wave function of the twisted electron [14].

In the framework of the quasipotential method in quantum electrodynamics, the Lamb shift (2P–2S), the energy intervals (1S–2S) and (1S–3S) and the isotopic shifts in the case of muonic ions of hydrogen, lithium, beryllium, and boron were calculated. The results on the light-by-light contributions to the muon anomalous magnetic moment (MAMM) were part of the detailed review on the MAMM problem within the Standard Model [15].

The vacuum structure and the spectrum of excitations were investigated in the model with dynamical symmetry breaking of electroweak interactions. A new approach to studying this problem was suggested, which is based on the Schwinger–DeWitt method. It was shown that, in contrast with the wide-spread point of view, the top-condensation model is able to describe the phenomenological values of the Higgs mass, top and bottom quarks. This result makes the top-condensation scenario more favorable [16].

The conductivity of quark–gluon plasma (QGP) in external magnetic fields was studied by means of lattice QCD simulations. The first estimation of the conductivity in QCD with physical quark masses was obtained. It was found that the nonzero magnetic field leads to an increase in conducivity in the parallel direction, giving evidence for the Chiral Magnetic Effect. In the perpendicular direction the conductivity is a decreasing function of the magnetic field, this is the magnetoresistance phenomenon in QGP [17].

The influence of the rotation on the confinement/deconfinement phase transition in $SU(3)$ gluodynamics was investigated using the Monte Carlo lattice simulations. The calculations were performed in the rotating reference frame, where the rotation is introduced using the external gravitational field. The Polyakov loop and its susceptibility were computed for various values of the temperature and angular velocity. Different types of boundary conditions (periodic, open, Dirichlet) were tested in directions orthogonal to the rotation axis. The obtained results show that the critical temperature of the confinement/deconfinement phase transition in $SU(3)$ gluodynamics increases with a growth in the angular velocity. It was shown that this effect, in general, does not depend on the lattice size and boundary conditions used [18].

Global polarization of Λ and anti-Λ was calculated based on the axial vortical effect. Simulations were performed within the model of the three-fluid dynamics. The equations of state with the deconfinement transition result in good agreement with STAR data for both Λ and anti-Λ polarization, in particular, with the Λ–anti-Λ splitting. Predictions for the global polarization in forthcoming experiments at NICA energies were made [19].

Hydrodynamical simulations for a large set of high-density matter equations of state (EOS) were used for systematic determination of the threshold mass M for prompt black-hole formation in equal-mass and asymmetric neutron star mergers. The so far most direct, general, and accurate method was devised for determination of the maximum mass of nonrotating neutron stars from merger observations revealing M. A new observable signature of quark matter in neutron star mergers was identified from consideration of hybrid EOS with a hadron–quark phase transition. These findings have direct applications in gravitational wave searches, kilonova interpretations, and multimessenger constraints on neutron star properties [20].

The phases of complex vector fields of neutral and charged bosons were studied. The Zeeman coupling of the vector boson field with the magnetic field was taken into account. It was shown that under certain conditions such systems can behave as ferromagnetic superfluids. The response to an external homogeneous static magnetic field H was studied. The spin-triplet pairing of neutral fermions with the preserved spin was considered, and new phases were found. In the external magnetic field, a phase with a zero mean spin turns out to be unstable to the formation of a phase with a nonzero spin. With a certain choice of parameters, ferromagnetic superfluid phases are formed already at $H = 0$ and are characterized by their own magnetic field h. It was shown that for $H > H_{\rm cr}$ spin-triplet pairing and ferromagnetic superfluidity can continue to exist above the "old" critical phase transition temperature. Spin-triplet pairing of charged fermions was also studied, new phases were found. $3P_2$ nn pairing in the matter of neutron stars was considered. The pp pairing in the $3P_2$ state, possible in the cores of the most massive neutron stars, was also considered, as well as the $3S_1$ np pairing in the nuclear systems of finite size: in nuclei and systems formed for a time in nucleus–nucleus collisions [21].

Phase transition and critical behavior in $SU(N)$ symmetric field models were investigated for an arbitrary flavor number N. Nonperturbative expansion of the functional renormalization group equation within the local potential approximation was presented and large-N analysis was performed. This approach is capable of recovering the one-loop β functions of the coupling constants of the epsilon-expansion. Moreover, it shows direct evidence that for flavor numbers $N > 3$ the system undergoes a fluctuation-induced first-order phase transition [22].

Theory of Nuclear Systems. In 2020, investigations were carried out in accordance with four projects:

- Microscopic models for exotic nuclei and nuclear astrophysics;
- Low-energy nuclear dynamics and properties of nuclear systems;
- Quantum few-body systems;
- Relativistic nuclear dynamics and nonlinear quantum processes.

Electron-capture rates were calculated for neutron-rich $N = 50$ nuclei (^{78}Ni, ^{82}Ge, ^{86}Kr, ^{88}Sr) at temperature $T = 0$ corresponding to capture on the ground state and at $T = 10^{10}$ K (0.86 MeV), which is a typical temperature at which the $N = 50$ nuclei are abundant during a supernova collapse. In agreement with recent experiments, there was found no Gamow–Teller (GT_+) strength at low excitation energies, $E < 7$ MeV, caused by Pauli blocking induced by the $N = 50$ shell gap. It was shown that at the astrophysically relevant temperatures this Pauli blocking of the GT_+ strength is overcome by thermal excitations, leading to a sizable GT contribution to the electron capture. These results indicate that the neutron-rich $N = 50$ nuclei do not serve as an obstacle of electron capture during a supernova collapse [23].

The 1^+ spectrum of ^{130}In populated in the β decay of ^{130}Cd was studied. The coupling between one- and two-phonon terms in the wave functions of 1^+ states was taken into account within the microscopic model based on the Skyrme interaction. The dominant contribution to the additional 1^+ states comes from the $[3^+ \otimes 2^+]$ two-phonon configurations constructed from the charge-exchange 3^+ phonons. A correlation was found between the low-lying $E2$ transition strengths of the parent ^{126,128,130}In and daughter ^{126,128,130}Cd isobaric companions [24].

The recent $(\alpha,\ \alpha')$ data on the Isoscalar Giant Monopole Resonance (ISGMR) and Isoscalar Giant Quadrupole Resonance (ISGQR) in ^{92,94,96,98,100}Mo were analyzed within a fully self-consistent Quasiparticle Random Phase Approximation (QRPA) approach with Skyrme interactions. It was found that in the ground state the inclusion of pairing correlations and axial deformations play important roles. Comparison between ISGMR and ISGQR distributions confirmed that even at modest deformations there is a deformation-induced coupling of the monopole and quadrupole modes [25].

The production cross sections of the heaviest isotopes of superheavy nuclei with charge numbers 112–118 were predicted in the xn-, pxn-, and αxn-evaporation channels of the ^{48}Ca-induced complete fusion reactions for future experiments. A way was shown to produce directly unknown superheavy isotopes in the $1n$- or $2n$-evaporation channels [26].

The coexistence of symmetric mass and asymmetric charge distributions of fission fragments was examined [27].

For the fermionic or bosonic oscillator fully coupled to several heat baths with mixed statistics, the analytical expressions for the occupation numbers were derived within the non-Markovian quantum Langevin approach. The role of statistics of the system and heat baths in the dynamics of the system was studied. The full coupling of a quantum system to a heat bath usually induces its evolution towards an asymptotic equilibrium. It was shown that such an equilibrium might never be reached when the system is coupled simultaneously to bosonic and fermionic heat baths unless different thermal reservoirs are related with each other. The conditions under which an asymptotic equilibrium can be reached were discussed [28].

A nondirect product discrete variable representation (npDVR) was developed for treating quantum dynamical problems which involve nonseparable angular variables. The npDVR basis was constructed on spherical functions orthogonalized on the grids of the Lebedev or Popov 2D quadratures for the unit sphere instead of the direct product of 1D quadratures. The use of the npDVR based on the Lebedev or Popov 2D quadratures substantially accelerates the convergence of the computational scheme. Moreover, the fastest convergence was obtained with the npDVR based on the Popov quadratures that have the largest efficiency coefficient [29].

The calculations of the electromagnetic form factors of three-nucleon systems in the static approximation were performed for various models of electromagnetic nucleon form factors at the momentum transfer squared up to 10 GeV^2. The calculation of the relativistic corrections to the form factors of three-nucleon nuclei associated with the Lorentz transformations was also performed. Calculations show a significant contribution of the relativistic corrections to the form factors [30].

The masses of the ground and excited states of pseudo-scalar glueballs were calculated within an approach based on the rainbow approximation to the Dyson–Schwinger and Bethe–Salpeter equations with effective parameters adjusted to lattice QCD data. The structure of the truncated Bethe–Salpeter equation with the gluon and ghost propagators as solutions of the truncated Dyson–Schwinger equations was analyzed in the Landau gauge. Both the Bethe–Salpeter and Dyson–Schwinger equations were solved numerically within the same rainbow-ladder truncation with the same effective parameters which ensure consistency of the approach. We found that with a set of parameters, which provides a good description of the lattice data within the Dyson–Schwinger approach, the solutions of the Bethe–Salpeter equation for the pseudo-scalar glueballs exhibit a rich mass spectrum which also includes the ground and excited states predicted by lattice calculations. The obtained mass spectrum contains also several intermediate excitations beyond the lattice approaches. The partial Bethe–Salpeter amplitudes of the pseudo-scalar glueballs were presented as well [31].

The thermodynamic quantities of the ideal gas of hadrons and the $(2+1)$-flavor lattice QCD scaled by the effective degeneracy factors of the corresponding models were compared. It was found that in terms of the scaled variables the quark–hadron duality of the lattice QCD and the hadron resonance gas (HRG) model disappears. However, the scaled variables lead to the quark–hadron duality of the lattice QCD and the quantum ideal gas of kaons and antikaons, namely, the ideal gas of those hadrons that contain all the three quarks u, d, s and their antiquarks. Despite in the ideal gas of kaons there is no phase transition, in the present calculations the scaled thermodynamic quantities of the ideal gas and the lattice QCD follow the same qualitative behavior and are consistent with each other [32].

For the first time, a comparative analysis of the scattering length of vector meson (ω, φ, J/ψ) — proton interactions was performed. A nontrivial exponentially strong dependence of the scattering length on the quark content of interacting hadrons was found [33].

Theory of Complex Systems and Advanced Materials. Theoretical investigations in 2020 were carried out in the framework of the following projects:

- Complex materials;
- Nanostructures and nanomaterials;
- Mathematical models of statistical physics of complex systems.

Small-angle scattering (SAS) of X-rays, neutrons, and light from asymmetric Janus particles (AJPs) with tunable structural and physical properties was theoretically investigated. It was shown that identification of AJPs and a quantitative description of their morphology can be achieved by using the method of SAS together with a contrast variation. This approach was illustrated by providing analytic expressions for SAS intensities and for contrast matching points for two kinds of common multiphase AJPs. The influence of the model parameters was presented and discussed, and the structural evolution of AJPs upon solvent deuteration was characterized. The results suggest that the combination of the SAS technique with multiphase modeling provides detailed information about the structural conformation of AJPs, which allows their identification from experimental SAS data. Monte Carlo simulations were performed both to validate the obtained results and to illustrate the above findings for complex AJPs for which analytic expressions are not available [34].

The $S = 1/2$ system $KCeO_2$ was analyzed, combining complementary theoretical methods. The lattice geometry was optimized and the band structure was investigated using density functional theory extended to the level of a GGA + U calculation in order to reproduce the correct insulating behavior. The Ce $4f^1$ states were then analyzed in more detail with the help of *ab initio* wave-function-based computations. Unusually large effective crystal-field splittings of up to 320 meV were predicted, which puts $KCeO_2$ in the strong field coupling regime. The calculated results revealed a subtle interplay between ligand-cage electrostatics and the trigonal field generated by the extended crystalline surroundings, relevant in the context of recent studies on tuning the nature of the ground-state wave function in the $4f$ triangular-lattice and pyrochlore compounds. It also makes $KCeO_2$ an interesting model system in relation to the effect of large crystal-field splittings on the anisotropy of intersite exchange in spin-orbit coupled quantum magnets [35].

Nonlinear effects in the antiferromagnetic zigzag phase of the extended Kitaev–Heisenberg model were investigated in a certain limit, which allows the diagonalization of the magnon Hamiltonian analytically. For various parameters of the spin Hamiltonian, the spectrum and damping rate of magnons due to the three-particle interaction caused by anisotropic terms in the Hamiltonian were calculated. It was shown that the damping of spin waves is sufficiently large and should explain the observed broadening of magnon spectral peaks in neutron scattering experiments [36].

The foundational issues of the problem of time and asymmetry of time were analyzed from a unified standpoint. Current theories and underlying notions were discussed, including the interdisciplinary aspects such as the role of time and temporality in quantum and statistical physics, biology and cosmology. Sophisticated ideas and approaches for treatment of the problem of time and asymmetry of time were compared by considering thoroughly the second law of thermodynamics, nonequilibrium entropy, entropy production and irreversibility in various aspects. The concept of irreversibility was discussed carefully and reanalyzed to clarify the concept of entropy production, which is a marked characteristic of irreversibility. The role of boundary conditions in the distinction between past and future was discussed with attention to this context [37].

Exact formulas of the mean current and diffusion coefficient were obtained in the q-boson zero range process, which is a stochastic interacting particle model with special interparticle interaction responsible for the model being exactly solvable. The analysis of their asymptotic behavior in the large system size limit $N \to \infty$ showed that for generic values of the interaction parameter $|q| \neq 1$ the leading terms of the diffusion coefficient demonstarate the $N^{3/2}$ scaling expected for models in the Kardar–Parisi–Zhang universality class. The scaling $q \sim \exp(-\alpha/\sqrt{N}) \to 1$ corresponds to the crossover between the Kardar–Parisi–Zhang and Edwards–Wilkinson universality classes. Under this scaling, the crossover scaling function was obtained that was previously derived for the asymmetric simple exclusion process and conjectured to be universal [38].

Within the framework of stochastic reactive molecular dynamics simulations, a statistical method for generating fluorinated graphene structures with desirable fluorine distribution was developed. Electronic transport properties of fluorinated graphene in a wide range of functionalization degree and system ordering were investigated. A strong correlation was found between irregularities in fluorine distribution and electronic properties. In particular, the proposed consideration allowed us to reproduce both the experimentally observed electron–hole asymmetry in transport properties of fluorinated graphene and a recently revealed conductivity peak at 10% fluoride content [39].

Performing exact diagonalization, a ferromagnetic ground state of the kinetic origin was shown to emerge in a system of N strongly correlated electrons on a ring. This phenomenon is brought about by the quantum necklace statistics originated from the no-double-occupancy constraint leading to a fractional shifted electron momentum quantization. As a consequence of such a special energy level distribution, the kinetic ferromagnetism is stable only for $N = 3$. For odd $N > 3$, the fully polarized ferromagnetic state energy is only a local minimum but it is protected by a finite energy barrier that inhibits one spin-flip processes. The metastable ferromagnetic state survives perturbations of small magnitude opening up a possibility of being experimentally observed by an appropriate tuning of the interdot tunneling amplitudes in currently available quantum dot arrays [40].

The analysis of ultralow temperature heat capacity of magnetite allowed one to find a unique contribution that has uncharacteristic behavior when the magnetic field and temperature are changed. This behavior allows one to propose that the frustrated network of trimerons is the origin of this contribution [41].

Magnetization reversal by an electric current pulse in a superconductor/insulating ferromagnet/superconductor Josephson junction placed on top of a three-dimensional topological insulator was studied. It was demonstrated that such a system is perspective for low-dissipative spintronics because of the strong spin-momentum locking in the topological insulator surface states. This property provides an ideally strong coupling between the orbital and spin degrees of freedom, thus giving a possibility of efficient reversal of the magnetic moment by current pulse with amplitude lower than the critical current. This results in strongly reduced energy dissipation. The underlying physical mechanism of the reversal was discussed. The influence of the magnetic anisotropy on the controllability of the reversal by the pulse duration was investigated. In addition, a way of a simultaneous electrical detection of the reversal was proposed [42].

Modern Mathematical Physics: Gravity, Supersymmetry and Strings. The topics of the main focus in the theme in 2020 were:

- Quantum groups and integrable systems;
- Supersymmetry;
- Quantum gravity, cosmology and strings.

A special representation of the Brauer algebra was found, which allows one to obtain a new form of solutions of the Yang–Baxter equations to construct the Behrends–Fronsdal (BF) spin projectors. Based on the found new tensor representation of the Brauer algebra (in which the numerator of the propagator of a massive spin one particle plays a key role), a scheme for constructing generalized D-dimensional projectors of the BF with an arbitrary type of symmetry of tensor indices was developed (each such a type of symmetry corresponds to a certain Young diagram). Following this scheme, the essence of which is to compare the idempotents of the Brauer algebra and generalized BF projectors, explicit formulae were written for two asymmetric BF operators corresponding to Young diagrams of the "hook" and "column" type of an arbitrary length [43].

The conditions were defined for the generalized fields in the space with additional commuting Weyl spinor coordinates, which define the infinite half-integer spin representation of the four-dimensional Poincare group. Using this formulation, the BRST approach was developed and the Lagrangian was derived for the half-integer infinite spin fields [44].

The harmonic superspace approach was applied to calculate the divergent part of the one-loop effective action of 6D, $N = (1, 0)$ supersymmetric higher-derivative gauge theory with a dimensionless coupling constant. Having the expression for the one-loop divergences, the relevant β function was calculated. The result fully matches the one obtained earlier in the component approach [45].

New static axially symmetric black holes in multi-Skyrmion configurations coupled to Einstein gravity were constructed in four-dimensional asymptotically flat space–time. In the simplest case, the event horizon is located in-between a Skyrmion–anti-Skyrmion pair, other solutions represent black holes with gravitationally bounded chains of Skyrmions and anti-Skyrmions placed along the axis of symmetry in alternating order [46].

Based on the systematic Hamiltonian and superfield approaches, the deformed $N = (4, 8)$ supersymmetric mechanics on Kähler manifolds interacting with constant magnetic field were constructed and their symmetries were studied. It was shown that the initial "flat" supersymmetries are necessarily deformed to $SU(2|1)$ and $SU(4|1)$ supersymmetries, and that the resulting systems inherit all the kinematic symmetries of the initial ones. The superfield formulation of these supersymmetric systems was presented based on the worldline $SU(2|1)$ and $SU(4|1)$ superspace formalisms [47].

A special degeneration limit $w_1 \to -w_2$ (or $b \to i$ in the context of $2d$ Liouville quantum field theory) was considered for the most general univariate hyperbolic beta integral. This limit was also applied to the most general hyperbolic analogue of the Euler–Gauss hypergeometric function and its $W(E7)$ group of symmetry transformations. The resulting functions were identified as hypergeometric functions over the field of complex numbers related to the $SL(2, C)$ group. A new similar nontrivial hypergeometric degeneration of the Faddeev modular quantum dilogarithm (or hyperbolic gamma function) was discovered in the limit $w_1 \to -w_2$ (or $b \to 1$) [48].

A univariate beta integral composed from general modular quantum dilogarithm functions using general modular group $SL(2, Z)$ was considered and its exact evaluation formula was proven. This integral represents the partition function of a particular $3d$ supersymmetric field theory on the general squashed lens space. Its possible applications to $2d$ conformal field theory were discussed as well [49].

The problem of cosmological perturbations in teleparallel gravity was studied within the covariant formulation of teleparallel gravity $f(T)$, which takes into account spin connection. Spin connection was calculated that symmetrizes the equation for perturbations and splits diagonal and nondiagonal part of the equation of motion. The existence of a minimal solution for spin connection, which leads to zero slip, was demonstrated; however, in this case, one additional equation appears, so the system may become overdetermined. It was shown that a more general solution exists, which is incompatible with zero slip but allows one to write down the equations of motion for cosmological perturbations in a self-consistent way [50].

It was found that in effective scalar-tensor theories at the one-loop level some nonminimal interactions are universally generated. The mechanism of their generation is similar to the generation of the anomalous magnetic moment of fermions. The influence of quantum corrections on the scalar field effective potential was studied, and it was found that such corrections do not generate new nontrivial minima in the effective potential [51].

DUBNA INTERNATIONAL ADVANCED SCHOOL OF THEORETICAL PHYSICS (DIAS-TH)

The educational program of the DIAS-TH in 2020 was significantly cut due to the coronavirus pandemic. Because of the restrictions introduced, it was not possible to organize three planned schools for students and young scientists: International School "Advanced Methods of Modern Theoretical Physics: Integrable and Stochatic Systems", Helmholtz International Summer School "Matter under Extreme Conditions in Heavy-Ion Collisions and Astrophysics", Helmholtz International Summer School "Hadron Structure, Hadron Matter and Lattice QCD". Nevertheless, seminars for undergraduate and graduate students, including online, continued and the DIAS-TH website was maintained. Preparations for the Winter School in Theoretical Physics "Actual Cosmology", scheduled for February 2021 online, were carried out.

COMPUTER FACILITIES

In 2020, a new server with 36 computing cores (2 Intel Xeon Gold 6254 processors) and 1.5 TB of RAM was brought into operation. To upgrade computers at workplaces, 10 PCs were purchased. Extensions of technical support were purchased, and updated versions were installed for Mathematica, Maple, Origin Pro, Intel Parallel Studio. The number of Mathematica network licenses increased from 8 to 10. Upgrade of pool of Ethernet switches was finalized. WiFi network was improved by installation of dual-band equipment. A denser deployment of 30 access points was implemented.

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VEKSLER AND BALDIN LABORATORY OF HIGH ENERGY PHYSICS

In 2020, the activity of the Veksler and Baldin Laboratory of High Energy Physics was aimed at construction, development and commissioning of separate units of the accelerator complex "Nuclotron–NICA" and MPD, BM@N and SPD experimental facilities. Experiments were also continued at external accelerators.

THE MOST IMPORTANT RESULTS IN THE DEVELOPMENT OF THE NICA COMPLEX

Nuclotron–NICA Project. ***Booster and Beam Transport Channels.*** On November 20, 2020, the Prime Minister of the Russian Federation M. Mishustin made a technological launch of one of the main units of the megascience project "NICA Complex" — a superconducting booster synchrotron, the Booster. By that moment the assembly of the Booster magnet cryostat system had been completed. All subsystems were installed and tested, the power supply system for the magnets was tested and tuned under operation at an equivalent load, the HILAc–Booster beam transport channel was constructed, adjusted and tested. By the end of the year, the initial commissioning tests and full-scale measurements aimed at testing and tuning of all systems when working with the He^{1+} ion beam had been performed. Work with the beam began on December 19, according to the approved schedule.

During the run, the following work was sequentially performed:

- the assembly and testing of the vacuum system were completed;
- the ACS of the Booster was launched, a monitoring system designed to monitor the process of cryostatting was put into operation, the magnet cryostat system was cooled to a temperature of 4.5 K;
- the quench detection and protection system was adjusted and put into operation, the energy dump system was tested, the system of cycle setting and the power supply system for the Booster magnets were tuned;
- the heavy-ion accelerator HILAc and the beam transport channel from HILAc to the Booster were adjusted, the injection system units were tuned to the design parameters;
- the beam was injected onto the magnetic field plateau corresponding to the injection energy, a circulating He^{1+} beam was obtained;
- the main systems for diagnostics of the circulating beam and the closed orbit correction system were consistently tested, the intensity of the circulating beam is ensured close to the design one;
- the high-frequency system was tuned, the adiabatic beam capture mode was tested in the acceleration mode, the acceleration of ions up to energy of 100 MeV/nucleon was ensured;
- the electron cooling system was switched on and tested;
- magnet power systems, cryogenic and magnet cryostat systems were tested when operating in a magnetic field cycle with design parameters.

The beam circulation mode was obtained without switching on the magnetic field error correction system, while the deviations of the beam orbit from the nominal position in the horizontal plane did not exceed ±15 mm (a few more in the vertical plane). This is a direct confirmation that the quality of production and assembly of the system elements meets the design requirements. During the run, there was a stable operation of the magnet cryostat system with a magnetic field cycle of about 400 h.

The use of the orbit correction system together with the tuning of the beam transport channel from HILAc to the Booster and the tuning of the injection system units made it possible to achieve the beam intensity at the level of $7 \cdot 10^{10}$ of circulating He^{1+} ions (Fig. 1), which is equivalent in current to 10^9 Au^{31+} ions.

The characteristic lifetime of ions due to recombination with molecules and atoms of the residual gas was approximately 1.9 s (Fig. 1). Taking into account the cross sections of the recharging processes, this value corresponds to the residual gas pressure in the beam chambers at the level of $(3–6) \cdot 10^{-8}$ Pa, which corresponds to the readings of vacuum gauges and to the design value with the starting configuration of the pump-out system.

During three shifts, work was carried out to test the electron cooling system (ECS). At the injection energy using the ECS dipole magnets and the Booster correction magnets, the orbit of the circulating beam was corrected under the field of the solenoid of the cooling section up to 0.07 T. In this field, a stable mode of energy recovery of the electron beam with an electron current of up to 150 mA was ensured. The effect of interaction between the electron and circulating ion beams was observed using an ionization profilometer. A decrease in the ion lifetime due to recombination with electrons in the cooling section, which depends on the electron energy, was reliably recorded. The optimum electron energy (the potential of the electron gun cathode) is in the range of 1.74–1.82 keV, which corresponds to the calculated value.

At the end of the run, a comprehensive testing of the magnet power systems, cryogenic and magnet cryostat systems was carried out during operation in a magnetic field cycle with the maximum consistently achievable parameters. As a result, a cycle with two “plateaus” corresponding to the injection energy and the energy of electron cooling was set in the area of the increasing field. A field of 1.8 T was achieved on the upper “plateau”, and a rate of field change of 1.2 T/s was ensured in the areas of increase and decrease of the field (Fig. 2), which fully corresponds to the design parameters of the cycle.

All tasks of the run were fully completed. For all Booster systems the necessary information was obtained for their further development during the preparation for the run to accelerate heavy ions.

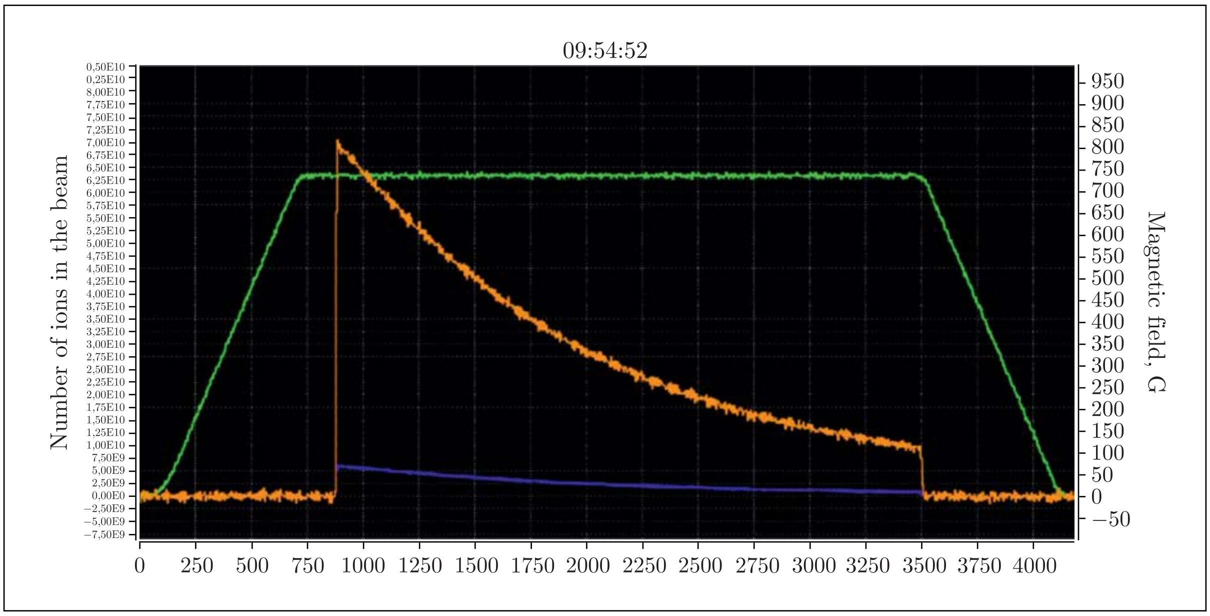

Fig. 1. Results of measuring the intensity of the circulating beam using a parametric power transformer (PPT) with optimum tuning of all systems. The green curve is the magnitude of the magnetic field in G, the blue curve is the PPT signal, and the orange curve is the number of circulating particles. Time along the horizontal axis is given in ms

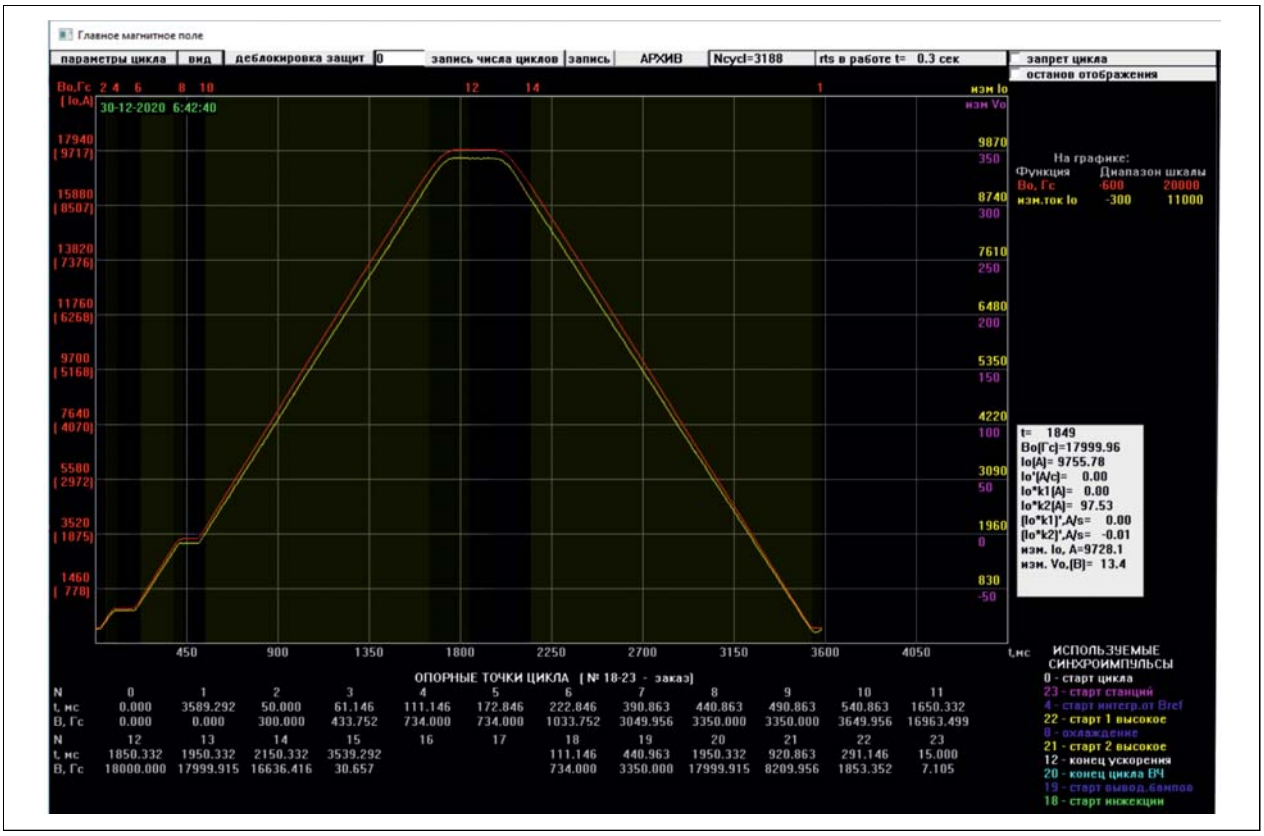

Fig. 2. Design cycle of the magnetic field

Collider. The NICA collider complex is located in building 17. The operation state of the building by the end of 2020 was as follows:

- piles (100%);
- concrete structures (99%);
- metal structure installation (99%);
- facades installation (47%);
- roofs (70%);
- earth works and temporary roads (98%);
- brick and foam block partition walls (63%);
- load-bearing floors (70%);
- finishing works (28%);
- wall drainage system (100%);
- displacement of water supply networks (90%);
- installation of household and storm sewer (15%);
- installation of individual heating units (20%).

A general view of the construction site is shown in Fig. 3. According to the civil works schedule, the deadline for completion of building 17 is December 2021. These terms are primarily due to a significant (50%) increase in construction volume at the stage of project implementation. The coronavirus pandemic has also affected meeting the contract deadlines.

In 2020, the production and testing of equipment for the collider subsystems continued. 80% of the collider's dipole and 10% of the quadrupole magnets have been already produced and tested on the high-technology line for assembling and testing of superconducting magnets.

Fig. 3. General view of the construction site of the collider complex (November 2020)

Cryogenic Complex. The new cryogenic compressor station, for the installation of which a separate building is being built, is one of the key elements of the upgraded cryogenic NICA complex. Civil works are in progress at a high pace and the terms of the contract should be met by mid-2021.

In general, at the end of 2020, the amount of work performed to develop the design configuration of the NICA complex was about 70%.

MPD Project. In 2020, the formation of the MPD collaboration, which numbered over 500 specialists from 39 institutes and 11 countries, was completed. Six collaboration meetings were held to discuss the progress of the project. The agreement process of Memoranda of Understanding documenting the rights and obligations of the participating institutes to construct the facility, including contributions to the general MPD fund, is being continued.

The MPD detector will be installed in a special pavilion in the main building 17 of the NICA complex. Works on the pavilion are mostly completed, and the installation of the incoming equipment has already started. Together with these works, electrical networks (1.2 MV) and their laying, ventilation system, water cooling and heating systems are being installed, technical documentation is being written for the laying of gas lines for MPD detectors and cryogenic lines (gaseous and liquid nitrogen and helium) for the Solenoid. Server units are installed.

Solenoid Magnet. In July 2020, the main parts of the magnet yoke (28 plates and 2 support rings) arrived in Dubna from the Czech Republic after the test assembly performed at the HM Vitkovice production plant. In the shortest time possible, 13 plates and support rings were assembled with the same high accuracy as that one at the plant: deviations of most of the measured geometric dimensions from the control parameters did not exceed 0.2 mm, with rare exception they were 0.5 mm, taking into account a magnetic circuit length of 8970 mm and a diameter of 6670 mm. After long discussions with specialists from the Italian company ASG Superconductors, which is responsible for the quality of the magnetic field in the MPD detector, the "go-ahead" was received to continue the assembly, and on December 25, 2020, the last 28th plate was installed. The final measurements of the geometry of the magnetic circuit again showed the high accuracy of the production of plates and support rings and their assembly into a single whole (Fig. 4).

In November 2020, a complex logistics operation for the transportation of the MPD superconducting solenoid magnet produced by ASG Superconductors company was successfully completed. The valuable cargo was delivered by sea and river to Dubna and placed in the MPD pavilion. In 2021, the magnetic circuit will be partially disassembled to the level of 13 plates, the Solenoid will be installed, and the magnetic circuit with a total weight of about 900 t will be completely re-assembled. After connecting the necessary communications, the Solenoid will be cooled. By the end of April, it is planned to cool it to the temperature of liquid nitrogen, and by September 2021 — to the temperature of liquid helium. After that, a measuring station with 32 Hall sensors will be installed to measure the uniformity of the magnetic field. To obtain the required field uniformity of $3 \cdot 10^{-4}$, it is planned to adjust the currents in the correction coils. After each adjustment it will be necessary to measure the 3D map of the field. At the end of 2021, the installation process of MPD detectors will start.

Time Projection Chamber. Time Projection Chamber (TPC) is the main tracking detector of the MPD experiment. In 2020, the outer TPC cylinder consisting of C3–C4 shells with a

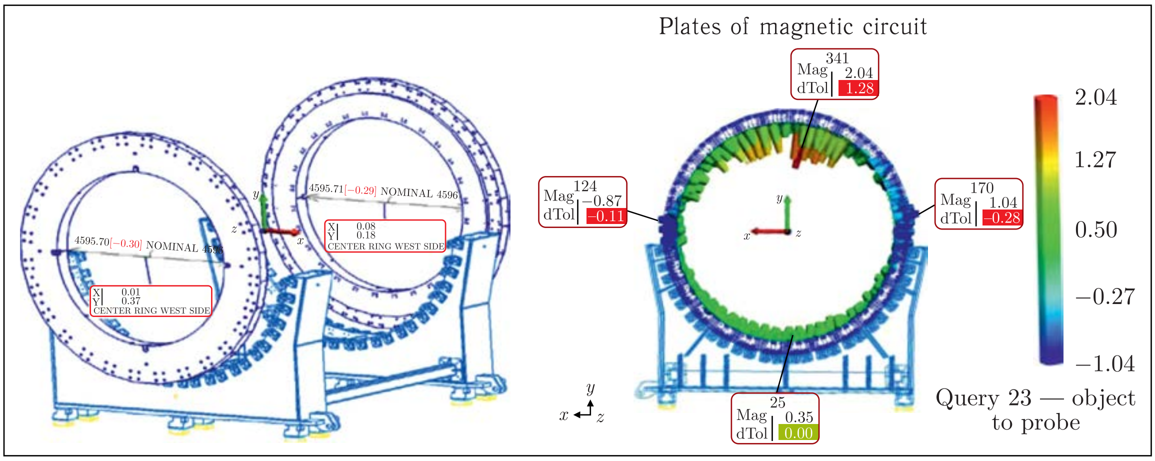

Fig. 4. Measurement results for magnetic circuit assembly

diameter of about 2.8 m and a length of 3.4 m was assembled, the work on the installation of a mechanical structure for fixing thermal shields was completed on the C4 shell. The main elements of the TPC, such as high-voltage electrode, flanges, rods, etc., are ready for assembly; all 24 readout chambers are produced and tested. 113 sets (8%) of front-end electronic cards are produced. The gas system for the TPC is ready. Special ultraviolet lasers and a laser beam distribution system at a small radius have been supplied to JINR, the purchase of units for low-voltage and high-voltage TPC systems developed at CAEN has begun. Cooling system, slow control system, DAQ, tools for installing the TPC into the MPD facility are being developed. The assembly of the TPC will be completed in early 2021, followed by testing the detector using cosmic rays.

Time-of-Flight System. MPD Time-of-Flight (TOF) system is based on multigap resistive plate chambers (mRPC), 40% of mRPCs have already been produced. The assembly of TOF modules and their testing with cosmic rays are underway. All test bench equipment matches the system that will be used in MPD. A part of assembly and installation equipment is being produced. A basic device for transferring and adjusting the TOF modules inside MPD is currently under development. The purchase of devices and subsystem components is almost completed. TOF gas system is already in operation in the test bench.

FHCal. Each of the two arms of the forward MPD detector includes 44 modules with dimensions of $150 \times 150 \times 1100$ cm, which are 42 alternating layers of lead and scintillator assembled in seven longitudinal segments. FHCal modules and readout electronics are ready for operation and are being tested with cosmic rays. The design of the FHCal support platform has been completed and a tender has been announced for its production.

ECal. The uniqueness and complexity of the ECal is in the projection geometry of the detecting modules. At two sites ("Tensor" Dubna and Protvino) in Russia, work on the production of modules for an electromagnetic calorimeter is going according to the plan. One fourth of all modules should be produced in China. In 2020, the PRC government financed the construction of modules that will be produced by several universities in China, headed by Tsinghua University. The entire infrastructure for mass production has already been prepared and work has started. The central part of the ECal consists of 38 400 "towers" with a cross section of 4×4 cm, the assembly of 16 "towers" forms one module. Currently, 300 modules have been produced. This is enough to construct three ECal sectors. By the middle of the year, modules for another three sectors will be produced in Russia, and colleagues from the PRC have planned to produce eight sectors by the end of 2021.

Milestones of the MPD Assembling. Milestones of the MPD assembling are described in the table.

Stage of assembly	Deadline
Preparing to switch on the solenoid magnet (cryogenics, power supply, etc.)	January–September 2021
Magnetic field measurements	October–November 2021
Preparing for installation of detector subsystems	December 2021
Installation of TOF, TPC, electronics platform, cabling	January–June 2022
Installation of a beam tube, FHCal, cosmic ray test system	July 2022
Facility tests on cosmic rays	July–December 2022
Commissioning	December 2022
Beam operation	March 2023

MC Simulation and Data Analysis. Preparation for physical analysis is carried out in five physics working groups of the MPD project. In recent months, large-scale Monte Carlo simulations have been performed at the "Govorun" supercomputer at JINR LIT, each including several million events. A procedure for validating Monte Carlo data has been developed. The NICA special computing cluster at VBLHEP is also regularly used by members of the MPD collaboration to analyze this data and evaluate the performance of the MPD facility. This allowed one to prepare several dozen scientific reports from the MPD collaboration for international scientific conferences in 2020.

BM@N Experiment. The BM@N collaboration includes 250 physicists and engineers from 20 institutes and 10 countries. The aim of the experiment is to study the dynamics of reactions and the properties of hadrons in dense nuclear matter, to investigate the production of strange hyperons close to the threshold and search for hypernuclei in interactions of the extracted beams of the Nuclotron with fixed targets. The project also studies the structure of nuclei at small internucleon distances.

Data Analysis. In 2020, an analysis of the experimental data recorded in the interactions of argon nuclei with kinetic energy of $3.2A$ GeV with the nuclei of Al, Cu, Sn, and Pb targets was performed. In these interactions the signal of Λ hyperons was obtained in the spectrum of effective masses of (p, π^-) pairs (Fig. 5).

Charged π^+, K^+ mesons, as well as protons and light nuclear fragments ^{3}He, $d/^4$He (Fig. 6), were identified according to the data of the central and external tracking systems and the time-of-flight system. The analysis of the yield of these particles is carried out depending on the kinematic variables.

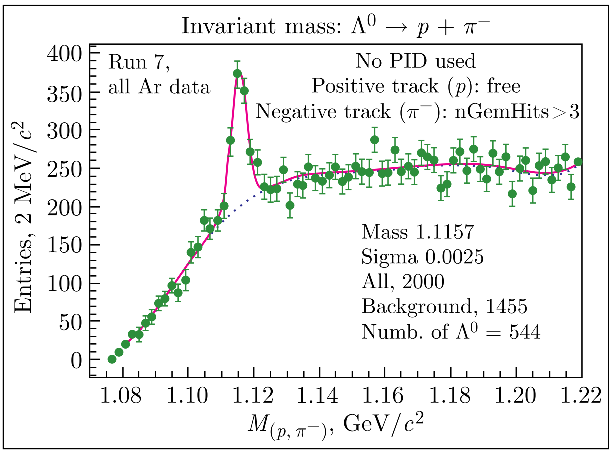

Fig. 5. Signal of Λ hyperons in the spectrum of effective masses of (p, π^-) pairs in interactions of an argon beam with energy of $3.2A$ GeV with various targets

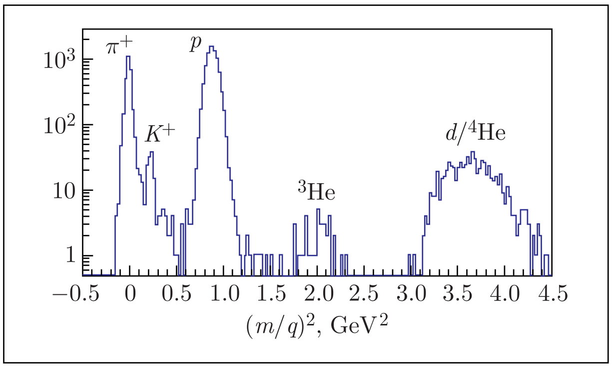

Fig. 6. Identification of π^+, K^+, p, ^{3}He and $d/^4$He by the TOF-700 system in interactions of Ar nuclei with energy of $3.2A$ GeV with different targets: the square of the mass distribution of identified particles normalized to charge value

A complete analysis of data in the studied interactions of carbon nuclei with a liquid hydrogen target was carried out using the program for studying nucleon correlations. Based on the results of the study, a paper "The Transparent Nucleus: Unperturbed Inverse Kinematics Nucleon Knockout Measurements with a 48 GeV/c Carbon Beam" was prepared and accepted for publication in *Nature Physics*. The quasi-elastic exclusive process $^{12}\mathrm{C} + p \to 2p + {}^{11}\mathrm{B}$ with the registration of all reaction products (Fig. 7) was measured, and the events of proton scattering by correlated nucleon pairs in the carbon nucleus in reactions like $^{12}\mathrm{C} + p \to 2p + {}^{10}\mathrm{B}/{}^{10}\mathrm{Be} + (n/p)$ were identified.

Experimental Facility Status. According to the development programme of the facility for studying the interactions of heavy nuclei, detectors for the complete BM@N configuration were developed (Fig. 8). Tests with cosmic muons of seven GEM detectors with an active region of 163×39 cm have been carried out, and readout electronics for these detectors based on chips by IDEAS company (Norway) have been produced.

The design was developed and silicon microstrip detectors were produced for three planes of the forward tracking detectors FwdSi, which will be installed immediately after the target; readout electronics based on chips by IDEAS company are being produced.

Silicon detectors have been produced for three Si beam trackers and two Si beam profilers, which will be installed before the target to measure the beam track and focus the beam on the target; the design of the detectors was developed, the readout electronics are being produced; a trigger detector is being produced based on azimuthal silicon segments.

A wide-aperture tracking system consisting of four planes of microstrip silicon STS detectors is being developed together with the CBM collaboration members; fast electronics for reading and receiving data for these detectors are being developed; a hybrid tracking system based on FwdSi/STS and GEM detectors has been simulated to determine the detection efficiency of cascade decays of hyperons and hypernuclei in interactions of heavy nuclei.

Three CSC cathode strip chambers of 133×107 cm have been produced in addition to the one already operating for recording tracks for the TOF-400 system; the design of two large

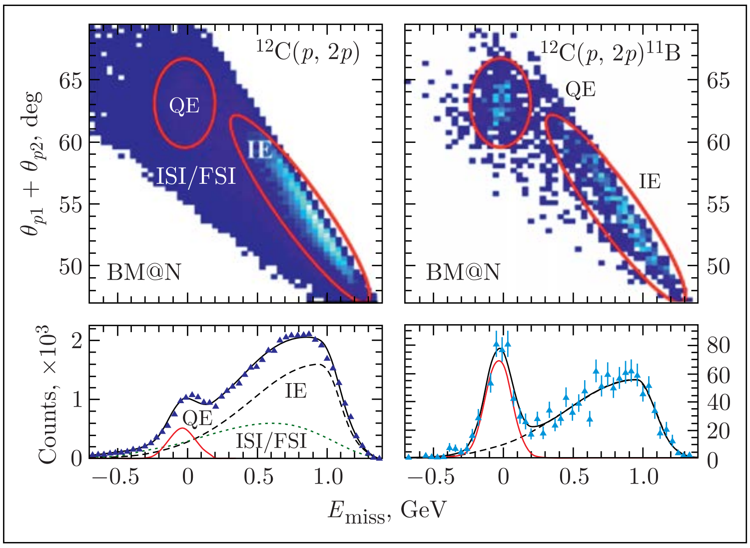

Fig. 7. Quasi-elastic events (QE) identified by the correlation between the missing $E_{\rm miss}$ energy in the ^{12}C rest frame and the angle between two scattered protons in the laboratory frame. The contribution of background events of inelastic interactions (IE) and secondary interactions in the initial and final states (ISI, FSI) is also shown

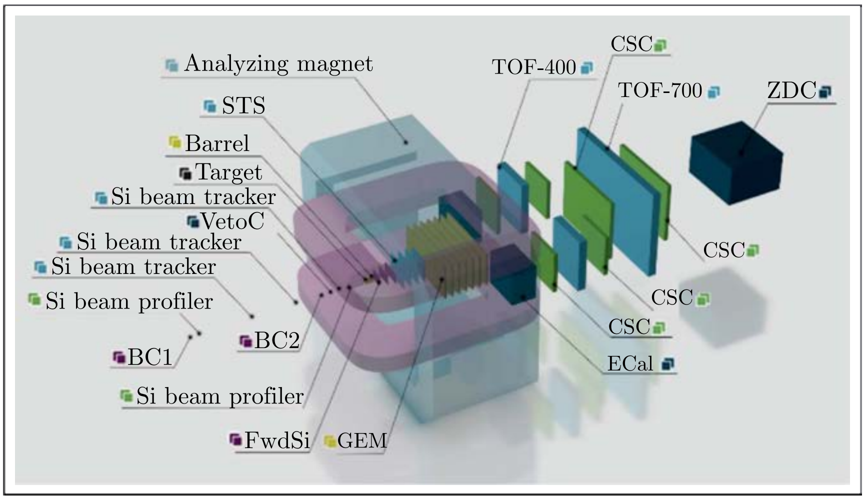

Fig. 8. Complete configuration of the BM@N detectors for studying heavy nucleus interactions

CSC cathode chambers of 219 × 145 cm for the TOF-700 system has been developed. Prospective fast readout electronics for GEM and CSC detectors based on VMM3a chips for high-intensity ion beams (2 MHz) are being developed.

A beam transport channel in the BM@N experimental zone up to the target has been produced and installed; a beam transport channel from thin carbon fiber inside the installation from the target to the ZDC hadron calorimeter to suppress interactions of heavy ions with air is being manufactured; a vacuum target station with several targets has been produced.

In addition to the FHCal calorimeter for measuring the centrality of interactions, a quartz hodoscope has been produced to register nuclear fragments in the region of high-intensity heavy ion beams.

In 2021, it is planned to resume research in the BM@N experiment, and in late autumn, an experiment is planned to be conducted under the research programme for nucleon correlations at short distances using a carbon ion beam.

SPD Project. In 2020, SPD CDR, which met the requirements of the updated physics programme and external conditions, was prepared for consideration by the PAC for Particle Physics. The expected performance of the facility was estimated using Monte Carlo simulation methods.

The following prototypes of detectors have been constructed and tested. A 16-layer prototype of the SPD muon system has been developed, electromagnetic calculations for the magnetic system have been performed. A prototype of the coordinate module of 63 × 63 mm vertex detector was developed based on the use of double-sided silicon microstrip detectors and a flat polyimide cable. The prototypes of the heterogeneous calorimeter were tested using cosmic rays. The first tests with a radioactive source of the VMM3a readout chip for the straw tracker prototype were carried out. A prototype detector based on microchannel plates for the inside part of SPD BBC (Beam–Beam Counter) has been successfully tested under ultrahigh vacuum conditions up to 10^{-10} Pa. The first version of the prototype of readout electronics with the Time-over-Threshold (ToT) option for the external scintillation unit of the BBC has been tested.

A miniSPD stand has been constructed for simultaneous irradiation of various SPD detectors with cosmic muons, which is also used for testing and tuning of systems of data acquisition, slow control, gas distribution, low-voltage and high-voltage power supplies. For the SPD test zone two target stations were developed and produced to locate targets and detectors in the common volume of vacuum of the extracted beam channel, two control rooms were constructed. Work is underway to produce detecting and metrological equipment for a low-energy channel, and simulation is being performed for a high-energy channel.

Three remote workshops of the SPD proto-collaboration were held for the preparation of the CDR and the physical programme; the draft of the SPD constitution was formulated, the formation of the Collaboration continues.

ALPOM-2 Project. The research under the ALPOM-2 project was aimed at finding the analyzing power in inclusive nucleon scattering. Three new approaches to the development of polarimetry — switching on a calorimeter to select high-energy nucleons in the final state using a charge exchange reaction and replacing a hydrogen-rich light target with heavier nuclei — open the way to simpler and more efficient measurements of nucleon polarization in the GeV energy range.

Figure 9 shows the analyzing power as function of the transverse momentum and different thresholds of energy deposit in the hadron calorimeter. It can be seen that the analyzing power increases by a factor of about 2 when the particles with low-energy deposit are suppressed. The new data and their interpretation [1] were highly appreciated at the Jefferson Laboratory (USA), where, on this basis, at the CEBAF complex at JLAB an experiment was approved to measure the ratio of the electromagnetic form factors of the neutron.

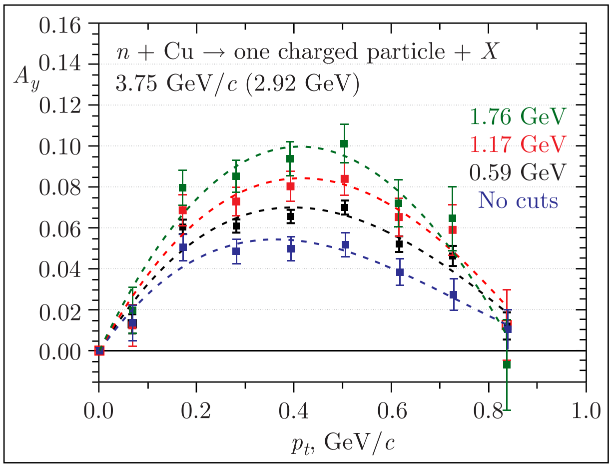

Fig. 9. Analyzing power of A_y in relation to the p_t transverse momentum

PARTICIPATION IN EXPERIMENTS AT EXTERNAL ACCELERATORS

Experiments at the Large Hadron Collider. ***ALICE.*** The main efforts of the JINR group in data analysis and physics simulation were focused on the study of femtoscopic correlations and the production of vector mesons in ultra-peripheral Pb–Pb collisions. In addition, the staff continued to participate in the maintenance and development of the GRID–ALICE analysis at JINR.

The analysis of femtoscopic correlations of K^+K^- pairs for Pb–Pb collisions at 2.76 TeV conducted within the FSI model using a new “Dubna approximation” with traditional parameters for the contributions of the $a_0(980)$ states (Martin, Achasov) and free parameters for $f_0(980)$ has been adjusted and completed [2]. A good correlation was obtained between the experimental data and the model predictions: the values of the $f_0(980)$ meson mass and width,

$M = (990 \pm 20)$ MeV/c^2 and $\Gamma = (39.70 \pm \pm 7.94$ (stat.) ± 11.80 (syst.)) MeV/c^2, correspond to tabular (PDG) data. These results were reported by the JINR group at the ICPPA-2020 conference. The publication is being prepared.

The results of the analysis of femtoscopic correlations for pairs of identical charged kaons in Pb–Pb interactions at 5.02 TeV were compared with the predictions of the EPOS hydrodynamic model. Figure 10 shows the radii of the kaon radiation sources, $R_{\rm inv}$, depending on the transverse momenta of the pairs, k_T, and the centrality of the events. Solid and dotted lines are model predictions with rescattering of particles in the final state and without it, respectively. It can be seen that the particle rescattering mechanism is important for a correct description of the experimental data. The results were also presented by the JINR group at ICPPA-2020 [3].

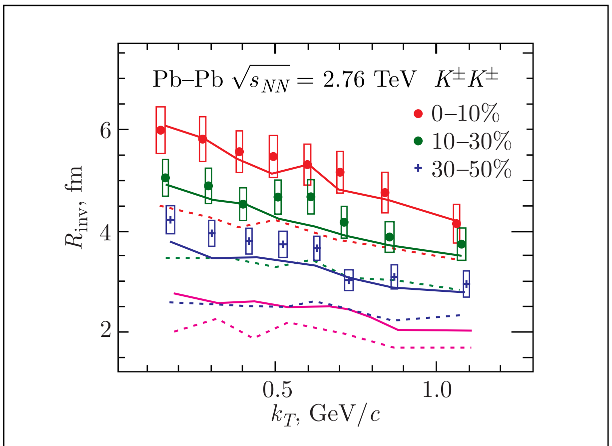

Fig. 10. Radii of sources of pairs of charged kaons depending on the transverse momentum of the pairs. Lines — EPOS model predictions

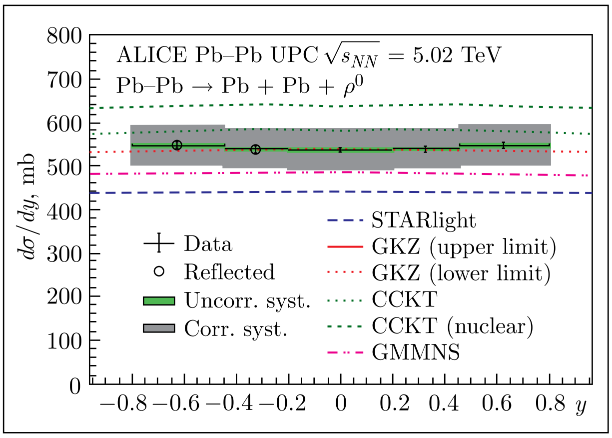

Fig. 11. Comparison of differential cross sections (by rapidity) of coherent production of ρ^0 mesons with predictions of various models

New analysis results of femtoscopic correlations of pairs of identical charged pions and kaons in pp interactions at 13 TeV were obtained separately for spherical ($S_T > 0.7$) and jet-like ($S_T < 0.3$) events (S_T is transverse sphericity). The main result is a decrease in the radii of particle radiation sources with increasing k not only in jet-like but also in spherical events, which indicates a nontrivial collective behavior of particles expected only for nucleus–nucleus collisions with the possible formation of quark–gluon plasma.

The analysis of the coherent production of ρ^0 mesons in ultraperipheral Pb–Pb collisions at 5.02 TeV was completed. Differential cross sections of their production have been determined and comparisons with the predictions of the models have been made (Fig. 11). In addition, the first measurements of the coherent photoproduction of an object similar to a resonant state with a mass of about 1700 MeV/c^2 were made. These results were reported at ICHEP-2020 in Prague and published in JHEP [4].

The JINR group continued active research within the framework of the project on upgrading the ALICE PHOS electromagnetic calorimeter in order to select the optimal photodetector and readout electronics.

ATLAS. Based on the statistics corresponding to the integrated luminosity of 139 fb^{-1} at the LHC at $\sqrt{s} = 13$ TeV, the study of the process of associated production of the Higgs boson with W or Z boson and its decay into a pair of b-quarks was continued, and the signal significance was observed in the channels with W or Z boson of 4.0 and 5.3 standard deviations with expected values of 4.1 and 5.1, respectively. The cross section for the associated Higgs boson production is measured as a function of the transverse momentum of the gauge boson (Fig. 12) [5]. All cross section measurements are in line with the Standard Model expectations, and overall uncertainties range from 30% at large transverse momenta of the gauge boson to 85% at low values. Also, the restrictions have been put on the parameters of the effective Lagrangian sensitive to the modification of the WH and ZH processes, as well as to the decay of the Higgs boson into b-quarks.

Together with colleagues from JINR FLNP, radiation tests of high-speed differential amplifiers were carried out. The results demonstrated good stability up to a neutron fluence value of $\sim 1 \cdot 10^{16}$ cm^{-2}.

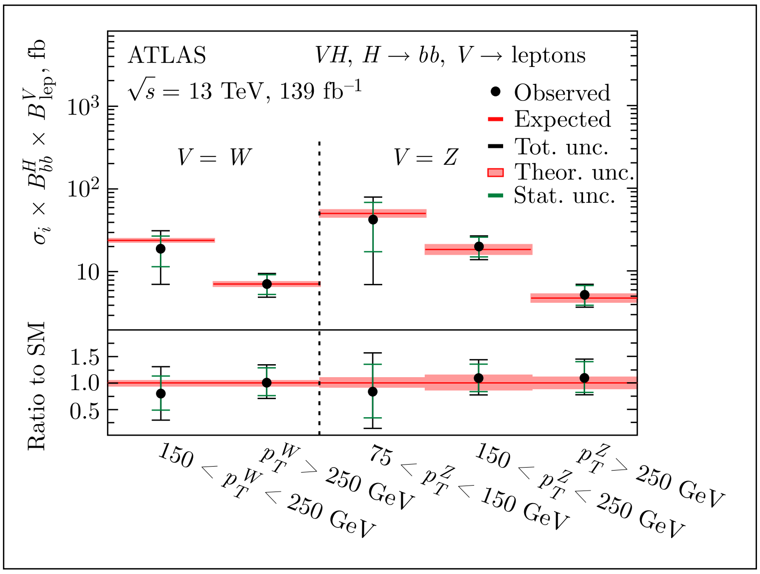

Fig. 12. Measured cross section $VH(bb)$, $V \to$ leptons

CMS. The studies carried out by the JINR group in the CMS experiment in 2020 were aimed at searching for signals of New Physics in a channel with a pair of leptons and multiple production of hard particles, at testing the predictions of extended gauge models with and without lepton flavour violation (LFV), scenarios with additional spatial dimensions, with an extended Higgs sector, as well as at testing simplified descriptions of interactions of dark matter (DM) with SM matter. Precision tests of the Standard Model were carried out in a channel with a pair of muons, as well as in processes of inclusive jet production.

In the channel with a pair of leptons, predictions were made (Fig. 13) for the mass limits

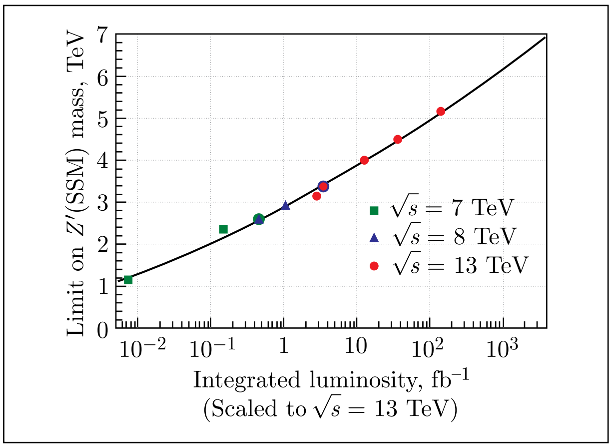

Fig. 13. Observed mass limits for the hypothetical gauge boson Z' in the SSM model at c.m.s. energies of 7, 8, and 13 TeV as function of the integrated luminosity

of the new heavy boson Z' (resonance with spin 1 in the SSM model) of the extended calibration sector of the SM, which can be achieved when the LHC operates in the high luminosity mode (1000–3000 fb^{-1}) based on the latest CMS data [6]. For the SSM model, the onset of the kinematic limit in the range of 7 TeV/c^2 at energy of 13 TeV was demonstrated, which corresponds to 7–8 TeV/c^2 at 14 TeV.

A generalizing analysis of the results and prospects of searching for multidimensional gravity signals under conditions of limited LHC energy (14 TeV) [7] has been carried out. It has been demonstrated that the LHC has reached the limit of its capability to observe possible signals from quasi-classical multidimensional black holes of RS- and ADD-type.

However, there is still a window of opportunity for the so-called "quantum" black holes (QBH) with a characteristic experimental signature with violation of flavor ($e\mu/e\tau/\mu\tau$). The obtained restrictions on the minimum acceptable values of the QBH mass are from 3.6 to 5.6 TeV/c^2 depending on the model and the number of additional n dimensions (Fig. 14).

In a channel with a pair of oppositely charged leptons, an experimental search for the interaction mediator between the SM fields and the dark matter sector has been carried out. In the absence of a significant excess of the signal over the expected SM background within the simplified DM model (with one DM Dirac particle and one mediator), upper limits on themasses of TM particles and axial-vector and vector mediators have been established [8, 9].

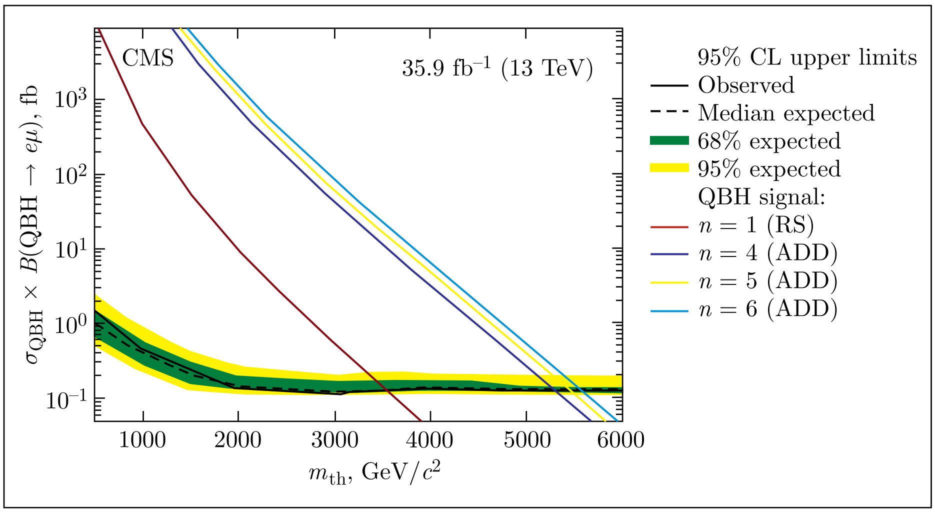

Fig. 14. Upper limits of the cross section for QBH production decaying to the final state $e\mu$ as function of the threshold value of the QBH mass. Predictions are shown for multidimensional QBH models for several choices of the number of extra dimensions: $n = 1$ (RS) and $n = 4$, 5, 6 (ADD)

Within the second phase of the CMS upgrade programme, JINR physicists participated in the refurbishment of the electronics and the CSC cooling system of the ME1/1 muon station. Tests of the assembled chambers were carried out with cosmic rays. An upgraded system of readout electronics of the central hadron calorimeters (HCal) based on silicon photomultipliers (SiPM) was put into operation. A new method for assembling active scintillation elements has been developed and tested on a prototype module of a highly granular end-cap calorimeter (HGCal). Studies were carried out on the radiation hardness of the components and on the optimization of the configuration of this calorimeter.

In 2021, it is planned to utilize the full statistics of the LHC while focusing at finding New Physics and measuring the characteristics of the Drell–Yan process. It is planned to complete the measurement of the forward–backward asymmetry and slopes, as well as to develop a prototype of an automated data quality control system.

Experiments at the CERN Super Proton Synchrotron. *COMPASS.* Measurement of the processes with the production of hadrons in semi-inclusive deep inelastic scattering (SIDIS) of leptons off unpolarized nucleons makes it possible to obtain information on the intrinsic transverse momentum of quarks in a nucleon and on the Boer–Mulders function by measuring the azimuthal modulations of the cross section of these reactions. These modulations have been recently measured in the HERMES experiment at DESY on proton and deuteron targets, as well as in the COMPASS experiment using a CERN SPS muon beam and ^{6}LiD target [10]. In both cases, the amplitudes of modulations $\cos\varphi h$ and $\cos 2\varphi h$ (Fig. 15) demonstrate strong kinematic dependences for both positive and negative charged hadrons. It has been known for some time that the measured hadronic final states in these experiments receive a contribution to SIDIS from exclusive diffraction processes with the production of vector mesons, which is of particular importance at large z values, the fraction of the virtual-photon energy carried by the hadron.

In previous measurements of azimuthal asymmetry, this contribution was not taken into account, since there was no information that it could distort azimuthal modulations. Nowadays a method has been developed for assessing the contribution of exclusive reactions to azimuthal asymmetries. Subtracting this contribution leads to a better understanding of the kinematic effects, and the residual nonzero $\cos 2\varphi h$ modulation gives an indication of the nonzero effect of the Boer–Mulders function.

Spin density matrix elements (SDMEs) were measured in the processes of hard exclusive production of ω mesons using polarized μ^+ and μ^- beams of 160 GeV/c directed to a liquid hydrogen target [11]. The measurement covers the range of invariant masses of the final hadronic state $5.0 < W < 17.0$ (GeV/c)^2 with average kinematics $Q^2 = 2.1$ (GeV/c)^2, $W = 7.6$ (GeV/c)^2 and $p_T^2 = 0.16$ (GeV/c)^2. The measured nonzero SDMEs for the transitions of transversely polarized virtual photons to longitudinally polarized vector mesons ($\gamma_T^* \to V_L$)

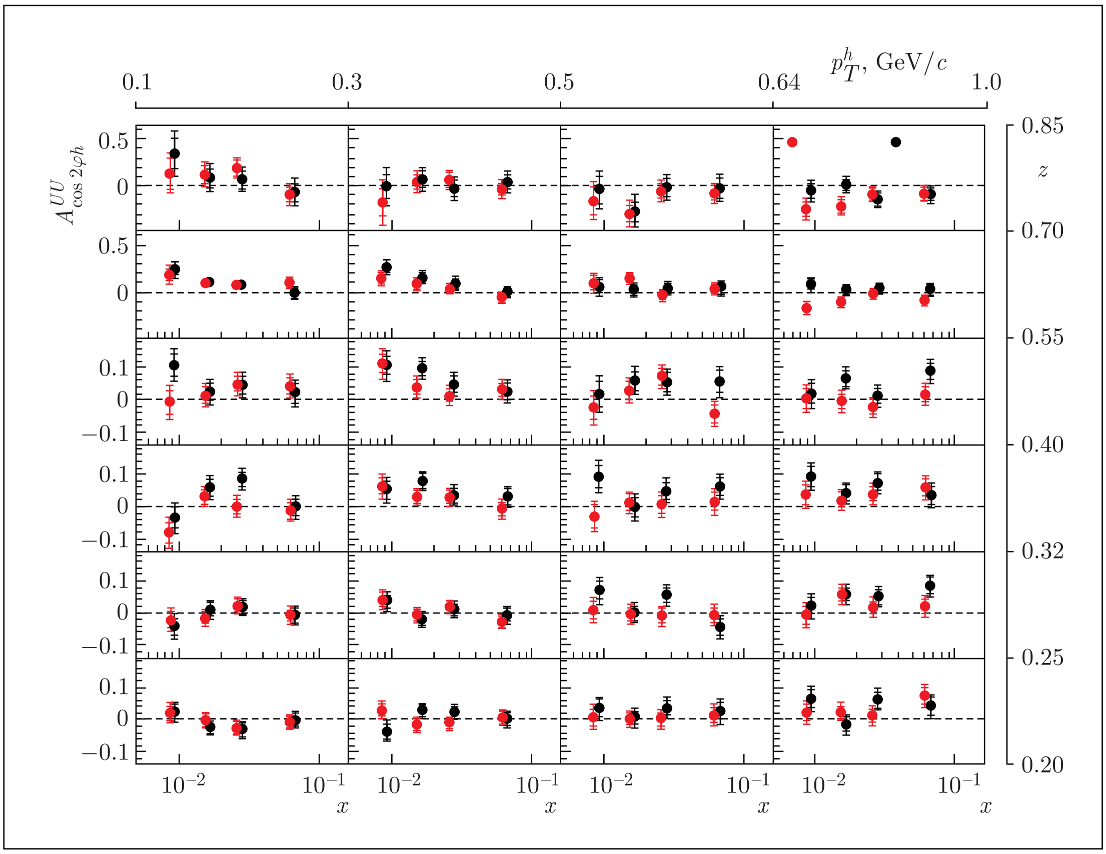

Fig. 15. Semi-inclusive asymmetries $A^{UU}_{\cos 2\varphi h}$ obtained on a ^{6}LiD target

indicate violation of s-channel helicity conservation. A significant contribution of unnatural parity exchange (UPE) transitions is observed, which decreases with increasing of W. The results obtained make it possible to estimate the contribution of the UPE transitions in a model-dependent manner and to evaluate the role of spiral-dependent generalized parton distributions in the processes of exclusive ω-meson production.

NA61/SHINE. The main goal of the NA61 experiment is to study the features of the onset of deconfinement and fireball formation, as well as to find the critical point. The search for the critical point of strongly interacting matter is carried out in the NA61/SHINE experiment by scanning the phase diagram both in temperature and in the baryon chemical potential, which is achieved by measuring at different energies and by studying the dependences on the sizes of colliding systems. The dynamic properties of the energy dependence of the ratio of kaons to pions yields and the slopes of the kaons transverse mass spectra, well known as the "step" and "horn" structures, were studied. In Pb + Pb collisions such structures arise during the formation of a mixed phase of hadronic gas (HG) and quark–gluon plasma (QGP). A fast change of "horn" in the energy dependence of K/π in central Pb + Pb and Au + Au has been found, which is explained as a manifestation of deconfinement in nuclear interactions — the transition from HG to QGP. The NA61/SHINE experiment supplemented these data with new measurements in the $p + p$, Be + Be and Ar + Sc reactions, which showed that the energy dependence of the slope parameter in $p + p$ interactions has the form of a "step" plateau; the data on Be + Be collisions are close to the results for $p + p$ interactions, and the data on Ar + Sc interactions show a dependence on the collision energy qualitatively similar to the data for the $p + p$ reaction, but the plateau is at a much higher level. The results for $p + p$ interactions may indicate the manifestation of deconfinement in small systems.

Due to the plans to increase the intensity of the lead ion beam by more than 10 times, the upgrade of almost all detector systems of this facility has begun at CERN. JINR staff members are upgrading the time-of-flight (TOF) system based on multigap resistive plate chambers (MRPC) with readout strips produced for the

NA61 experiment based on the developments performed at VBLHEP for the NICA project.

NA62 (NA48/2). The NA62 experiment at CERN is aimed at studying the very rare decay of a charged kaon into a charged pion, neutrino and antineutrino. A new result in studying the decay $K^+ \to \pi^+\nu\nu$ was obtained in the experiment based on data recorded in 2018. Sensitivity to a single event at the level of $1.11 \cdot 10^{-11}$ has been achieved, which corresponds to 7.6 events expected within the Standard Model. Seventeen candidates for signal events with an expected background level of 5.3 events have been experimentally found. Together with the three events previously discovered by the NA62 collaboration in 2016 and 2017 data, this leads to the most accurate measurement of the relative decay probability: $\mathrm{BR}\,(K^+ \to \pi^+\nu\nu) = (11.0^{+4.0}_{-3.5} \pm 0.3_{\text{syst.}}) \cdot 10^{-11}$, which agrees with the expectations of the Standard Model $(8.4 \pm 0.1) \cdot 10^{-11}$. NA62 will resume registration after a long shutdown of the LHC to achieve the originally planned 10% accuracy.

New results of the analysis of the flavor-changing decay $K^+ \to \pi^+\mu^+\mu^-$ were obtained [12]. The preliminary measured values of the form factor parameters are $a = -0.592 \pm 0.015$, $b = -0.699 \pm 0.058$, and the relative probability for the decay $\mathrm{BR}\,(K^+ \to \pi^+\mu^+\mu^-) = (9.27 \pm 0.11) \cdot 10^{-8}$. The accuracy achieved in the NA62 experiment significantly improves the available world data on this decay.

The JINR group also takes an active part in the maintenance and development of the facility; adjustment of the production of straw tubes of small diameter and simulation of the efficiency of particle tracks registration are in progress.

NA64. During the reporting period, in the NA64 experiment, which was highlighted in 2019 by the CERN Directorate as one of the most interesting and promising projects from a scientific point of view, the data on the search for the dark photon A' production and decay signals collected in 2016–2018 runs on the SPS CERN e-beam were completely processed and published. The total statistics were composed of $\sim 4 \cdot 10^{11}$ events. The candidates for a signal corresponding to the dark photon signature were not found.

The JINR group is responsible for the development and construction of coordinate detectors based on thin-walled straw tubes for the experiment. The Institute made commitments to produce, equip with electronics and put into operation seven new double-layer chambers made of 6 mm straw tubes with dimensions of 600×1200 mm. In 2020, all planes were produced. Their instrumentation with electronics and testing are underway.

Experiments at RHIC. The VBLHEP employees take an active part in the STAR experiment in Brookhaven to study collisions of relativistic heavy ions. Due to the smallness of the measured difference of relative mass of hypertriton and antihypertriton equal to $(1.1 \pm 1.0\ (\text{stat.}) \pm 0.5\ (\text{syst.})) \cdot 10^{-4}$, it was concluded that there were no violations of CPT symmetry [13]. The most important scientific priority of the STAR collaboration is the Beam Energy Scan II programme. The goal of the programme is to search for signatures of phase transitions and a critical point in nuclear matter. The planned measurements were performed at five collider energies (7.7, 9.1, 11.5, 14.6 and 19.6 GeV). In 2021, it is proposed to additionally conduct measurements at the sixth energy of 16.7 GeV. Indications that the energy dependence of "net-baryon" fluctuations may undergo significant changes have been obtained. Data analysis is being continued using various models. When studying the plane of the event, a nonzero value of $\nu 1$ was obtained to estimate the magnitude of the direct flow in $\mathrm{Au} + \mathrm{Au}$ collisions at energy of $\sqrt{s_{NN}} = 27$ GeV.

As part of the preparation of the spin programme at the NICA accelerator complex, the members of the group are developing a ZDC calorimeter prototype based on gallium–gadolinium garnet crystals and absorbers based on W/Cu composite alloys. Prototype assembly and testing with a beam are planned for 2021. In addition, four detectors for a polarimeter based on GaGG crystals with a diameter of 52 mm and a length of 50 mm were designed and produced to be installed at the output of the linear accelerator LU-20.

Experiments at GSI. *HADES.* The main goal of the HADES experiment is to study the properties of dense hadronic matter produced in collisions of heavy ions. The JINR group carried out work on the interpretation of the data obtained in HADES on the production of e^+e^- pairs in the pion–nucleon interaction. The OPER model is being modified to simulate $pp \to pp\pi^+\pi^-$ and $np \to np\pi^+\pi^-$ processes at energies of 3.5 and 4.5 GeV. The employees also participated in the maintenance of the multiwire drift chambers and in the replacement of the recording electronics.

CBM. The CBM experiment will be one of the main experiments at FAIR, which is being constructed. In 2020, the JINR group performed calculations of the magnet with muon detectors of the CBM facility. An estimate of the forces acting on the coils of a superconducting magnet and on a muon detector has been obtained. For the CBM muon system, a trial batch of FEE was produced based on the AST1-1 microcircuit for 50×50 cm straw detector prototype, and radiation tests of the prototype were carried out. A 16-channel board with SiPM readout for a hadron calorimeter was produced and tested.

EVENTS

On April 20–21, the 5th meeting of the BM@N collaboration was held in Dubna. Over 40 reports were presented, and recent results on interactions of carbon and argon nuclei with fixed targets were discussed.

On April 23–24, the 5th meeting of the MPD collaboration was held in a video conference format. Twenty-seven reports were presented on the development of the MPD detector systems and the results of physics analyses.

On August 26, the JINR delegation took part in the solemn opening ceremony of the Years of Russian–Chinese Cooperation in Science, Technology, and Innovation scheduled for 2020 and 2021. An Agreement between the Ministry of Science and Technology of the People's Republic of China and the Joint Institute for Nuclear Research was signed at the event on the participation of China in the construction and operation of the NICA accelerator complex.

On September 15–16, the second meeting of the NICA Cost and Schedule Review Committee (CSRC) was held. The Committee emerged on the decision of the Committee of Plenipotentiaries of the governments of the JINR Member States. The Committee noted considerable progress in the implementation of the NICA project since its last meeting in February and congratulated the team and management on their achievements. The Committee paid special attention to the progress in construction (the MPD hall is almost completed and will soon be ready for magnetic testing) as well as the completion of installation of the Booster and the start of a comprehensive commissioning process.

On October 20–23, VBLHEP hosted an international conference "RFBR Grants for NICA", where the grant holders reported on the results of their studies during the first two years of their work on grants. In addition, the first day of the conference was full of review lectures by leading theorists, presentations by NICA project leaders, by MPD, BM@N and SPD experiment leaders and reports by the representatives of experiments at the FAIR, LHC and RHIC accelerator facilities. The conference programme is available at https://indico.jinr.ru/event/1469.

On October 26–27, the 6th meeting of the BM@N collaboration was held in Dubna. Some of the reports were presented in person and some of them — via video conference. More than 25 out of 40 reports were presented by young employees at parallel sections.

On October 28–30, the 6th meeting of the MPD collaboration was held in a video conference format with 151 participants. Forty reports were presented.

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DZHELEPOV LABORATORY OF NUCLEAR PROBLEMS

NEUTRINO PHYSICS AND RARE PHENOMENA, ASTROPHYSICS

The sixth and seventh clusters of **Baikal-GVD** (a cubic-kilometre-scale deep underwater neutrino telescope currently under construction in Lake Baikal) were deployed and commissioned in April 2020 [1]. With their putting into operation, the efficient telescope volume for the high-energy astrophysical neutrinos increased to 0.35 km^3. The telescope has 2016 underwater PMT-based Cherenkov light detectors and operates in the regime of data acquisition and accumulation. The atmospheric muon and neutrino flux data are in good agreement with the expectation [2]. The counting rate of the first detected high-energy neutrino events is in agreement with the data on the flux of astrophysical neutrinos obtained by the IceCube Antarctic neutrino telescope. The combined operation of these two largest telescopes of the Northern and Southern hemispheres allows the whole-sky neutrino survey and searches for astrophysical sources. The Baikal-GVD detector participates in the international multimessenger alert systems in order to search for and study transient astrophysical sources with the techniques of multimessenger astronomy.

The **Daya Bay** experiment was shut down in December 2020. The data analysis will continue till 2022. The JINR group was assigned a task of developing the format of the analysis, which may be published together with the analysis code within the long-term data storage programme. Using the Global Neutrino Analysis (GNA) software developed at JINR, we have completed the Daya Bay model containing the full set of systematic uncertainties, introduced the CLs method, and estimated the Daya Bay sensitivity to the sterile neutrinos. Based on the time window splitting, we have developed a method to suppress the uncertainty of θ_{13} and Δm^2_{32} related to the ^{8}He/^{9}Li background.

The design of the Top Tracker support for the **JUNO** experiment is developed, and full documentation is sent to the manufacturer. The manufacturing will start in 2021. The development of the DAQ software is going on. The mass production of the HV modules ($\sim 25\,000$ items) developed by the JINR group was started after several factory tests. The detailed tests of 20 000 large PMTs for the Central Detector and the Veto System come to completion.

Within the **Borexino** experiment, the JINR group participated in the analysis of the pile-up events and the likelihood profiles for the recently published paper on the first direct carbon–nitrogen–oxygen (CNO) neutrino detection [3]. Limits on the neutrino magnetic moment were obtained for the paper on neutrinos from astrophysical sources [4]. A new method of the data analysis using a multilayer perceptron for the data selection was proposed and successfully tested. It was demonstrated that the current limit on the neutrino effective magnetic moment can be improved with this method.

In 2020, the **NOvA** experiment performed data analysis with an increased exposure, which now amounts to $13.6 \cdot 10^{20}$ POT (protons on target) in a neutrino beam and $12.5 \cdot 10^{20}$ POT in an antineutrino beam. Interpretation of different oscillation channels allowed one to refine the parameters of this phenomenon: the best fit value is at the point with the normal ordering, in the upper octant of the angle θ_{23} with

$\sin^2\theta_{23} = 0.57^{+0.03}_{-0.04}$, $\Delta m^2_{32} = (+2.41 \pm 0.07) \times 10^{-3}$ eV^2 and $\delta_{CP} = 0.82^{+0.24}_{-1.0}\pi$. Thus, the NOvA data prefer the combinations of the oscillation parameters leading to the symmetry between neutrinos and antineutrinos, while the opposite combinations (inverse ordering, $\delta_{CP} = \pi/2$, and normal ordering, $\delta_{CP} = 3\pi/2$) are rejected at the levels of $> 3\sigma$ and $> 2\sigma$, respectively [5].

Within the **NEMO-3** experiment, the results of the search for the double-beta decay of ^{82}Se to the 0^+_1 excited state of ^{82}Kr were published [6]. This study was performed using 0.93 kg of enriched ^{82}Se measured for 4.75 y, corresponding to an exposure of 4.42 kg · y. No evidence of the $2\nu\beta\beta$ decay to the 0^+_1 state was observed, and a limit of $T^{2\nu}_{1/2}(^{82}\text{Se}, 0^+_{\text{gs}} \to 0^+_1) > 1.3 \cdot 10^{21}$ y at 90% CL was set. Concerning the $0\nu\beta\beta$ decay to the 0^+_1 state, a limit for this decay was obtained to be $T^{0\nu}_{1/2}(^{82}\text{Se}, 0^+_{\text{gs}} \to 0^+_1) > 2.3 \times 10^{22}$ y at 90% CL, irrespective of the $2\nu\beta\beta$ decay process (Fig. 1).

Within the **EDELWEISS** experiment, a breakthrough made by creating detectors sensitive to the nuclear recoil energy range below 100 eV opens up completely new possibilities not only for dark matter (DM) search but also for studying neutrinos with CEνNS. In 2020, constraints on sub-MeV/c^2 DM particles interacting with electrons and on dark photons down to 1 eV/c^2 were obtained from the analysis of the accumulated data [7].

In 2019–2020, due to synergy between the EDELWEISS and CUPID-Mo experiments, world-class results were obtained in the search for neutrinoless double-beta decay of ^{100}Mo. Twenty Li_2MoO_4 scintillating crystals were operated as bolometers in the EDELWEISS cryostat. Comparison of light and phonon signals

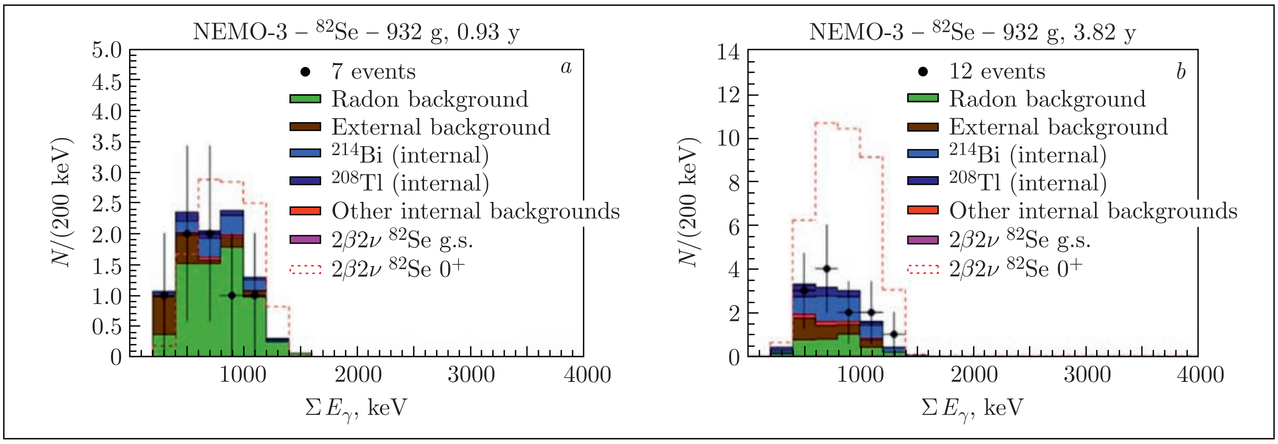

Fig. 1. Distributions of two-electron summed kinetic energy in selected $2e2\gamma$ events for Phase 1 (*a*) and Phase 2 (*b*). Experimental data are compared to the MC simulation for different backgrounds. The dotted red line represents the expected signal of the $2\nu\beta\beta$ decay to the 0^+_1 state for a half-life of $3 \cdot 10^{20}$ y

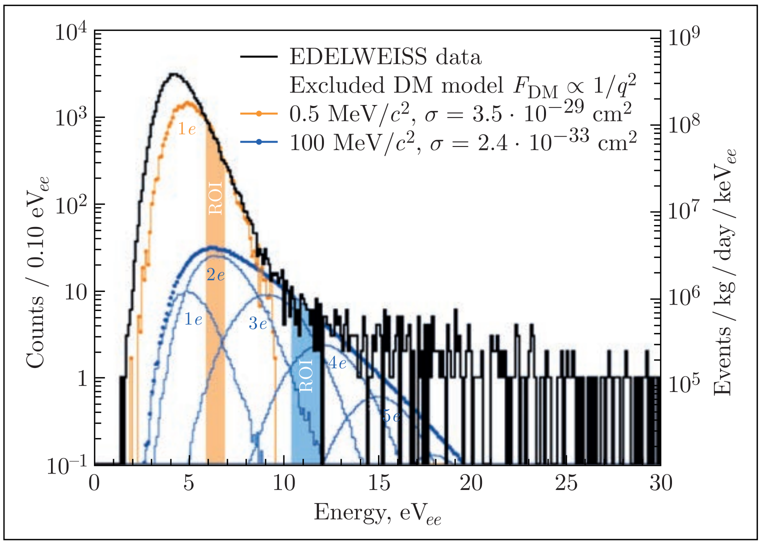

Fig. 2. Experimental spectrum of ultralow-energy events and expected spectra of dark matter particles in the region that has never before been studied with germanium detectors

allowed very efficient alpha-to-beta/gamma separation and background-free search for the $0\nu\beta\beta$. With data accumulated during one year (2019–2020), CUPID-Mo set the new best limit $1.5 \cdot 10^{24}$ y for the $0\nu\beta\beta$ decay of ^{100}Mo [8] (Fig. 2).

Within the **GERDA** experiment, the analysis of the full data set was completed in 2020. With a total exposure of 127.2 kg · y (103.7 kg · y in Phase II), no $0\nu\beta\beta$ signal was observed and the world's best lower half-life limit of $T^{0\nu}_{1/2} > 1.8 \cdot 10^{26}$ y (90% CL) was derived (Fig. 3) at the unique median sensitivity of $1.8 \times \times 10^{26}$ y [9]. In Phase II, GERDA achieved an unprecedentedly low background $B = 5.2^{+1.6}_{-1.3} \times \times 10^{-4}$ counts/(keV · kg · y), thus realizing the design goal of background-free performance: the mean background expected in the signal region ($Q_{\beta\beta} \pm 2\sigma$) was 0.3 counts. The background-free regime results in a nearly linear improvement of sensitivity vs exposure [10].

The ***ν*GeN** experiment is aimed at precise investigation of the electroweak sector and search for New Physics from detections of coherent elastic neutrino–nucleus scattering (CEvNS) in full coherency regime. The search for neutrino magnetic moment down to the level of $(5–9) \cdot 10^{-12}\mu_B$ is also performed. The energy resolution of 77.99(33) eV (FWHM) is achieved. This allows exploring low-energy events below 250 eV. Backgrounds are suppressed by multilayer passive shielding of borated polyethylene, lead, copper, and nylon. Moreover, to further decrease the cosmogenic background, an active plastic muon veto has been created and installed.

The **DANSS** detector detected about 4M reactor antineutrinos. After analyzing most of the collected statistics ($\sim$ 3M events), we did not observe a significant oscillation effect [11]. The largest part (as compared to competitors) of the phase space of parameters ($\sin^2(2\theta_{14}), \Delta m^2_{14}$) of possible oscillations, including the point of the best fit of the reactor antineutrino anomaly excluded at a level of more than 5σ, is excluded [12] (Fig. 4). For four years the reactor power has been monitored with a statistical error of $\sim$ 1.5% for two days of measurements. The applicability of the proposed technology for long-term monitoring of the reactor was confirmed. The sensitivity of the DANSS detector to the composition of nuclear fuel (the ^{239}Pu-to-^{235}U isotope ratio, changing during the fuel campaign) was clearly demonstrated in three reactor campaigns.

In 2020, the 1-km^2 **TAIGA** setup should be put into operation. Three Imaging Atmospheric Cherenkov Telescopes (IACT) of the TAIGA-IACT array are installed at the vertices of a triangle with the sides of 300, 400 and 500 m approximately between the TAIGA-HiSCORE optical stations. The telescopes have an alt-azimuth mount and a camera in the focus of the segmented Davies–Cotton design reflector with the diameter of 4.3 m and focal length of 4.75 m. The preliminary distribution of the detected EASs was obtained from 40-h observation of a source in the Crab nebula. The distribution is constructed both for events

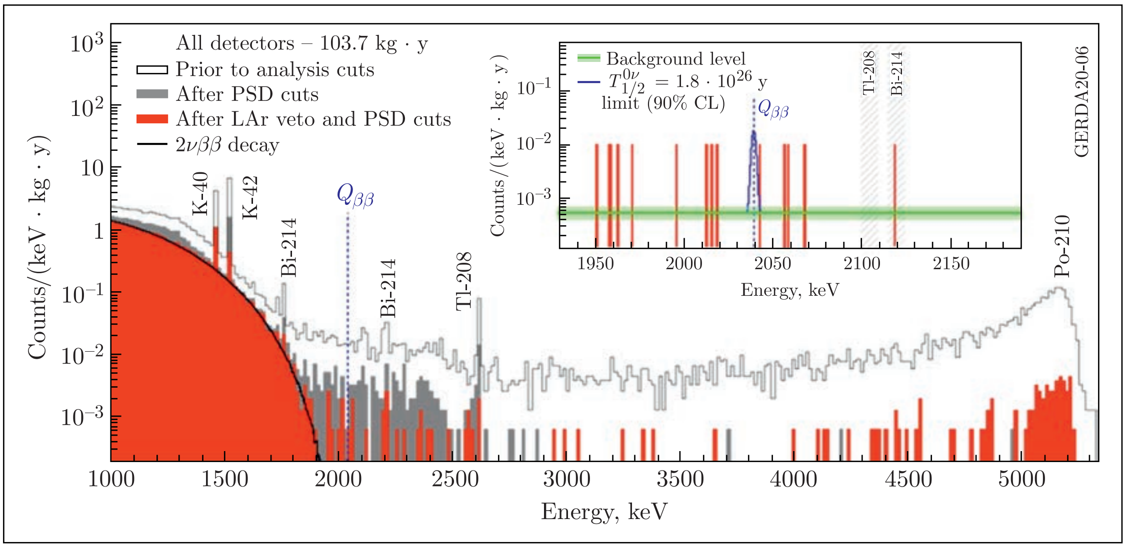

Fig. 3. Energy distribution of GERDA Phase II events between 1.0 and 5.3 MeV before and after analysis cuts for the full Phase II exposure of 103.7 kg · y. The inset displays the analysis window including the background level (green line). The blue curve depicts the 90% CL limit for a $0\nu\beta\beta$ signal at $T^{0\nu}_{1/2} = 1.8 \cdot 10^{26}$ y

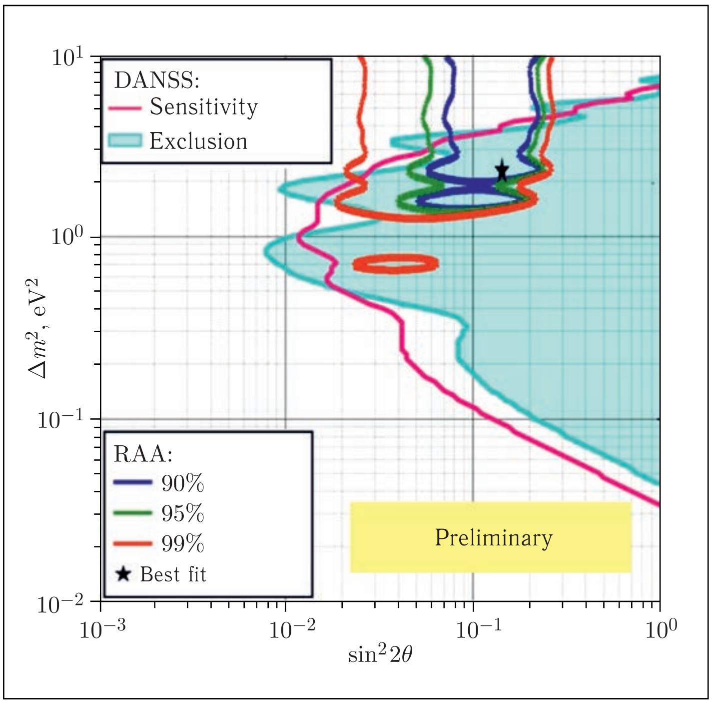

Fig. 4. Area excluded by the current analysis (cyan fill) and the sensitivity area (light purple curve). The $3+1$ model, which corresponds to the best fit according to the RAA publication (*Mention G.* // J. Phys.: Conf. Ser. 2013. V. 408. P. 012025), is shown in different colours depending on the level of confidence (blue/green/red curves for CL = 90/95/99%), while the black star shows the best fit

when the telescope is pointed at the source (ON distribution) and at the background region without the source (OFF distribution). By the excess of events at small angle the significance of the signal from the source is determined. The distribution showed a clear excess of events for ON distributions, which indicates the detection of gamma rays from the Crab nebula by the first TAIGA-IACT at the 6.3σ significance [13, 14].

The **OPERA** experiment data analysis is close to completion. The analysis of the 2018 DsTau pilot run data is in progress. It is aimed at studying the processes of tau neutrino production and search for the internal charm of the proton in p–A interactions. The JINR group has developed a Machine Learning algorithm for suppression of the hadronic interaction background.

ELEMENTARY PARTICLE PHYSICS

Within the **ATLAS** project, a search was performed for the decay of the SM Higgs boson into a bb pair when produced in association with a W or Z boson. All the data collected from pp collisions in the LHC at $\sqrt{s} = 13$ TeV were used. The production of a Higgs boson in association with a W or Z boson is established with the observed (expected) significances of 4.0(4.1) and 5.3(5.1)σ, respectively. The cross section measurements are all consistent with the Standard Model expectations [15].

Within the **BESIII** experiment, the $e^+e^- \to p\bar{p}$ process was studied at 22 centre-of-mass energy values from 2.00 to 3.08 GeV [16]. The Born cross section of the process was measured with the energy-scan technique and found to be consistent with the previously published data but with much improved accuracy. A partial-wave analysis was performed for the $e^+e^- \to K^+K^-\pi^0\pi^0$ process using e^+e^- collision data samples with the centre-of-mass energies ranging from 2.000 to 2.644 GeV [17]. The corresponding measurements are consistent with those of BaBar but have much improved precision. The analysis of the cross sections revealed a structure with the mass $M = (2126.5 \pm 16.8 \pm 12.4)$ MeV/c^2 and width $\Gamma = (106.9 \pm 32.1 \pm 28.1)$ MeV with an overall statistical significance of 6.3σ. The resonant parameters of the observed structure allow it to be identified as $\varphi(2170)$, which is important for understanding the internal structure of $\varphi(2170)$.

Software development is the main technical contribution of the JINR group to the BESIII experiment. Maintenance of the software packages developed earlier by the JINR group, including the ROOT-based analysis framework BEAN, was continued in 2020. The support of the JINR segment of the BESIII distributed computing system was continued as well.

Four modules 4.5 m long for the **Mu2e** Cosmic Ray Veto (CRV) system were constructed at the production facilities of the High Energy Physics Department of the University of Virginia (USA) according to the schedule of mass production of scintillation detectors for the Mu2e experiment. Also, the JINR participants in the collaboration took part in the assembly of Straw modules for the Mu2e experiment at the University of Minnesota (USA). Despite the good mechanical elaboration of the assembly technology, there were fundamental miscalculations in the process of installing the anode wires, which, in turn, led to deterioration in the quality of the wire as an anode element of the tube. As a result, the assembled modules did not pass the high-voltage tests at Fermilab. Thanks to extensive experience in mass production of wire detectors for DELPHI, DZERO, COMPASS, and other experiments, the participants have fundamentally solved this problem. After the modification of the operations with anode wires, fast high-voltage tests showed good results, which made it possible to successfully carry out the assembly of the modules [18, 19].

Within the **COMET** project, straw tubes with the diameter of 4.8 mm and wall thickness of 12 μm were developed in 2020 (Fig. 5). Their main advantage is a small amount of material on the way of charged particles, minimum gas leakage, and stable operation in vacuum. Those parameters were achieved using the ultrasonic welding technology that employs a special high-frequency generator. By now, 100 straw tubes with the length of 70 cm have been produced for the tracking detector prototype that is currently under development at JINR. The achieved characteristics of the new straw tubes give them a great advantage and an opportunity to be used in all current experiments with straw tracking detector systems [20].

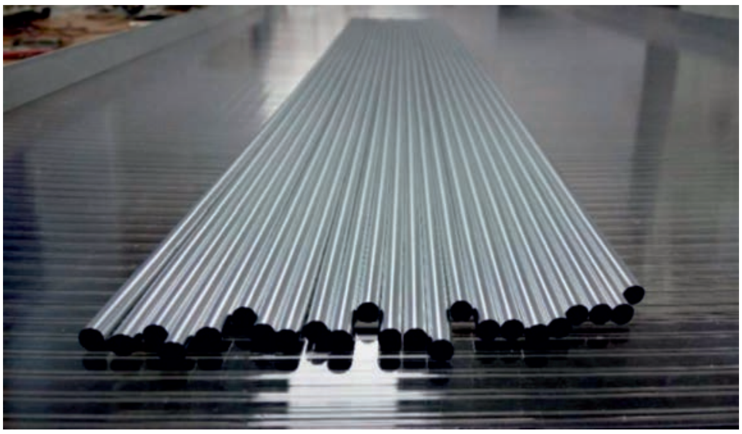

Fig. 5. New straw tubes for the JINR detector prototype

Within the **GDH&SPASCHARM** project, the A2 collaboration performed the world's first precision measurements of the total cross sections and angular distributions for π^0 photoproduction off quasi-free nucleons bound in the deuteron. Significant difference was found between the cross sections for free and bound protons due to the effects from final state interactions. This difference was used to estimate the photoproduction cross section of neutral pions on free neutrons. These data are obtained using the polarized proton (deuteron) target developed by DLNP employees [21].

APPLIED RESEARCH AND ACCELERATOR PHYSICS

At the DLNP Department of Multiple Hadron Processes, two prototypes of the modified precision laser inclinometer **(MPLI)** were manufactured and investigated. At present, daily monitoring of angular microseisms is carried out with the MPLI prototype on the JINR DLNP site. The microseismic background of industrial origin was investigated in order to use the MPLI at the NICA collider. The results of the study show the usefulness of the MPLI network for monitoring angular microseisms during the operation of the collider [22, 23]. Installation of five PLIs (two on the VIRGO gravitational antenna and three on CERN Transport Tunnel No. 1) and transportation of the sixth PLI to CERN were completed. The state patent of the Russian Federation was obtained for inventions related to the Precision Laser Inclinometer [24].

JINR and ASIPP (Hefei, China) have jointly developed the **SC200** superconducting cyclotron for hadron therapy. The commissioning of the SC200 superconducting cyclotron in Hefei is now close to completion. All systems are manufactured and tested. Magnetic measurements and shimming of the magnetic field of the SC200 cyclotron have been completed. The beam was successfully accelerated to the final energy of 200 MeV. Work continues with the beam aimed at improving the transmission coefficient, increasing the intensity, and organizing the extraction [25]. As production of the cyclotron for Hefei faced a lot of engineering challenges, some design solutions for the Dubna cyclotron have been reconsidered after careful analysis of the SC200, other projects, and operating cyclotrons for proton therapy. For the new Dubna SC230 cyclotron project, a low magnetic field was chosen. The accelerator as a source of an intense proton beam opens up opportunities for upgrading equipment for precise control and delivery of high dose rates for investigations of the Flash therapy method [26].

In 2020, on the basis of the **Medico-Technical Complex (MTC)** the effect of gold nanoparticles (^{79}Au) on irradiation of the A 549 tumour cell culture (human lung carcinoma) with gamma rays (^{60}Co) was studied. The number of micronuclei (MNs, markers of chromosomal changes in cells) was estimated. Gold nanoparticles increase the genotoxic effect of gamma irradiation. Formation of reactive oxygen species (ROSs) in the presence of gold nanoparticles under gamma irradiation was studied. Increased ROS formation can lead to oxidative stress. Gamma irradiation in the presence of gold nanoparticles increases the formation of ROSs.

In 2020, new scientific results were obtained in the study on the effect of ionizing radiation of different quality on the structure and function of the central nervous system (CNS). New information was obtained about the role of functional changes in glutamate receptors and the role of neuroglial interactions and brain neuromodulatory systems in response to ionizing irradiation. In the studies, the focus was on comparison of various molecular mechanisms in interrelation with functional changes at the level of behavior and on molecular mechanisms important for the development of promising drug countermeasures against negative effects of ionizing radiation [27].

In the **Section of Molecular Genetics of the Cell**, the world's first transcriptome analysis of the *D. melanogaster* line of Russian origin and other lines of various geographic origins was carried out, which made it possible to identify a number of candidate genes important for the adaptation of insects to global warming conditions [28]. RNA-seq of model *D. melanogaster*, which were in low radiation background conditions of DULB-4900 laboratory (Baksan Neutrino Observatory, INR RAS), was performed to assess the effect of natural and low background radiation on the vital processes of a complex multicellular organism [29]. Metagenomic sequencing of samples from a deep underground spring of the BNO INR RAS was carried out; during the analysis of the data, new genera and species of extreme microorganisms were discovered, which are of great interest for fundamental and applied research.

Within the **R&D of new semiconductor detectors**, the main elements of the operating X-ray tomograph prototype with a rotating sample were installed and commissioned, and its adjustment and calibration began. Cooperation with the international Medipix4 collaboration continued. At the Federal Scientific Research Centre "Crystallography and Photonics", Russian Academy of Sciences, a unique monochromator for X-ray radiation in the energy range 8–60 keV was developed and manufactured for JINR. The study of the background radiation in the ATLAS mine using semiconductor pixel detectors with gallium arsenide sensors was completed [30–32]. The first stage of the electron linear accelerator was put into operation. A stable electron beam with energies up to 200 MeV was obtained.

The project **"Development of Experimental Techniques and Applied Research with Slow Monochromatic Beams"** focuses on applied research in solid state physics and materials and surface engineering using the method of positron annihilation spectroscopy. In 2020, the investigations were concerned with the self-healing materials in which radiation degradation was drastically suppressed, e.g., the thin foil system of Nb–Zr [33] and nanostructured titanium [34], and the materials proposed for generation IV nuclear reactors, which have to withstand extreme irradiation, namely, carbides, nitrides and tungsten. Irradiation phenomena were also studied [35].

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FLEROV LABORATORY OF NUCLEAR REACTIONS

OPERATION AND DEVELOPMENT OF THE FLNR ACCELERATOR COMPLEX (DRIBs-III)

Employing the FLNR cyclotrons DC-280, U-400, U-400*M*, IC-100, and the MT-25 microtron, a wide variety of scientific and applied investigations in heavy-ion physics were conducted. The total operation time of the accelerators in 2020 amounted to 15 000 h.

The basic facility of the Factory of Superheavy Elements accelerator complex — DC-280 cyclotron — operated for 3700 h, including 500 h dedicated to experiments on the synthesis of element 115 (moscovium) in the ^{243}Am + ^{48}Ca reaction. We continued working out accelerating modes for titanium ions. ^{48}Ti beams with an intensity of 1 particle μA were produced.

The programme for experimental investigations at the FLNR U-400 accelerator complex was implemented according to the plan. The operation time of the U-400 cyclotron in 2020 amounted to 5700 h. Contract obligations of FLNR JINR (Roscosmos, track membrane production) were completely fulfilled on time.

The U-400*M* cyclotron operated for 2900 h during the first half of the year. In July 2020, its upgrade was begun, which will last about two years. The cyclotron and transportation channel components, outdated vacuum and water cooling system equipment were dismantled. U-400*M* is now ready for the replacement of the main magnet coils. At the same time, a new control system is developed; new components of the cyclotron are developed and manufactured. The modernization aims at enhancing the reliability and stability of the accelerator (replacement of the main magnet coils, accelerator vacuum system components, control system, and radiation control system) as well as increasing the intensity of heavy-ion beams.

In September 2020, the construction of a new DC-140 accelerator for applied investigations was begun. The new setup will be placed where the decommissioned U-200 cyclotron was located. The U-200 equipment is being dismantled. Design work for preparing the building for the new accelerator complex is underway.

The construction of the assembly hall continued, which is important, in particular, for the implementation of the FLNR plans to develop and upgrade the fleet of cyclotrons.

SYNTHESIS OF NUCLEI AT STABILITY LIMITS AND THEIR PROPERTIES

Completion of Test Experiments and First Experiment at the GFS-2 Gas-Filled Separator. Test experiments aimed at defining the optimal parameters of the GFS-2 gas-filled separator for transporting ^{48}Ca reaction products with the ^{nat}Yb, ^{174}Yb, ^{170}Er, and ^{206}Pb targets continued through 2020. These tests were required for preparing for experiments on the synthesis and study of superheavy nuclei (SHN). The experiments showed that for more efficient collection of nuclei the detector's size in the focal plane of the separator had to be increased.

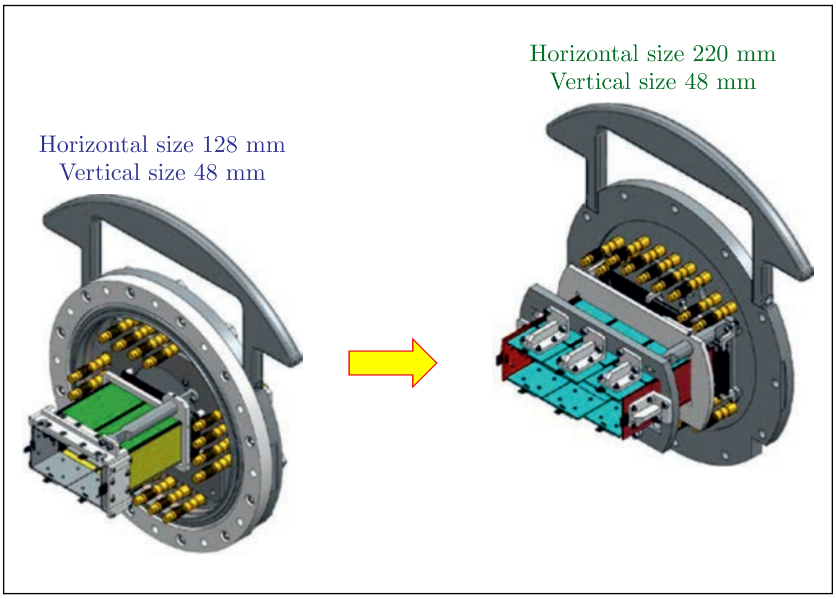

Fig. 1. Schematic drawing of initially employed vs new detectors of the GFS-2 separator

A new system of detectors 48×220 mm in size (Fig. 1) was manufactured and tested. The system allows an increase in the efficiency of the reaction product collection by a factor of 1.5, which is of paramount importance for long-running experiments on SHN synthesis.

With the new detectors the optimal setting parameters of GFS-2 were defined, as well as dispersion of the dipole magnets, the effect of gas pressure on the separator transmission, and the equilibrium charge of ions, the products of the ^{174}Yb, ^{206}Pb + ^{48}Ca reactions.

Experiments were performed for studying the stability of the separator Ti entrance window and the target at ^{48}Ca beam intensities up to 5 particle μA, which revealed a need for an increase in the target diameter and for switching to operation with the differential gas pumping system without the Ti window. The system was assembled and tested.

At the end of November 2020, an experiment was launched to thoroughly study the properties of Mc ($Z = 115$) isotopes and their production cross sections in the complete fusion reaction ^{43}Am(^{48}Ca, 2–5n)$^{286-289}$Mc. During the three-week run, over 30 decay events of the ^{288}Mc and ^{289}Mc isotopes were observed, which nearly doubled the statistics on these isotopes gathered at the U-400 accelerator complex for the period from 2003 to 2012. One of the important preliminary research results was the registration of the alpha decay of ^{268}Db, which has never been observed before and is leading to the discovery of a new isotope of lawrencium — ^{264}Lr. The results demonstrated high performance capability of the Factory of Superheavy Elements.

Spectroscopy of Heavy and Superheavy Nuclei. In February 2020, experiments aimed at studying the complete fusion reactions of ^{38,40}Ar beams and ^{208}Pb, ^{232}Th targets were carried out at the SHELS separator. The experimental investigation of the ^{40}Ar + ^{208}Pb = $^{248-x}$Fm + xn reaction was aimed at measuring the excitation function and specifying the properties of the radioactive decay of the ^{246}Fm nucleus. The ^{38}Ar + ^{232}Th reaction was studied under the assumption that the ^{266}Sg nucleus and an α particle were formed in the exit channel. One event was registered during the ten-day irradiation of the ^{232}Th target with ^{38}Ar ions, which can be attributed to spontaneous fission of ^{262}Rf, the ^{266}Sg α-decay daughter nucleus. Taking into account the efficiency of registration of such events, the yield of ^{266}Sg nuclei in the reaction under investigation was lower by a factor of 10 to 30 compared to that we had expected.

The properties of the radioactive decay of the ^{249,250,251}No isotopes observed in the ^{48}Ca + ^{204}Pb reaction were studied. In our experiments, we used the integrated detection system GABRIELA (α, β, and γ spectrometry). The experimental data are processed. In studies of the complete fusion reaction ^{48}Ca + ^{204}Pb = $^{252-x}$No + xn, the regularities were determined for the formation of the nuclei of ^{249,250,251}No. The data on internal conversion coefficients for the ^{250m}No isomeric state decay were supplemented. The half-life and α-decay

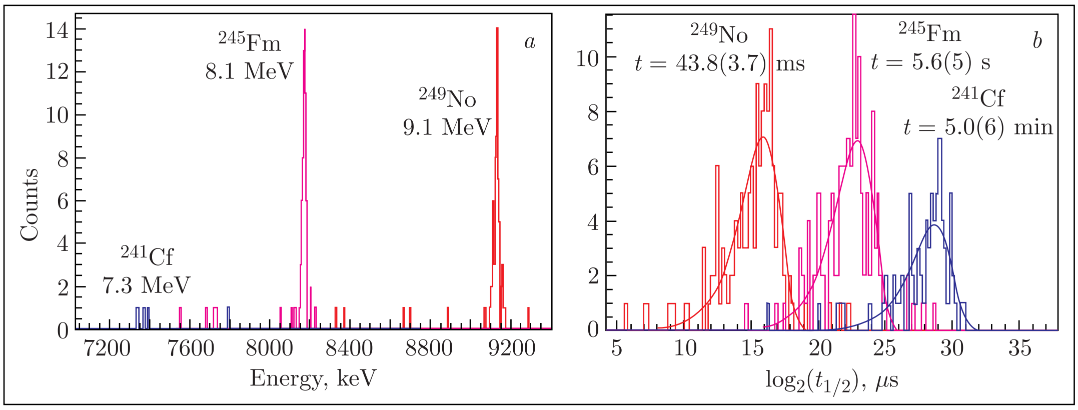

Fig. 2. *a*) The measured α spectrum of ^{249}No and its daughter products ^{245}Fm and ^{241}Cf. *b*) Experimental decay times of the found nuclei and the estimation of half-lives

energy were determined for ^{249}No synthesized in the $3n$-channel for the first time (Fig. 2).

The current status of SHELS and some of the experimental results are presented in [1–4].

Dynamics of Heavy-Ion Interaction, Fission of Heavy and Superheavy Nuclei. The investigation of the influence of the entrance channel on the dynamics of fusion–fission, quasi-fission, and deep inelastic transfer continued. Experiments were carried out with beams extracted from the U-400 accelerator using the double-arm time-of-flight CORSET spectrometer.

A detailed analysis of mass and energy distributions of binary fragments formed in the ^{32}S + ^{232}Th reaction leading to the formation of ^{264}Sg ($Z = 106$) at energies near and above the Coulomb barrier was completed [5]. The bulk of fission-like events were found to form during quasi-fission: the contribution of the fission of the ^{264}Sg compound nucleus to the symmetric mass region amounted to 72, 80, and 88% at the interaction energies of 165, 181, and 200 MeV, respectively. A high-energy component was observed in the energy distribution of ^{264}Sg fission fragments at an excitation energy of 45 MeV, which can be attributed to the SuperShort fission mode in ^{264}Sg.

In addition, we studied the ^{136}Xe + ^{198}Pt ($E_{\rm lab} = 710$ MeV) reaction, one of the most promising combinations of collision partners for producing neutron-rich heavy nuclei in multinucleon transfer reactions in the vicinity of the neutron closed shell $N = 126$. The analysis of angular distributions showed that the maximum yield of fragments with masses over 200 u was observed at angles close to those for grazing collisions, as in the case of the ^{136}Xe + ^{208}Pb reaction studied earlier. The probability of the formation of fragments heavier than 200 u was ~ 15% of all formed fragments with energy loss over 40 MeV. The experimentally obtained cross sections and their comparison with theoretical calculations provide evidence which suggests that multinucleon transfer reactions are efficient for producing new neutron-rich superheavy and heavy nuclei, including those located in the vicinity of the neutron closed shell $N = 126$, and are extremely important for understanding the r-process of astrophysical nucleosynthesis.

Moreover, we studied the characteristics of mass and energy distributions of binary fragments formed in the ^{52,54}Cr + ^{248}Cm and ^{68}Zn + ^{232}Th reactions leading to the formation of superheavy composite systems with $Z = 120$ [6, 7]. The contribution of quasi-fission fragments formed in long-lived composite systems was found to decrease immensely during the transition from systems with $Z_1Z_2 \approx 2300$ (^{52,54}Cr + ^{248}Cm) to those with $Z_1Z_2 > 2500$ (^{64}Ni + ^{238}U, ^{68}Zn + ^{232}Th). The main reaction channels were shown to be few-nucleon transfer reactions and deep inelastic collisions. The fusion probability was found to drop by approximately three orders of magnitude in transitioning from the ^{48}Ca + ^{238}U to the ^{54}Cr + ^{248}Cm reaction and by more than five orders of magnitude during the transition to the ^{68}Zn + ^{232}Th reaction at energies above the Coulomb barrier. On the basis of the obtained fusion probability for the ^{54}Cr + ^{248}Cm reaction, the production cross section of superheavy element $Z = 120$ is expected to be about a few femtobarns, whereas in the ^{64}Ni + ^{238}U and ^{68}Zn + ^{232}Th reactions this value will be one and two orders of magnitude lower, respectively.

Structure of Exotic Nuclei. In 2020, research with radioactive high-quality beams con-

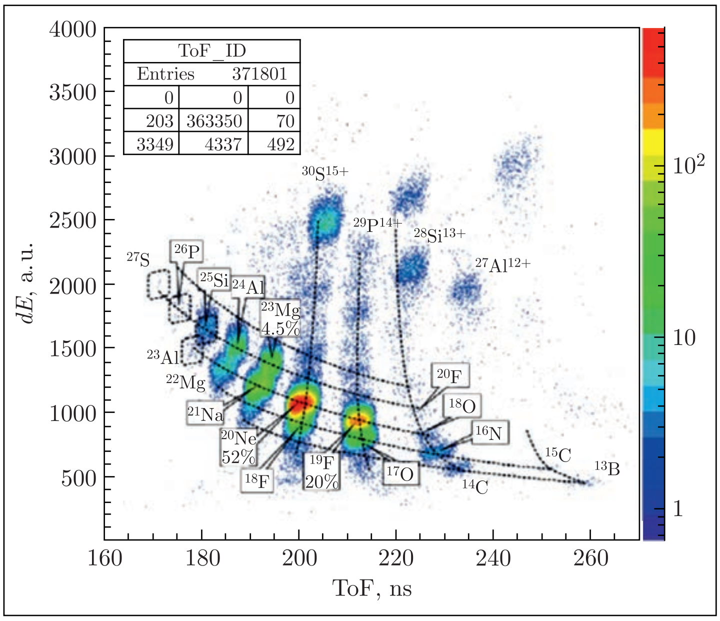

Fig. 3. Identification of isotopes in adjusting the ACCULINNA-2 separator to the maximum yield of the ^{26}P and ^{27}S isotopes in the reaction of ^{32}S (51.5 MeV/nucleon) on the Be (1 mm) target

tinued at the new ACCULINNA-2 fragment separator of the U-400*M* heavy-ion accelerator using cutting-edge detection systems [8–10]. Experiments were performed both with neutron-rich (^{6}He, ^{8}He, ^{9}Li, ^{10}Be, etc.) and neutron-deficient (^{24}Al, ^{25}Si, ^{26}P, ^{27}S, etc.) isotopes produced in fragmentation reactions of the beams of ^{15}N (49.7 MeV/nucleon) and ^{32}S (51.5 MeV/nucleon) heavy ions, respectively, reacting with a beryllium target.

An experiment aimed at searching for ^{7}H resonance states in the $^{8}\mathrm{He}\,(d,{}^{3}\mathrm{He})^{7}\mathrm{H} \to t + 4n$ reaction was carried out [9]. The key indicator of ^{7}H events were coincidences of low-energy ^{3}He particles ($E \sim 9$–30 MeV, $\theta \sim 8$–26° in the laboratory system) with tritons ($E \sim (70 \pm 30)$ MeV) moving at forward angles in a narrow cone ($\theta \leqslant 6^\circ$). To improve the accuracy of measurements of the specific energy losses of reaction products using 20-micron silicon detectors, the thickness of the detectors had to be defined with a precision of about 0.2 μm [9]. Using the ΔE–E method, we managed to separate hydrogen, helium and lithium isotopes originating from $^{8}\mathrm{He} + d$ collisions and measure their energies with a detection threshold of about 1 MeV/nucleon. We obtained 380 ^{3}He–t coincidence events, which were in line with the kinematics of the $^{8}\mathrm{He}\,(d,{}^{3}\mathrm{He})^{7}\mathrm{H}$ reaction and could be well separated from background events. The experimental data are analyzed. New information about the ground and first excited states of the ^{7}H system is awaited.

Moreover, an experiment aimed at studying the low-lying states of the ^{9}He isotope in the $^{8}\mathrm{He}\,(d,p)^{9}\mathrm{He} \to n + {}^{8}\mathrm{He}$ reaction was carried out. To register protons emitted backward in the laboratory system in coincidence with the ^{9}He decay products, notably the ^{8}He nucleus and a neutron emitted at forward angles, we used the technique developed earlier [10]. To define the experimental energy resolution of the entire detection system and the normalization of the missing mass spectrum of ^{9}He, triple coincidences p–^{6}He–n in the $^{6}\mathrm{He}\,(d,p)^{7}\mathrm{He}$ reaction were additionally measured using a radioactive ^{6}He beam. The experimental data are being analyzed. We expect to obtain a spectrum of ^{9}He low-lying states at $E^{*} < 4$ MeV with the experimental resolution $\Delta E \sim 250$ keV (FWHM).

A joint experiment with the Warsaw University group was carried out to study the rare decay channels of the neutron-deficient ^{26}P and ^{27}S nuclei (beta-delayed emission of several protons) using the optical time projection chamber (OTPC). The high identification quality of the radioactive beam attained at the ACCULINNA-2 separator (Fig. 3) using the time-of-flight measurement provided high-statistics data needed for obtaining new information on the decay of these nuclei via the βp, $\beta 2p$, and $\beta 3p$ channels. The experimental data are processed.

Reactions with Beams of Light Stable and Radioactive Nuclei. In 2020, experiments using the new high-resolution magnetic analyzer (MAVR setup) were launched.

Experiments aimed at measuring energy spectra of alpha particles in a wide energy range were carried out at the U-400 heavy-ion cyclotron.

The reactions with the ^{48}Ca and ^{56}Fe beams accelerated to 6 MeV per nucleon and ^{238}U and ^{181}Ta targets were studied. The differential cross sections for the emission of alpha particles at 0° were measured as a function of their energy (Fig. 4). Fast alpha particles at energies corresponding to the two- and three-body reaction channels, including those with energies close to the two-body kinematic limit, were observed in the recorded spectra.

The analysis of the experimental data conducted within the model of moving sources revealed several sources of fast alpha particles. The energy spectra of alpha particles were shown to be mainly characterized by the properties of heavy target nuclei and, to a lesser extent, by the properties of incident beam nuclei.

The investigations of the total cross sections for the reactions of the ^{6}He, ^{8}He, and ^{9}Li beams with the ^{28}Si, ^{59}Co, and ^{181}Ta targets were pursued. The energy dependence of the total cross sections, $\sigma_R(E)$, for the reactions was measured in the range of 20–40 MeV per nucleon. The cross sections for the interaction of ^{6}He, ^{8}He, and ^{9}Li with ^{59}Co and ^{181}Ta were measured for the first time. The measurements were carried out using the 4π γ-ray MULTI spectrometer comprising 12 CsI(Tl) and nine $CeBr_3$ scintillation detectors that have high γ-ray detection efficiency in a wide energy range. On the basis of a newly developed method for experimental data analysis, we obtained the total cross sections σ_R and their distribution over the γ-ray multiplicity [11].

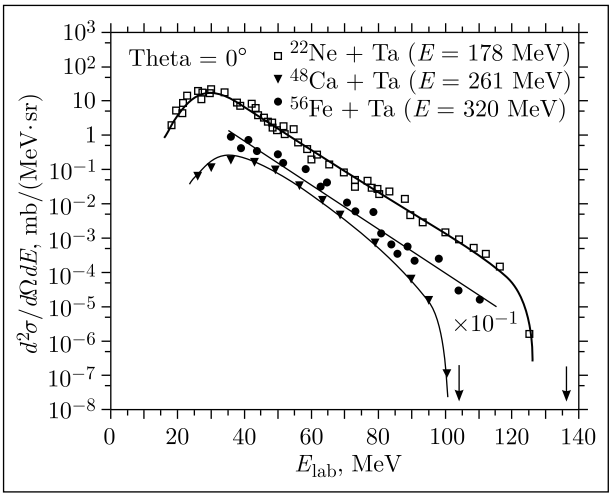

Fig. 4. Energy spectra of alpha particles measured at 0° in reactions with the ^{181}Ta target using different projectiles. The arrows show the energies of alpha particles corresponding to the kinematic limit of the two-body reaction channels using ^{48}Ca (left arrow) and ^{22}Ne (right arrow) nuclei

RADIATION EFFECTS AND PHYSICAL BASES OF NANOTECHNOLOGY, RADIOANALYTICAL AND RADIOISOTOPE INVESTIGATIONS AT FLNR ACCELERATORS

1. The mechanisms of transformation of latent tracks into a system of through pores of the subnanometer range were thoroughly studied after the irradiation of PET film with accelerated Xe and Bi ions with the energy losses in the polymer of 11 and 18 keV/nm, respectively. The evolution of the free volume and accumulation of carboxyl groups in the irradiated films at different stages of treatment were studied using gravimetry, IR and UV spectroscopy, conductometry, and electron microscopy methods. The permeability and selectivity of the resulting membranes were found to depend on several critical parameters: energy loss of the bombarding ion, temperature and pH of the solution used for extraction, and ion fluence [12].

2. The interrelation between the electrical, osmotic, hydraulic, and structural characteristics of an asymmetrically etched ion-track nanopore was examined. Several consecutive phases of pore evolution were identified. The temporal dependences of two counter fluxes — the diffusional flux of the etchant and the volume flux of stopping media — were measured and analyzed in terms of their effect on the nanopore configuration. The osmotic reflection coefficients of highly asymmetric pores were estimated under etching conditions and in diluted electrolyte solutions. The results allow a new level of understanding of the phenomena underlying the development of asymmetric ion-track nanopores for their applications in sensors and in various fields [13].

3. The effect of high-energy heavy ions in a nonconducting matrix of graphene oxide and fluorinated graphene was studied. The formation of graphene quantum dots (QDs) was established. The number density and diameter of QDs can be governed by a suitable choice of irradiation parameters (ion type, fluence, and energy) [14].

4. The parameters of latent tracks in polycrystalline and amorphous silicon nitride were studied using high-resolution transmission electron microscopy and molecular dynamics simulation. The threshold levels of electronic stopping powers for track formation, their sizes and material density profiles in isolated ion-track regions were determined [15].

5. Transmission electron microscopy (TEM) studies revealed the patterns of gas porosity development during annealing in three experimental ferritic alloys homogeneously ion-doped with helium: the invariance of the specific surface area of bubbles during their thermal growth; the coarsening mechanism of bubbles; and the dependence of gas pressure on the bubble size at constant temperature [16].

6. Techniques were examined for the formation of coatings on the surface of a poly(ethylene terephthalate) track-etched membrane using the method of electron-beam deposition of ultra-high-molecular-weight polyethylene and polytetrafluoroethylene in vacuum. Polytetrafluoroethylene as a target for dispersion was shown to allow the formation on the membrane surface of superhydrophobic coatings with a morphologically developed structure. The obtained composite membranes can be used in membrane distillation processes for desalination of seawater [17].

7. A technique for obtaining chitosan nanofiber deposited on the surface of metallized track membranes was developed at the pilot electroforming facility. Nanofibers were characterized using scanning electron microscopy methods. The performance characteristics, the electrosurface and adsorption properties of composite membranes were investigated [18]. The obtained materials can be used for membrane-sorption extraction of heavy metal ions from water, including ^{137}Cs.

8. The equipment pool was expanded. New physicochemical methods for studying (spectroscopy of surface-enhanced Raman scattering, dynamic light scattering, measurement of thermo-stimulated currents in dielectrics) and synthesizing (electrospinning) nanostructures were introduced into practice.

9. Analytic work on the certification of uranium ore within the CGL503 project carried out at the Central Geological Laboratory of Mongolia was done with nuclear physics methods used at FLNR JINR.

CONSTRUCTION OF NEW AND DEVELOPMENT OF EXISTING EXPERIMENTAL SET-UPS

Construction of the Separator Based on Resonance Laser Ionization (GaLS Setup). The development of the GaLS setup has continued. The facility is based on selective laser ionization and was designed for the separation of heavy nuclides produced in multinucleon transfer reactions. The following main results were achieved in 2020:

1. The ionization channel based on three solid-state tunable Ti–Sa lasers was tested and optimized. Testing was conducted covering the entire wavelength range using laser wavelength meters in visible and UV regions.

2. The ion guide was developed, designed, constructed and delivered to FLNR. It comprises a segmented S-shaped RFQ in low-vacuum volume, a micro-RFQ at low/high vacuum transition, and a segmented linear RFQ in high vacuum volume. The equipping of the system with electrical components has begun. The expected transport time is 487.2 μs and transport efficiency is 97.7%.

3. Preparations were made for installing the mass separator components onto U-400M. FLUKA simulations for radiation protection in the cabin were performed, and the requirements for optimizing the system in order to ensure radiation safety were outlined. A high-voltage platform was developed and launched into production.

Ion Gas Catcher. The assembly of the cryogenic ion catcher, a new setup of the Factory of Superheavy Elements, has begun. The “warm” component of the chamber was installed and vented to 10^{-3} mbar.

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FRANK LABORATORY OF NEUTRON PHYSICS

In 2020, the scientific program of the Frank Laboratory of Neutron Physics was aimed at obtaining new results within the framework of seven research themes of the JINR Plan for Scientific Research and International Scientific and Technical Cooperation: in condensed matter physics ("Investigations of Condensed Matter by Modern Neutron Scattering Methods", 04-4-1121-2015/2020, headed by D. P. Kozlenko, V. L. Aksenov and A. M. Balagurov; "Multimodal Platform for Raman and Nonlinear Optical Microscopy and Microspectroscopy for Condensed Matter Studies", 04-4-1133-2018/2020, headed by G. M. Arzumanyan and N. Kučerka); in neutron nuclear physics ("Investigations in the Field of Nuclear Physics with Neutrons", 03-4-1128-2017/2022, headed by E. V. Lychagin); in the development of the FLNP basic facilities ("Development of the IBR-2 Facility with a Complex of Cryogenic Neutron Moderators", 04-4-1105-2011/2022, headed by A. V. Belushkin, A. V. Vinogradov and A. V. Dolgikh); in the development of the IBR-2 spectrometers and computation complex ("Development of Experimental Facilities for Condensed Matter Investigations with Beams of the IBR-2 Facility", 04-4-1122-2015/2020, headed by S. A. Kulikov, V. I. Prikhodko and V. I. Bodnarchuk); in the development of the design of a new neutron source ("Development of the Conceptual Design of a New Advanced Neutron Source at JINR", 04-4-1140-2020/2022, headed by V. N. Shvetsov and S. A. Kulikov); in the development of the SOLCRYS structural research laboratory in Poland ("Development of the SOLCRYS Structural Research Laboratory at the SOLARIS National Synchrotron Radiation Centre", 04-4-1141-2020/2022, headed by N. Kučerka).

CONDENSED MATTER PHYSICS

In 2020, the IBR-2 reactor operated for physical experiments within the FLNP User Program for 92 days. From November to the end of the year, the program was implemented completely without direct participation of users. Eighty-six applications for experiments were received: 23% of them were aimed at solving problems of materials science, 31% were devoted to physical problems, and the remaining 46% covered research in the field of chemistry, geological sciences, biology and applied problems. Eighty submitted applications were accepted for realization.

Structure Investigations of Novel Oxide, Intermetallic and Nanostructured Materials. The effect of high pressures on the atomic and magnetic structure of quasi-2D van der Waals antiferromagnet $FePS_3$ was studied in a wide temperature range [1]. The geometry of the magnetic lattice of these compounds is similar to that of graphene, and recently, in layered nanostructures of such compounds, the emergence of magnetic ordering has been revealed at sufficiently high temperatures within a single atomic layer. A wide variety of new physical phenomena, including insulator–metal transitions, spin-crossover, and superconductivity, have also been discovered in these compounds with changes in thermodynamic parameters (temperature and pressure). Our study revealed an isostructural phase transition to a new monoclinic modification at $P = 1$ GPa, accompa-

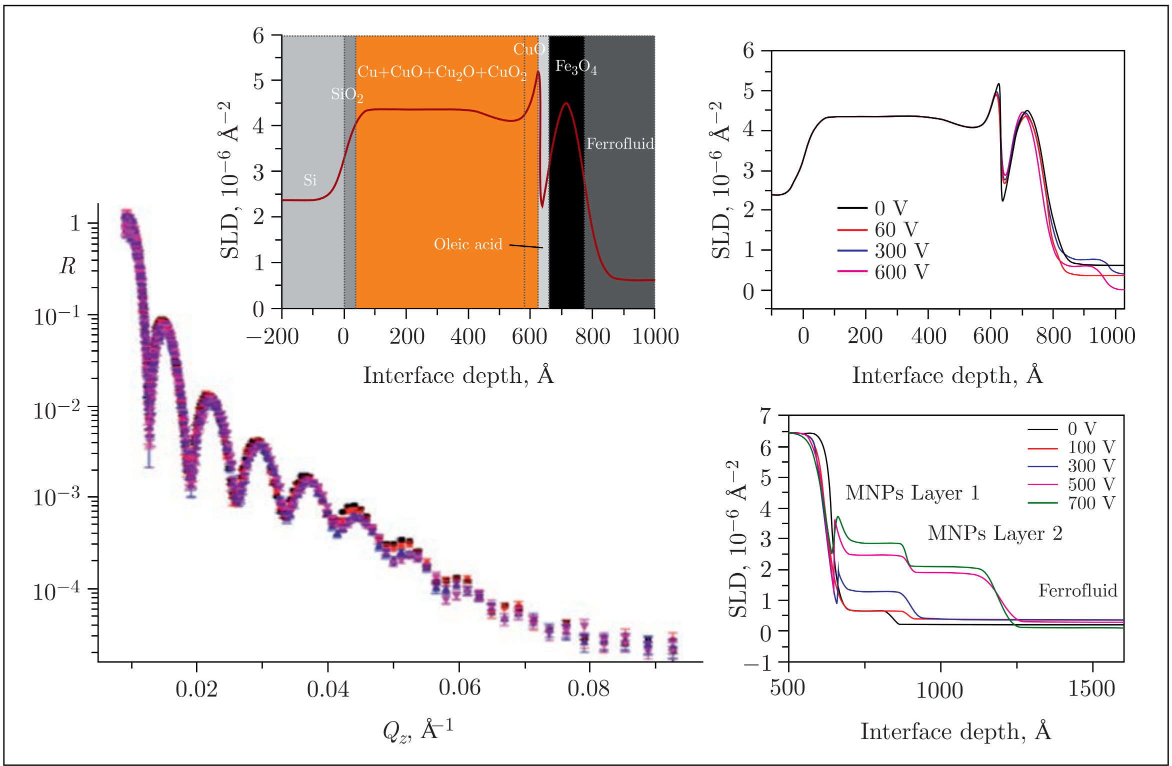

Fig. 1. Depth profile of the distribution of nanoparticles from a dielectric magnetic fluid on the planar surface of a copper electrode exposed to an external electric field (perpendicular to the surface) using neutron reflectometry data

nied by a significant change in the lattice parameters and a change in the nature of the AFM ordering from quasi-2D (propagation vector $k = (0\ 1\ 1/2)$) to three-dimensional character ($k = (0\ 1\ 0)$).

Structural studies of Fe–Ga magnetostrictive alloys with a relatively low gallium content (17.5–19.5at.%Ga) were continued using neutron, electron and X-ray diffraction. It was shown that in disagreement with the existing phase diagrams, the long-term isothermally annealed (at 450–500°C) Fe–17.5%Ga alloy has a two-phase structure with two co-existing ferromagnetic phases: *bcc* $A2$ (or its ordered modification $D0_3$) as a matrix and *fcc* $A1$ (or its ordered modification $L1_2$) with needle-shaped precipitates. For 17.5 and 19.5%Ga alloys, time-temperature-transformation (TTT) diagrams were developed [2], which were used to determine the critical cooling rates with respect to the transformation between metastable and equilibrium phases.

Investigation of Magnetic Fluids and Nanoparticles. Studies of the effect of an external electric field on the adsorption of magnetic nanoparticles at planar interfaces from dielectric magnetic fluids were continued [3]. The latter are used as thermalizing additives in high-voltage transformers. A magnetic fluid based on transformer oil with magnetite nanoparticles coated with a single layer of surfactant (oleic acid) was studied. The magnetic fluid was in contact with a copper thin-film electrode deposited on monocrystalline silicon. Using neutron reflectometry (GRAINS reflectometer), the formation of several layers of magnetic nanoparticles was revealed on the electrode surface (Fig. 1). With increasing field strength, the near-surface structure undergoes nontrivial changes in the density depth profile, which is in qualitative agreement with the previously detected inhomogeneities developing in the bulk of dielectric magnetic fluids exposed to an external electric field.

Investigation of Carbon Nanomaterials. The anti-amyloid disassembly activity of C_{60} and C_{70} fullerenes dispersed in 1-methyl-2-pyrrolidinone (NMP) was demonstrated (Fig. 2) [4]. The study was carried out with model aqueous solutions of amyloid fibrils preformed from lysozyme and insulin using a combination of different experimental techniques. Thioflavin T fluorescence assay and atomic force microscopy were applied for moni-

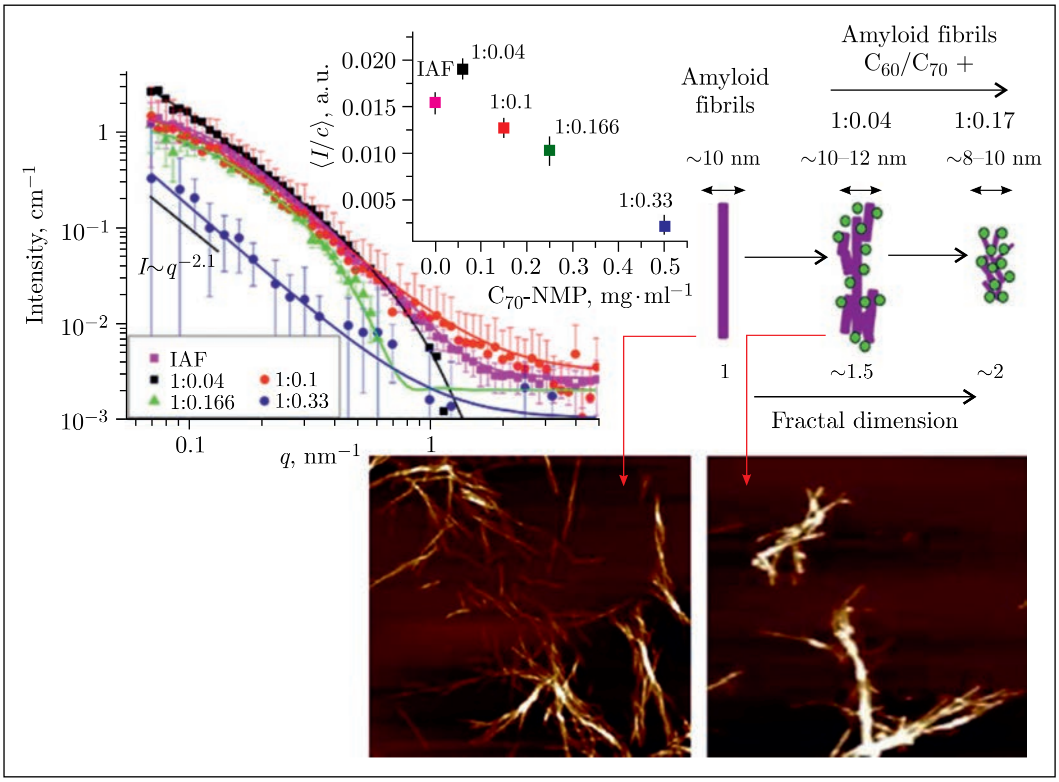

Fig. 2. Destruction of amyloid fibrils upon interaction with fullerenes complexed with NMP. SANS data (YuMO, IBR-2) and AFM images are given

toring the disaggregation activity of fullerenes. Both types of fullerene-based complexes were shown to be very effective in disassembling preformed fibrils and are characterized by a low deaggregation concentration (DC50) in the range of ~ 22–30 μg/ml. Small-angle neutron scattering was employed to monitor different stages of the fibril disassembly process, including determining the size and morphology of the aggregates. Based on the obtained results, a possible disassembly mechanism for amyloid fibrils interacting with fullerene/NMP complexes was proposed. The study is an important step in understanding the mechanism of destruction of protein amyloids by fullerenes in living organisms; it also provides valuable information on how macromolecules can be engineered to disassemble unwanted amyloid aggregates through different mechanisms.

Investigation of Layered Nanostructures and Electrochemical Interfaces. On the YUMO instrument, using small-angle neutron scattering, the study of the effect of conductive carbon additives (soot, graphene, and carbon nanotubes (CNTs)) on the porous structure of positive electrodes based on lithium iron phosphate ($LiFePO_4$, or lithium ferrophosphate (LFP)) was continued (Fig. 3) [5]. To separate scattering by closed pores from scattering by open pores, the electrodes were wetted with a deuterated electrolyte, which made it possible to compensate for scattering by open pores. It was found that the used additives change the porosity of the electrodes to different degrees and affect the wettability of the material both due to the different efficiency of the embedding of CNTs into the pores and due to changes in the LFP matrix. Thus, the CNT network embedded in the electrode layer provides its greater wettability by an electrolyte compared with widely used carbon black. This results in better electrode C-rate performance. The structural analysis made it possible to improve and optimize the manufacturing technology of large-area LFP-based electrodes. It was demonstrated that the use of CNTs as conductive additives opens up prospects for the production of electrodes with an area capacity of more than 5 mAh/cm^2. The practical applicability of the considered electrode technology was proven on a pouch cell prototype with specific energy density of 150 Wh·kg^{-1}/295 Wh·l^{-1}.

On the REMUR reflectometer, studies were conducted to detect a new electromagnetic proximity effect induced by current $\mathbf{j}$ related to magnetization $\mathbf{M}$ ($\mathrm{rot\,rot}\ \mathbf{A} \approx 4\pi (\mathbf{j} = c \times \mathrm{rot}\,\mathbf{M})/c$), which should exist for any type of ferromagnetics. The region of the chan-

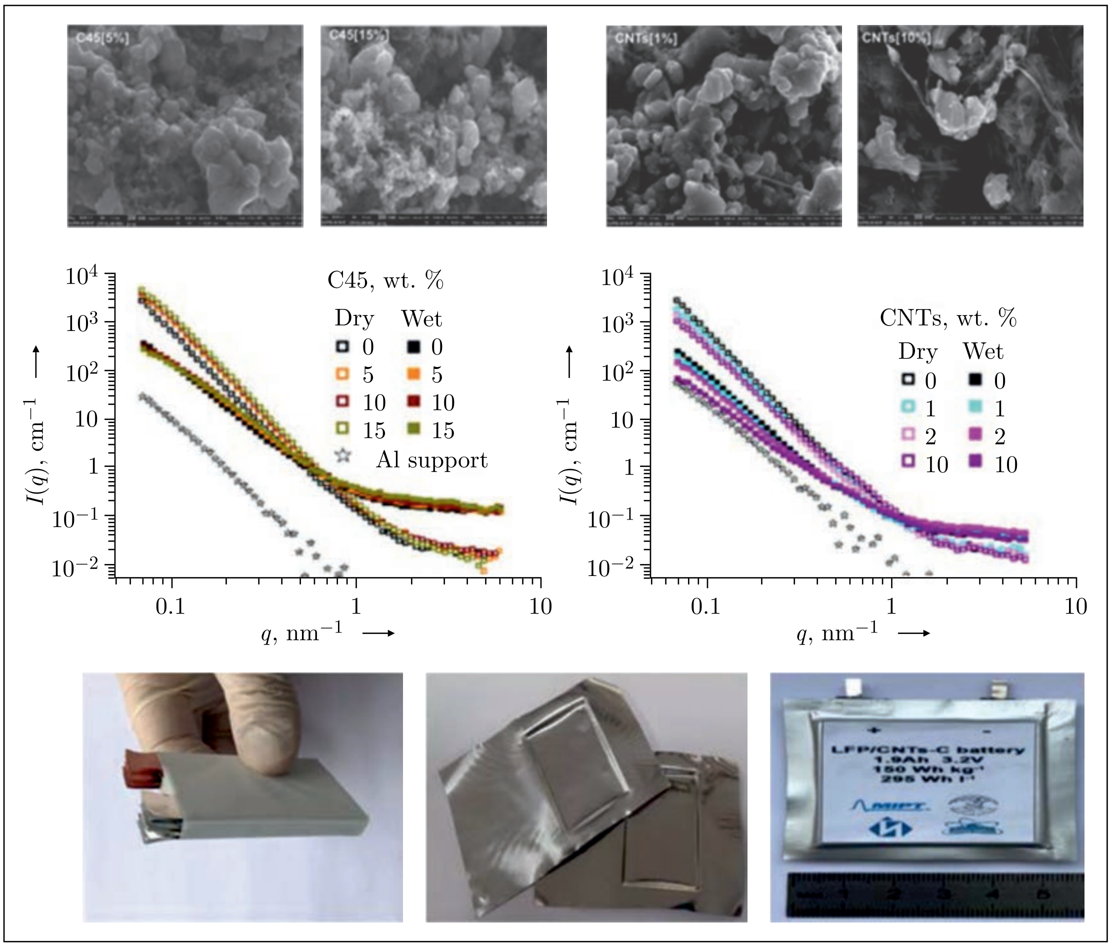

Fig. 3. Structural studies of cathode LFP-based materials with carbon additives using electron microscopy and SANS (YuMO, IBR-2), and the use of advanced materials in the production of prototypes of lithium-ion batteries

ge in magnetization in a superconductor in this case is much greater as compared to the usual direct proximity effect in ferromagnetics of transition elements with conduction electrons and is on the order of the penetration depth of the magnetic field in the superconductor. We studied the structure Nb(15 nm)/V(70 nm)/Gd(3 nm)/Nb(100 nm)/Al_2O_3 where ferromagnetic gadolinium and niobium and vanadium superconductors were used. The results of preliminary data treatment show that the magnetization induced in superconducting layers is 2–5% of its value in the ferromagnetic layer. The size of the induced region is of nanometric dimensions and is on the order of 20 nm. The obtained values of these parameters suggest that the electromagnetic proximity effect actually takes place. Further efforts will be focused on detailed analysis of experimental data as well as measurements with structures with various thicknesses of the gadolinium layer, for which the change in magnetization should be of a different sign.

Investigations of Biological Nanosystems, Lipid Membranes and Lipid Complexes. Biomembranes are one of the key objects of numerous studies in biology and biophysics, which are of great importance for medicine. In particular, unusual properties are exhibited by thin quasi two-dimensional liquid crystalline membranes with bending rigidity of several k_BT. The first-order chain-melting phase transition of lipid membranes is observed to be accompanied by a pseudocritical behavior of membrane physical-chemical properties. However, the investigation of the nature of the anomalous swelling of a stack of lipid membranes in the vicinity of the transition by different groups led to conflicting conclusions about the level of critical density fluctuations and their impact on the membrane softening, as well as the contribution of Helfrich's undulations. To study the effect of anomalous membrane swelling, studies were carried out using small-angle neutron scattering (SANS) and neutron spin-echo (NSE) techniques [6]. Our SANS data showed the abnormal behavior of the repeat distance between the membrane lipid bilayers (DMPC in D_2O) in the vicinity of the main phase transition due to the increase in the intermembrane distance. The NSE experiments with unilamellar lipids demonstrated that the bending rigidity of lipid membranes decreases in the region of the anomalous membrane swelling. The presence of significant critical fluctuations in the vicinity of the transition, which induce membrane softening, was revealed. However, contrary to the existing paradigm, the obtained results show that an increase in the undulation forces cannot explain the anomalous swelling of the membrane stack. We suggested that the observed effect is determined by the dominant enhancement of the short-range entropic repulsion. According to the theory, an increase in the amplitude of the out-of-plane fluctuations of lipid molecules leads to an increase in the decay length of the short-range forces and therefore membrane swelling.

The mechanism of formation of lipid domains (rafts) in lipid membranes containing cholesterol was studied [7]. The formation of these domains in the membrane is an important mechanism for regulating cell life processes. To study the collective dynamics of lipid molecules, high Q-resolution inelastic X-ray scattering was used. The obtained dispersion curves of multicomponent membranes, in addition to the known acoustic phonon modes, also contain a new optical phonon mode associated with the existence of stable lipid pairs consisting of two different types of lipid molecules. The observed gap of the optical phonon mode suggests a finite size of the region of existence of optical phonons. These regions are stable on the picosecond time scale, since their size does not depend on the component composition of the membrane. This means that any lipid raft consists of a set of identical lipid domains, the number of which is determined by the thermodynamic parameters of the membrane. This result is unique because it provides insight into the collective dynamics of lipid molecules on nanometer space and picosecond time scales simultaneously.

Research of Polymeric Materials. A generalized nonkinetic off-lattice algorithm to construct stochastic fractal clusters of polydisperse particles with tunable cluster parameters including dimension was developed [8]. The model based on a hierarchical procedure extends the previous studies in this area to the general case of the cluster–cluster aggregation and, in contrast to the previous kinetic models, makes it possible to generate clusters with a continuous change in the structure, in particular, covering the full range of natural mass fractal dimensions between one and three. An example of the morphological study of numerically generated clusters based on the correlation analysis in both direct and reciprocal spaces is given. In the latter case, it is demonstrated that the use of the developed fast algorithm gives an accurate and self-consistent description of the small-angle scattering data. The polydispersity of primary particles was shown to be a key aspect for widening the fractal dimension range covered in the modeling. The particular cases were considered to show that the previous algorithms dealing with monodisperse primary particles are special cases of the presented approach. Thus, the developed hierarchical procedure allows one to obtain full self-similarity over an arbitrary wide-size scale. The particle size/structure polydispersity is a common case in practical applications, so the introduction of particle polydispersity into modeling of fractal clusters extends the possibilities for studying correlations in natural fractal systems and modeling physical properties of different nanomaterials.

Atomic and Molecular Dynamics. The physicochemical properties and vibrational dynamics of methylhexanol isomers were studied by experimental and theoretical methods in a wide temperature range using infrared absorption spectroscopy and inelastic incoherent neutron scattering. The inelastic scattering spectra of three alcohols with a single phenyl ring were obtained using the NERA inverted-geometry spectrometer at the IBR-2 reactor (FLNP, JINR). The measurements covered a wide temperature range (5–260 K) in several cooling/heating cycles. The existence of a crystalline state for these systems was not detected. The vibrational motions of proton groups measured at liquid-helium temperature are consistent with the results obtained from the DFT-based simulation. Data analysis showed that no significant differences in the $G(v)$ spectrum were found for 3methylhexan-1-ol and 3methylhexan-2-ol. Differences can be observed only for 3methylhexan-3-ol. Torsional motions of the functional groups are observed in the $G(v)$ spectra in the region of lattice vibrations due to the low-energy barrier. Thus, it was shown that the motion of the proton, described by the positions of vibrational bands, is practically independent of the group of neighboring atoms.

Applied Research. Welding is one of the key technologies used in most major industries. The quality and integrity of welded joints are critical from the point of view of safety for a wide range of products and structures, including the automobile industry. In the framework of cooperation with the National R&D Institute for Welding and Material Testing — ISIM (Timisoara, Romania), it is planned to develop a computer system that, using the available database, makes it possible to plan the welding process and choose the most suitable combination of welding materials, welding technologies and welding parameters for obtaining a welded structure with desired properties. The aim of the joint research is to create a database of residual stresses in welded joints based on the results of neutron diffraction and to determine the correlation between the parameters of welding processes and the state of residual stresses in the resulting welded joints. Careful selection of welding parameters and optimization of heat input allows one to obtain the mechanical characteristics of the joints that are suitable for a particular application.

In order to study the effect of different welding modes on the distribution of residual stresses and microstrains in welds, a series of 20 specimens with a thickness of 2 mm made of alloyed fine-grained steel S460MC, which has a wide range of structural applications, was studied using the FSD diffractometer. GMAW (Gas Metal Arc Welding) butt welds in the specimens were according to EN 10149-2 standard. In the experiments, scanning across the welds of the specimens was performed over a wide range of X-coordinate using a small scattering volume of $2\times2\times10$ mm, which was defined by radial collimators. The measured high-resolution diffraction spectra were processed applying full-profile analysis based on the Rietveld method. The obtained experimental data of lattice parameters and diffraction peak width coefficients as a factor of interplanar spacing d_{hkl} were used to determine the components of the tensors of residual stresses and strains, as well as microstrains in the specimens under study in the weld area.

The level of residual stresses in the studied specimens is quite moderate and reaches the maximum values in amplitude (in the range from 100 to 300 MPa) in the weld area and surrounding heat-affected zone (HAZ). It should be noted that the profile of the residual stress distribution along the X-direction is quite different for specimens with different heat treatments. Additionally, from the broadening of the diffraction peaks in comparison with the resolution function of the instrument, we obtained information on the distribution of residual microstrains in the material. The amplitudes of microstrains are approximately equal in magnitude for all specimens and reach a value of $1.13\cdot10^{-3}$, while the position of the maximum in the distribution of microstrains coincides with the position of the center of the weld. In the future, it is planned to compare the obtained neutron data with the results of classical nondestructive and destructive tests (tensile tests, hardness measurements, visual tests, penetrating liquid tests, etc.) to establish mathematical (statistical) dependences between the applied welding parameters and the state of internal stresses in welded joints.

MULTIMODAL PLATFORM FOR RAMAN AND NONLINEAR OPTICAL MICROSCOPY AND MICROSPECTROSCOPY FOR CONDENSED MATTER STUDIES

The main goal of the theme is aimed at the development of the modern methods for highly sensitive detection (single units of molecules) and chemically selective, contrast visualization of organic molecules. The method is based on Coherent Anti-Stokes Raman Scattering (CARS) spectroscopy of molecules adsorbed on plasmonic nanostructured substrates. This method provides Surface-Enhanced Raman Scattering (SERS) employing ultrashort (picosecond) pulses of IR laser radiation. This phenomenon, known as Surface-Enhanced Coherent Anti-Stokes Raman Scattering (SECARS) is currently poorly studied.

The other important part of the theme is the study of photo- and upconversion luminescence based on promising core-shell nanostructures. In recent years, core-shell nanoparticles are at the leading edge of hot research topics and offer a wide range of applications in biomedicine, optics, environmental science, materials, and so forth, due to their excellent properties such as versatility, tunability and stability. The core-shell nanomaterials containing noble metals are plasmonic nanomaterials. They can be employed for contrast imaging, biomedical applications, etc.

Systematic/Regular Experiments on SECARS Spectroscopy: Laser Intensity Limits in Surface-Enhanced Linear and Nonlinear Raman Microspectroscopy. The work was aimed at studying the possibilities of detecting reproducible SERS and SECARS signals from TNB molecules at the Au NPs/CeO_2 SERS-active surface without destruction of the surface itself or the conjugates. This will be in the base of systematic experiments and measurement on SECARS. Optical damage thresholds are evaluated for different excitation wavelengths at laser intensity levels acceptable for Raman diagnostics of reporter molecules, both in continuous wave (CW) and high repetition rate picosecond-pulse modes of laser operation. The data provided by linear and nonlinear modalities of Raman spectroscopy are compared in our systematic studies.

SECARS Excited by 85 MHz Repetition Rate 6-ps Laser Pulses. The intensity limits for CW or quasi-CW ps-pulse laser beams, employed in SERS or SECARS detection of Au-NP-bound TNB reporter molecules, were experimentally evaluated. For 85-MHz repetition rate sequence of 6-ps laser pulses in the range of 785–1064 nm, the average threshold intensity was evaluated to be less than 0.5 $mW/\mu m^2$, which corresponds to a peak intensity of 1000 $mW/\mu m^2$. The results of the experiments demonstrate that extreme care should be taken about the laser power employed while using SERS-active structures for analytical purposes in linear or nonlinear Raman experiments. These studies formed the basis and allowed in the future to carry out regular SECARS measurements.

Measurement and Detection of Extremely Low Concentrations of Organic Molecules with the Use of SERS — Setting up a Method for Microspectroscopy of Single Molecules. In 2020, we pursued a goal to achieve a reliable single-molecule imaging through utilizing solid SERS-active substrates based on volumetric silver dendrites enriched with a great number of hot spots. The growth of the 3D densely packed layer of the silver dendrites was facilitated by using a template of macroporous silicon (macro-PS). DTNB acid was selected as an analyte for the detection since it is an important reagent in chemical and biomedical analysis including but not limited to bacteria detection and quantification of protease activity. The unique feature of the DTNB molecule is its breaking up to two TNB ions in presence of atoms of transition metals. These ions are known to be adsorbed on the metallic surface as a monomolecular TNB layer. Therefore, an informative SERS-spectrum (containing three main characteristic bands at approximately 1076, 1335, and 1556 cm^{-1}) obtained from the area overlapped with a submicron diameter laser spot carries a signature of the TNB products at the amount attributed to the single-molecule concentration.

SERS-Measurements. In 2020, for the first time, we experimentally demonstrated that the analyte molecules tend to coalescence into the DTNB nanoclusters rather than to form the single-molecule layer of TNB on the surface of the SERS-active substrates at concentrations over 10^{-12} M. The DTNB nanoclusters were formed from the 10^{-6}–10^{-12} M solutions, while further decrease in the analyte molecules down to the attomolar concentration was favorable for the adsorption of the TNB molecules' single layer. SERS imaging of the single TNB molecule was demonstrated with the SERS-active silver dendrites kept in the attomolar DTNB solution.

NEUTRON NUCLEAR PHYSICS

Investigations of the Fission Process. In the framework of the FLNP JINR – ITEP – PNPI – FRM II collaboration, a series of experiments were continued to study T-odd effects in the emission of prompt γ rays and neutrons in the binary fission of ^{235}U and ^{233}U nuclei induced by polarized neutrons. The experiments are carried out using the POLI instrument at the FRM II reactor (Garching, Germany) [9]. The experimental data on the ROT effect in the fission of ^{235}U nuclei induced by “hot” polarized neutrons with an energy of 0.06 eV were processed. From the angular dependence of the T-odd asymmetry of prompt γ rays (Fig. 4), the value of the rotation angle of the compound nucleus $^{236}U^*$ was obtained, which was $\delta = 0.09(2)^\circ$. The rotation angle has the same sign as the axis rotation angle for ternary fission.

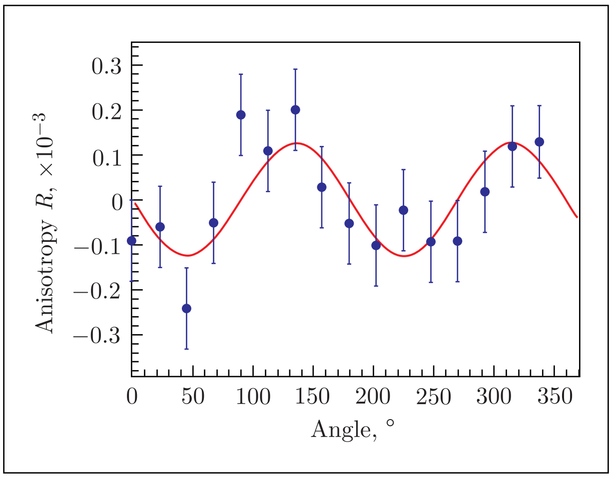

Fig. 4. Experimental angular dependence of the coefficient of T-odd asymmetry for prompt γ rays in the binary fission of $^{236}U^*$

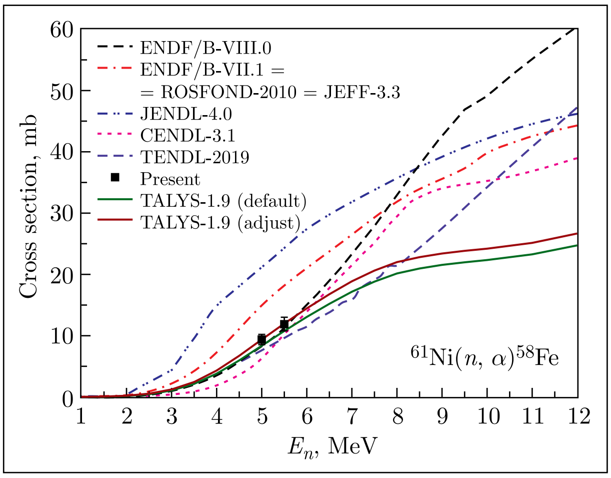

Fig. 5. New data on the cross section of the $^{61}Ni\,(n,\alpha)^{58}Fe$ reaction in comparison with the existing estimates

Research Reactions with Fast Neutrons. Experimental and theoretical investigations of the (neutron-charged particle) reactions induced by fast neutrons were carried out. The experiments were conducted at the Van de Graaff accelerators EG-5 of FLNP JINR and EG-4.5 of the Institute of Heavy Ion Physics of Peking University. Data on neutron reactions with the emission of charged particles induced by fast neutrons are of much interest for studying the mechanisms of nuclear reactions and atomic nuclear structure as well as in choosing construction materials and in performing calculations in the development of new facilities for nuclear power engineering. The cross-section measurements for $^{14}N(n,\alpha)^{11}B$, $^{35}Cl(n,\alpha)^{32}P$ reactions were performed in the neutron energy range of 3–5.5 MeV, and for $^{58,60,61}Ni(n,\alpha)^{55,57,58}Fe$ they were carried out in the neutron energy range of 4.50–5.50 MeV. An upgraded ionization chamber served as a detector. Data on the $^{61}Ni(n,\alpha)^{58}Fe$ reaction in the MeV energy range were obtained for the first time (Fig. 5) [10].

Activities within the TANGRA Project. A study of the reaction induced by the inelastic scattering of 14.1-MeV neutrons on carbon, magnesium and chromium nuclei was carried out using the tagged-neutron method at the TANGRA facility based on the ING-27 neutron generator. The energies of visible γ transitions occurring in various reactions of neutron interaction with C, Mg, and Cr nuclei and their partial cross sections were determined [11, 12]. The results obtained by measuring the angular distribution of γ rays for ^{52}Cr and ^{24}Mg were compared with respective results of other published experimental studies. An illustration for ^{24}Mg is shown in Fig. 6. The results of the measurements for ^{12}C, ^{24}Mg and ^{52}Cr were also compared with the model calculations performed using the TALYS 1.9 code in order to estimate the dynamics of the discrepancy between the calculation and the experiment and check the applicability of the program for data interpretation. Due to the fact that TALYS 1.9 is a universal program that includes a number of theoretical models (optical model, DWBA, coupled channel model, level density models), the use of this program (after planned code modifications) looks promising for future calculations of the values measured in our experiments.

Ultracold Neutrons. At the Institut Laue Langevin (France), an experiment was carried out to search for the heating of ultracold neutrons (UCNs) by surface acoustic waves excited on the surface of a lithium niobate single crystal ($LiNbO_3$). The frequency of the excited wave was 35 MHz, and the neutron energy transfer in the inelastic scattering by SAW was about 140 neV. The change in the energy occurred mainly due to a change in the velocity component normal to the crystal surface. Neutrons were detected by the detector positioned above the sample. The entrance window of the detector was covered with copper foil; therefore, the detector was sensitive only to neutrons with energies exceeding the cut-off energy of copper, $E > 170$ neV. At an average detector count rate of about 25 cps, the difference in the count rate of the detector upon excitation of a SAW in the sample and in the absence of the wave was (0.139 ± 0.022) cps. Thus, the effect of UCN heating by SAW was reliably detected.

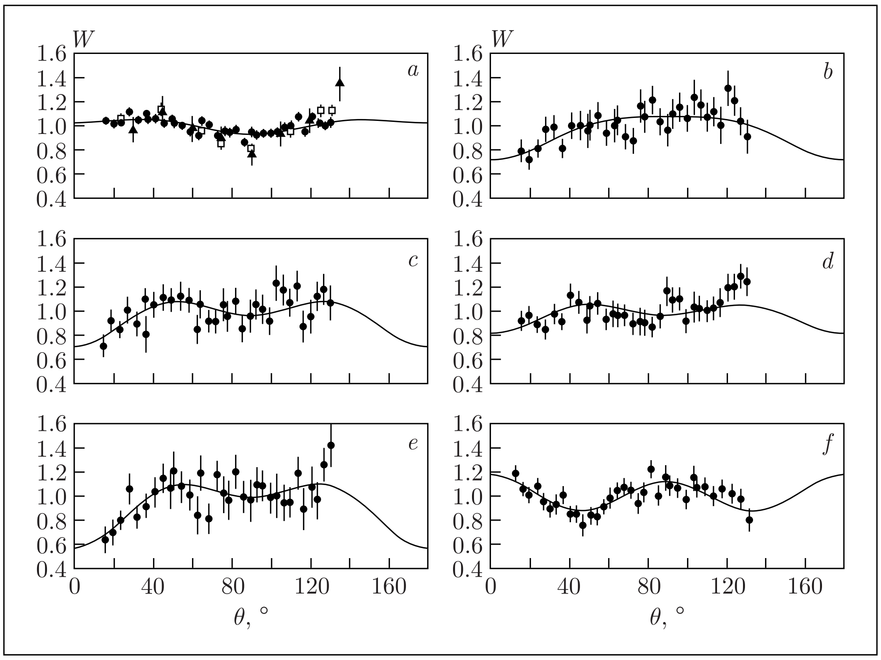

Fig. 6. Angular distributions of gamma rays for the transitions in the ^{24}Mg$(n, n'\gamma)^{24}$Mg reaction at $E_\gamma =$ $= 1368.6$ (*a*), 3866.1 (*b*), 4237.9 (*c*), 2754.0 (*d*) and 4642.2 keV (*e*), as well as gamma rays at $E_\gamma = 350.5$ keV from the ^{24}Mg$(n, \alpha)^{21}$Ne reaction (*f*). In plot *a* rectangles and triangles are data from other studies. The solid line corresponds to the approximation of the data by Legendre polynomials

Analytical Investigations at the IBR-2 Reactor and the IREN Facility. In 2020, a multielement instrumental neutron activation analysis of about 2000 samples was carried out at the REGATA facility in the framework of programs and grants of the JINR Member States and Protocols on scientific and technical cooperation with the JINR Non-Member States. The objects of investigation included: vegetation, soil, air filters, technological and biological samples, as well as samples of extraterrestrial origin. A number of studies were performed within the collaborations with other JINR Laboratories. The elemental analysis of ~ 1500 samples was performed using a Thermo Scientific iCE 3500 Atomic Absorption Spectrometer.

Neutron and related analytical methods (X-ray fluorescence analysis, Fourier transform infrared spectrometry) were used for mass analysis of the elemental and molecular composition of various archaeological samples (ceramics, remains of medieval Russian nobility and ancient people, masonry mortars, medieval wall paintings, metals, alloys, etc.) [13, 14]. The samples were irradiated at the IBR-2 reactor and the IREN facility.

The development and application of the neutron resonance analysis technique to determine the elemental composition of samples were continued. Being absolutely nondestructive, the method is based on the detection of neutron resonances during radiation capture and measurement of the yield of reaction products in these resonances. In 2020, an ancient Greek vessel for wine (VI–IV centuries BC) from the antique burial ground Volna 1 on the Taman Peninsula, a medallion of the Old Russian time (XII–first half of the XIII centuries) were found during excavations near the Tver Kremlin [15], and a number of methodological measurements were carried out at the IREN facility.

FLNP BASIC FACILITIES

IBR-2 Pulsed Reactor. In 2020, the IBR-2 research nuclear facility was operated in a nominal mode under Rostekhnadzor license valid until 30.09.2022. Statistical data on the IBR-2 operation are presented in the table.

Using the VITESS software package for Monte Carlo simulations, the influence of the delayed neutron background on data of reflectometry experiments at the IBR-2 pulsed reactor was evaluated. The model was based on the

No. cycle	Period	Moderator type	Reactor operation for physics experiments, h
1	16.01–29.01	Water	312
2	10.02–19.02	Water	207
3	18.03–30.03	Water	267
4	13.04–24.04	—	Cancelled
5	14.05–25.05	—	Cancelled
6	09.09–23.09	Water	337
7	01.10–12.10	Water	242
8	19.10–31.10	Water	289
9	10.11–22.11	Cryogenic	257
10	07.12–22.12	Water	312
		Total:	2223

time dependence of the fast neutron flux from the reactor core measured in [16]. In the measured dependence, the main power pulse of the reactor decreases not to zero, but to a certain quasi-constant level due to the emission of delayed neutrons, which, on average over time, account for about 8% of the reactor energy release. The dependence given in this work was used in the model of the source with one difference, which was that the main power pulse with a width of about 320 μs was generated by one virtual moderator, and the remaining part (background) was generated by another — a background moderator. Operating simultaneously, both moderators generated in the model exactly the same neutron flux that the IBR-2 reactor core generates during its pulse repetition period of 200 ms. Thus, by switching the background moderator on and off, it is possible to reveal the influence of background neutrons on measurement results. In the simulation, it was assumed that the intensity of thermal neutrons at a certain point in time corresponds to the intensity of fast neutrons at the same point in time. On the neutron beam formed in this way, a model reflectometer was created, including a background chopper, similar to those used on other IBR-2 instruments. Figure 7 shows a model of the source with two moderators and experimentally measured time dependences of the fast neutron flux.

IREN Facility. Despite the difficult epidemiological situation and the associated quarantine restrictions in the work of both installations and entire teams, in 2020, the IREN facility operated for a total of 1160 h, with 1010 h for experiments. After a fairly long "training" of the accelerating and radiofrequency systems of the LUE-200 accelerator, which started in December 2019, an increase in the average electron energy by a factor of almost 1.5 was achieved at a pulsed current of 2 A. At low values of the pulse current, the energy of some electrons exceeds 100 MeV [17].

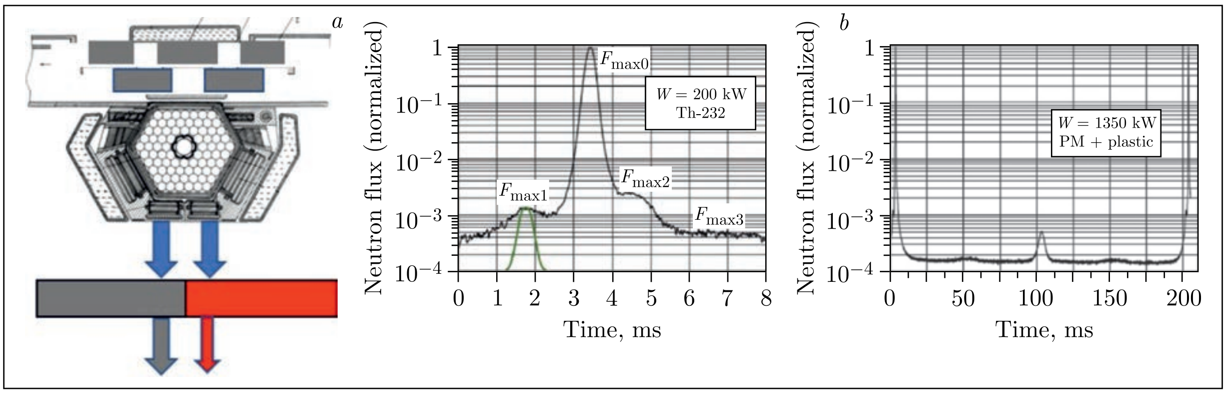

Fig. 7. *a*) Model of the source with two moderators used in the simulation. One moderator (red) forms only the main power pulse of the reactor, the other (gray) — only the background component. *b*) Experimentally measured time dependence of the fast neutron flux from the IBR-2 reactor core. Between the main power pulses of the reactor is a quasi-permanent background level, which accounts for approximately 8% of the time-averaged energy release of the IBR-2 reactor

THE PROJECT OF NEW NEUTRON SOURCE

In 2019, JINR proposed to build a new advanced neutron source DNS-IV (Dubna Neutron Source of the IV generation) on its site. In combination with state-of-the-art moderators, neutron guides and neutron scattering instruments, DNS-IV promises to become one of the best neutron sources in the world and will open up unprecedented possibilities for research in condensed matter physics, fundamental physics, chemistry, novel materials and life sciences to scientists from the JINR Member States and around the world.

The DNS-IV will produce shorter neutron pulses while providing the same flux density as the European Spallation Source (ESS, to be operational in 2024). It will indeed be no worse than ESS for low-resolution experiments and significantly outperform it for high-resolution experiments.

From the various concepts studied, a pulsed neutron reactor IBR-3 with ^{237}Np core was chosen for the DNS-IV project. Therefore, the pulsed neutron reactor IBR-3 with NpN fuel has currently become a working project with the planned start of the DNS-IV operation in 2036–2037. The approximate cost estimate for today is about 440 M€. More accurate figures are expected by the end of 2022 at the preliminary design stage of the project.

In 2020, in the framework of theme 04-4-1140-2020/2022, work continued on the design of a pulsed reactor with neptunium-based fuel. Under the contracts concluded with the N. A. Dollezhal Research and Development Institute for Power Engineering (NIKIET) and the Bochvar High-Tech Research Institute of Inorganic Materials (VNIINM), two configurations of the new reactor core were developed, and technical specification for the production of fuel elements of the new source was prepared. FLNP specialists carried out a number of detailed calculations in support of the idea of changing the fuel composition of the peripheral fuel elements of the reactor in order to radically improve the parameters of the reactor from the point of view of reliability and safety. The results of these studies formed the basis for the design changes made by NIKIET specialists. The Laboratory has completed the work on the formation of a structural unit that will be engaged in the development of the project and the creation of the new neutron source; the necessary personnel changes will be carried out in 2021.

THE SOLCRYS STRUCTURAL RESEARCH LABORATORY AT THE SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

The SOLCRYS project for constructing a JINR–SOLARIS laboratory for condensed matter research utilizing synchrotron radiation at the Polish National Synchrotron Centre has been started within the framework of the bilateral agreement. The planning phase of this project is progressing into the contracting phase now. The construction of a superconducting wiggler, as one of the project major parts, has been contracted mid-year 2020 and is currently underway.

Another important component of the project is the enlargement of the experimental hall to accommodate the laboratory. Its technical project has been prepared recently, and it will enter the tender stage soon. Within the conceptual design of the experimental beamlines, it is planned to construct a small-angle X-ray scattering end-station operating in the high-intensity and low-resolution mode and a molecular crystallography end-station operating in the high-resolution mode.

EVENTS

On June 23, at the Frank Laboratory of Neutron Physics, a memorial seminar “60 Years of the Launch of the IBR Reactor” was held. The seminar was held in the Conference Hall of the Laboratory and also in the format of a video conference.

The international conference “Condensed Matter Research at the IBR-2 Reactor” was held from 12 to 16 October 2020. The video conference brought together more than 200 scientists from 27 countries from almost all continents, from Australia to South America.

The Conference of Young Scientists and Specialists of the Frank Laboratory of Neutron Physics was held in an online format from November 30 to December 2, 2020. The participants presented reports on the grants from the Association of Young Scientists and Specialists of JINR, as well as those applied for Frank scholarship, Shapiro scholarship, and grants from the AYSS JINR.

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LABORATORY OF INFORMATION TECHNOLOGIES

In 2020, the studies on two themes of first priority “Information and Computing Infrastructure of JINR” and “Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data” were carried out by the Laboratory of Information Technologies (LIT) within the direction “Networks, Computing, Computational Physics”. The LIT staff participated in research on 26 themes of the JINR Topical Plan as part of cooperation with the other JINR Laboratories. The LIT activity is aimed at developing the JINR network, information and computing infrastructure, mathematical support and software for research and production activities underway at the Institute and its Member States on the basis of the JINR Multifunctional Information and Computing Complex (MICC).

In 2020, the staff of the Laboratory of Information Technologies published over 170 scientific papers and presented more than 120 reports at Russian and international conferences.

INFORMATION AND COMPUTING INFRASTRUCTURE OF JINR

One of the major directions of the LIT activity in 2020 was the development of the JINR MICC [1] and provision of the reliable functioning of the JINR network infrastructure, which during the pandemic was subject to additional demands to accommodate remote work of all the JINR employees. The MICC development encompassed the continuation of extensive modernization of the MICC cooling and power supply systems, which started in 2019, modernization and development of the MICC computing resources and data storage systems, development of the IT infrastructure of the NICA megascience project, expansion of the performance of the grid components, i.e., Tier-1 and Tier-2, extension of the cloud component and creation of an integrated cloud environment for JINR experiments, enlargement of the HybriLIT heterogeneous computing platform, including the “Govorun” supercomputer.

JINR Telecommunication Channels. In 2020, the reliable functioning of the following JINR telecommunication channels was ensured: the Moscow–JINR redundant channel with a bandwidth of 3×100 Gbit/s; the JINR–CERN direct channel with a bandwidth of 100 Gbit/s and its 100 Gbit/s backup channel, which passes through MMTS-9 in Moscow and Amsterdam, ensuring the operation of the LHCOPN network for the connection between Tier-0 (CERN) and Tier-1 (JINR) and of the LHCONE external superimposed network designed for the JINR Tier-2 center; direct channels up to 100 Gbit/s for communication with the collaboration of RUHEP research centers and the Runnet and ReTN networks using the RU-VRF technology [2].

The distribution of the incoming and outgoing traffics by the JINR subdivisions in 2020 (exceeding 25 TB by the incoming traffic) is shown in the table.

Subdivision	Incoming, TB	Outgoing, TB
DLNP	425.84	271.81
VBLHEP	208.03	130.76
FLNP	97.70	130.15
LIT	93.26	87.99
Hotel and Restaurant Complex	87.04	27.71
Dubna State University	86.97	51.16
FLNR	81.98	70.52
Remote access node	63.91	10.89
JINR Directorate	56.09	90.55
University Centre	31.40	10.59
BLTP	24.39	27.85

The overall incoming traffic of JINR, including the general-purpose servers, Tier-1, Tier-2, the computing complex, the "Govorun" supercomputer and cloud computing, amounted to 29.91 PB in 2020, while the overall outgoing traffic reached 36.94 PB. The traffic with the scientific and educational networks, accounting for 97% of the total, is overwhelming.

JINR Local Area Network (LAN). In 2020, the fault-tolerant operation of the backbone of the Institute's local area network with a bandwidth of 2 × 100 Gbit/s and the distributed computing cluster network between the DLNP and VBLHEP sites with a capacity of 400 Gbit/s was ensured. To increase the reliability of the optical backbone network, double redundancy was provided.

The work on the development and improvement of the network components of the JINR IT infrastructure was in progress. The EOS distributed storage network and the network "Cloud Computing" were connected to the RU-VRF/LHCONE external network. The commissioning of the fourth module in the MICC hall and its equipping with computing resources were performed together with setting up and connecting central and rack switches.

Several systems (Cisco Meeting Server, BigBlueButton, Videomost, Zoom, etc.) were tested for video conferencing. For mass use, the Cisco Webex system was chosen, and 816 meetings were held in 2020 using it.

The modernization of the cluster of virtual services of the JINR network service was in progress. The NOC network service works with virtual machines that provide key services for the entire network infrastructure of JINR: DNS, DHCP, relays — intermediate mail servers, network database servers, the NOC web hosting server, as well as a number of third-party services for LIT and JINR University Centre.

The cluster consists of six compute nodes and two data storage systems. The data storage systems operate under the management of the ZFS file system. The cluster functions in a 24 × 365 mode. The architectural solution enables nonstop work during updates of both software and hardware components of the network cluster.

The functionality of the system for network traffic analysis was expanded with the help of new written scripts that can identify infected and hacked user computers. The support of the Wi-Fi eduroam network at LIT, the "Dubna" hotel, the House of International Meetings, the House of Scientists, and the UC hostel is provided. The status of 560 hosts, of more than 150 services and conditions is monitored in the network monitoring system. Several types of notifications, namely, e-mail messages and SMS alerts, are used.

JINR LAN comprises 8895 network elements and 16 884 IP-addresses, 7388 network users, 3192 users of mail.jinr.ru, 1419 users of electronic libraries, and 445 users of the remote access service.

MICC Engineering Infrastructure. In 2020, the work on the replacement and improvement of the MICC engineering infrastructure, designed to ensure a reliable, uninterrupted and fault-tolerant operation of information and computing systems and data storage resources, was in progress. The system of central uninterruptible and redundant power supply based on accumulator sources and diesel-generator units was put into operation for the MICC hall. The climate control system, involving a complex of interconnected equipment with different air and liquid cooling schemes, which creates a temperature regime for the MICC functioning in a 24 × 365 mode, was partially modernized.

JINR Grid Environment. The JINR grid infrastructure is represented by the Tier-1 center for the CMS experiment at the LHC and the Tier-2 center for processing data from the experiments ALICE, ATLAS, CMS, LHCb, BES, BIOMED, MPD, NOvA, STAR, ILC and others. Both JINR grid sites ensure 100% availability and reliability of services.

In 2020, the Tier-1 data processing system was increased to 13 376 cores, providing a performance of 203.569 kHS06. The storage system, comprising disk arrays and long-term storage of data on tapes, was expanded. The total usable capacity of disk servers was increased to 13.7 PB. In April, the commissioning of a new tape library IBM TS4500 with a total volu-

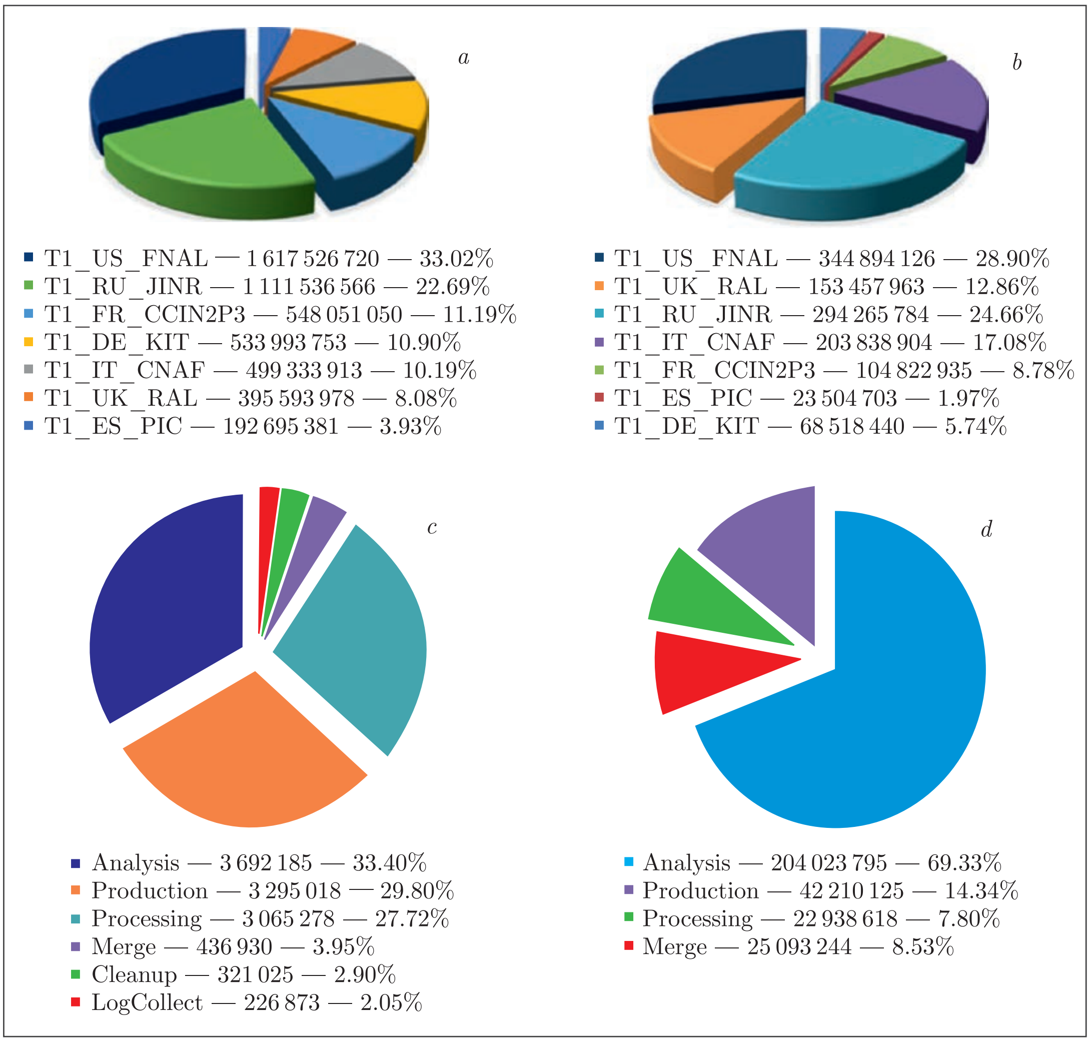

Fig. 1. Contribution of the world Tier-1 centers to CMS experimental data processing in 2020: *a*) distribution by the normalized CPU time in HS06 hours; *b*) number of processed events. Statistics on the use of the JINR Tier-1 center by the CMS experiment by different types of data stream processing in 2020: *c*) distribution of jobs; *d*) distribution of events by type of processing

me of 40 PB was completed. To date, the data long-term storage system consists of the IBM TS3500 and IBM TS4500 libraries and is focused on servicing the NICA and CMS experiments.

In terms of performance, Tier-1 (T1_RU_JINR) is ranked second among all the Tier-1 world centers for the CMS experiment (Fig. 1, *a*). In 2020, more than 294 million events were processed, which accounts for 25% of the total number of processed events (Fig. 1, *b*) and 23% of the total CPU load of all Tier-1 centers for the CMS experiment.

Figure 1, *c*, *d* shows the number of jobs and events processed at the JINR CMS Tier-1 center in 2020 by different types of data stream processing (reconstruction, modeling, reprocessing, analysis, etc.).

In 2020, at Tier-1 there happened a transition related, on the one hand, with the end of support of the software used for compute elements, i.e., CREAM-CE, the Torque batch processing system and the Maui scheduler, and, on the other hand, with the fact that the previous software and systems could not cope with the increased load and a large number of computing machines. To replace CREAM-CE, ARC-CE (Advanced Resource Connector-Computing Element) was chosen; it is widely used in WLCG (Worldwide LHC Computing Grid). SLURM, an open source, highly scalable, fault-tolerant cluster manager and job scheduler for large clusters, was selected as a resource manager. It enables flexible planning with priorities, fair distribution of resources between different users and optimization of the utilization of computing

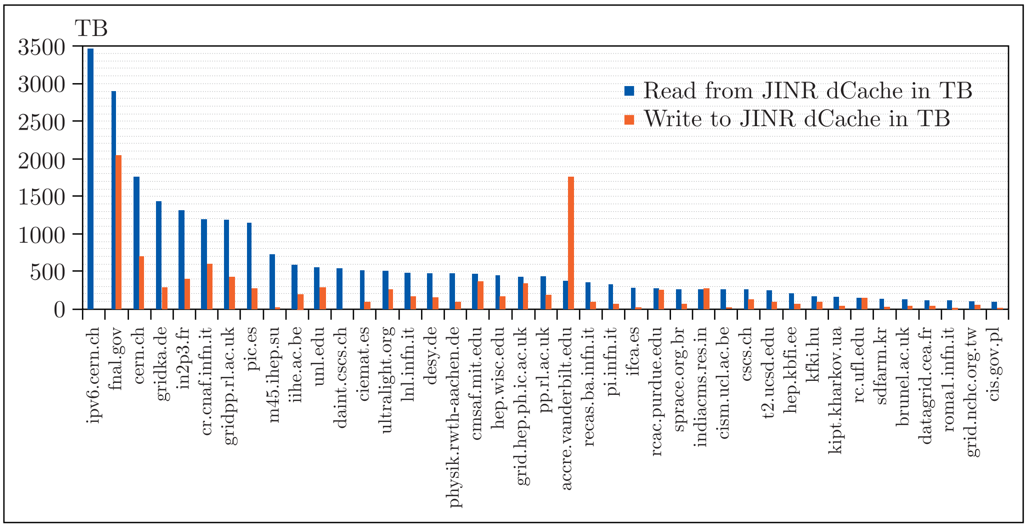

Fig. 2. Statistics on the exchange of JINR Tier-1 data with the world data processing centers of the WLCG infrastructure via the dCache-based data storage system: blue color — amount of data transferred from JINR Tier-1 to the other world Tier-1 and Tier-2 centers; red color — amount of transferred data from the world Tier-1 and Tier-2 centers to JINR Tier-1 for writing and processing

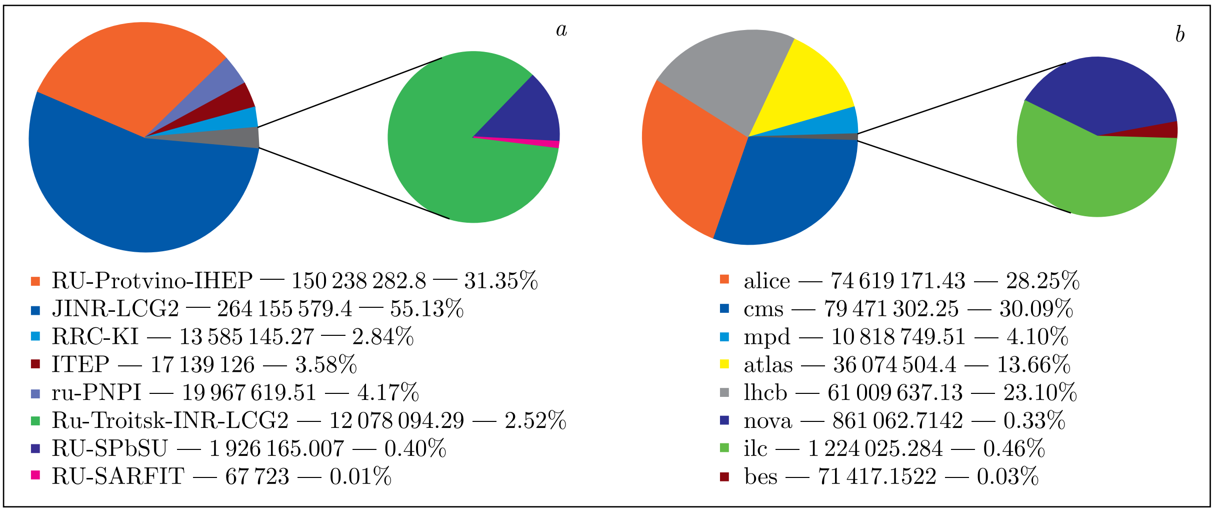

Fig. 3. Statistics of the JINR Tier-2 operation: *a*) distribution of the CPU time by the grid sites of the organizations being part of the Russian Consortium RDIG; *b*) use of the JINR Tier-2 site by virtual organizations of the global grid infrastructure (by the normalized CPU time in HS06 hours)

resources. SLURM is also used on the "Govorun" supercomputer.

One of the main functions of Tier-1 is to provide data exchange with all world sites operating for the CMS experiment and storage of raw experimental and simulated data. In 2020, the overall volume of data exchange with the dCache-based storage system, taking into account local exchanges, was 106 PB, of which 22 PB of new files were written. Figure 2 illustrates the statistics of data exchange of JINR CMS Tier-1 with the other grid centers with a volume of more than 100 TB for the outgoing traffic. 192 WLCG data processing centers for the LHC experiments downloaded 26 154.5 TB from the Tier-1 storage system, 130 of which transferred 10 655.7 TB of data for writing.

In 2020, the computing resources of the Tier-2 center were expanded to 7060 cores, which currently provides a performance of 100 kHS06. The total usable capacity of disk servers is 4763 TB for ATLAS, CMS and ALICE and 140 TB for other virtual organizations (VOs). The JINR Tier-2 site is the best in the Russian Consortium RDIG (Russian Data Intensive Grid). In 2020, 55% of the total CPU time spent on data processing and analysis using the RDIG resources were carried out at the JINR

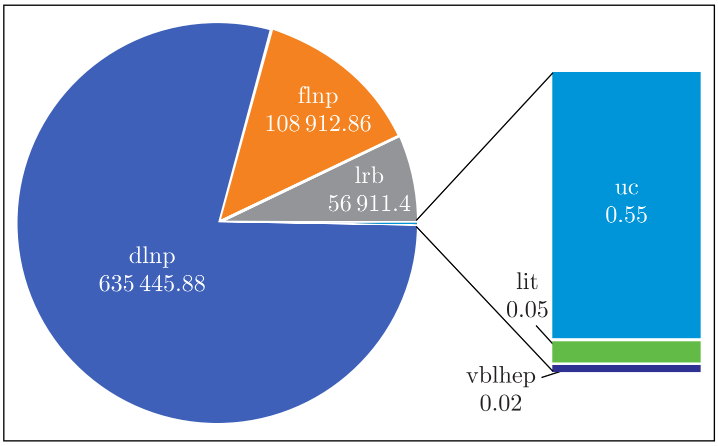

Fig. 4. Statistics on the use of the computing cluster: distribution by the CPU time in hours, normalized to 1000 Specint2000, by jobs performed on the local (not grid) computing cluster by the Institute's subdivisions and user groups

Tier-2 site (Fig. 3, *a*). The data on utilizing the JINR Tier-2 site by virtual organizations within grid projects in 2020 are shown in Fig. 3, *b*.

The MICC allows users to perform calculations outside the grid environment. It is necessary for some experiments and local users of the JINR Laboratories. JINR and grid users have access to all computing power via a unified batch processing system. The time distribution of jobs performed on the MICC computing cluster by the Institute's subdivisions and user groups is given in Fig. 4.

In 2020, the EOS-based data storage system was extended. At present, 7.12 PB of disk space is available for EOS users. Baikal-GVD, DANSS, FOBOS, JUNO, BM@N, MPD, SPD, PANDA are its major users.

The stable and efficient operation of Tier-1, Tier-2, storage systems and the required level of cluster cybersecurity were ensured by systematic updating of the firmware of the server components, the version of the operating system kernel and the firmware of the service modules of the IDRAC/IPMI servers.

Cloud Environment. In 2020, the resources of the cloud infrastructure were enlarged due to contributions of the NOvA experiment (480 CPU cores, 2.88 TB of RAM, 1.728 PB of disk space for ceph-based storage) and the commissioning of 2880 CPU cores with 46.08 TB of RAM purchased by the JUNO experiment. The total amount of the resources located in the JINR cloud infrastructure is 5000 CPU cores, 60 TB of RAM and 3.1 PB of raw disk space in ceph-storage. Figure 5 shows the information on the resource consumption of the cloud infrastructure in 2020.

The JINR cloud is one of the participants of the distributed information and computing environment (DICE) based on the resources of

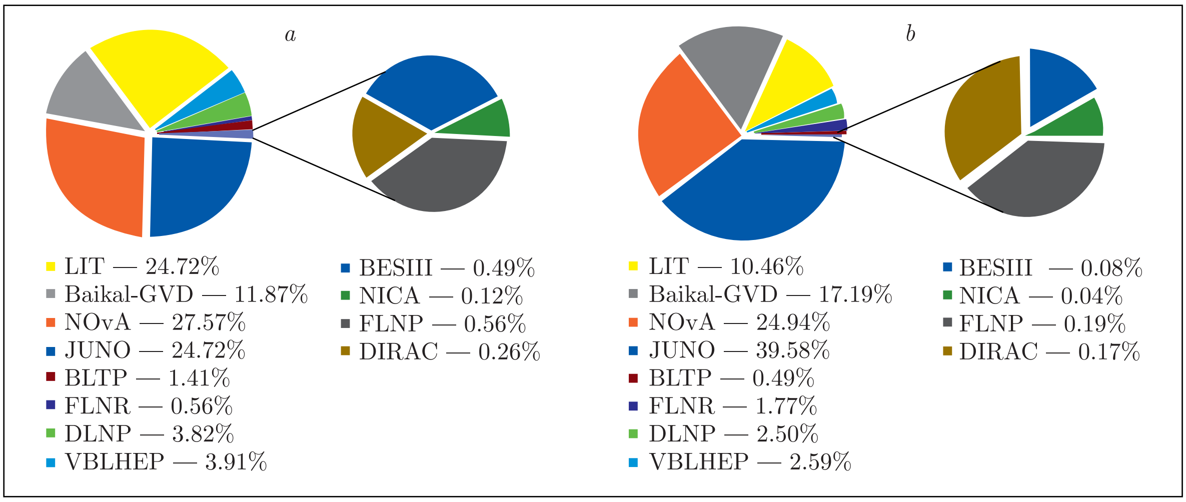

Fig. 5. Consumption of the resources of the JINR cloud infrastructure in 2020: *a*) CPU time, *b*) RAM usage

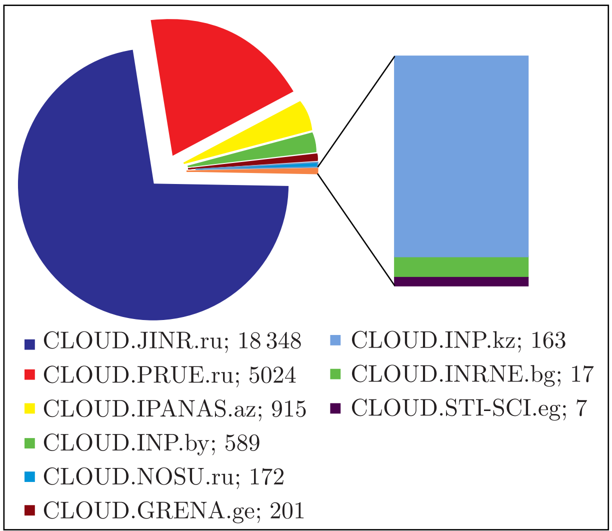

Fig. 6. Distribution of the number of successfully completed jobs by users of all VOs on the cloud resources of the JINR Member States' organizations in 2020

JINR and its Member States' organizations. In 2020, cloud infrastructures at North Ossetian State University, Sofia University "St. Kliment Ohridski" and the Institute for Nuclear Research and Nuclear Energy of the BAS were deployed and connected to the DICE. The deployment of cloud infrastructures at Georgian Technical University and the Egyptian National STI Network of the Academy of Scientific Research and Technology was started.

In 2020, the Baikal-GVD experiment joined the utilization of the DICE computing power. A pie chart with the number of jobs successfully performed in 2020 on the resources of all DICE participants by users of all virtual organizations is represented in Fig. 6.

In 2020, idle resources of the DICE were involved in research on the SARS-CoV-2 virus within the Folding@Home platform. Figure 7 illustrates a pie chart with the contribution of each of the DICE resource centres.

Heterogeneous Infrastructure. The heterogeneous infrastructure of the JINR MICC is represented by the HybriLIT component, which consists of the education and testing polygon and the "Govorun" supercomputer, managed by a unified software and information environment. In 2020, the development and implementation of an ecosystem for machine/deep learning and high-performance computing (ML/DL/HPC ecosystem) into this environment were completed; the ecosystem is actively used to create algorithms based on neural network approaches for solving applied tasks.

In 2020, up-to-date versions of more than 20 software packages, in particular, GSL (BLTP); FairSoft, FairRoot, PyROOT with add-ons for BmnRoot and MpdRoot, SMASH, Valgrind (NICA); ABINIT, Wien2k, Amber, AmberTools (FLNP); DIRAC, ELPA, FLUKA, LAMMPS (FLNR); FreeSurfer, FSL, MRIConvert, GROMACS (LRB); Expect, FORM, SMILEI (LIT), etc., were implemented into the HybriLIT environment and supported at the request of user groups.

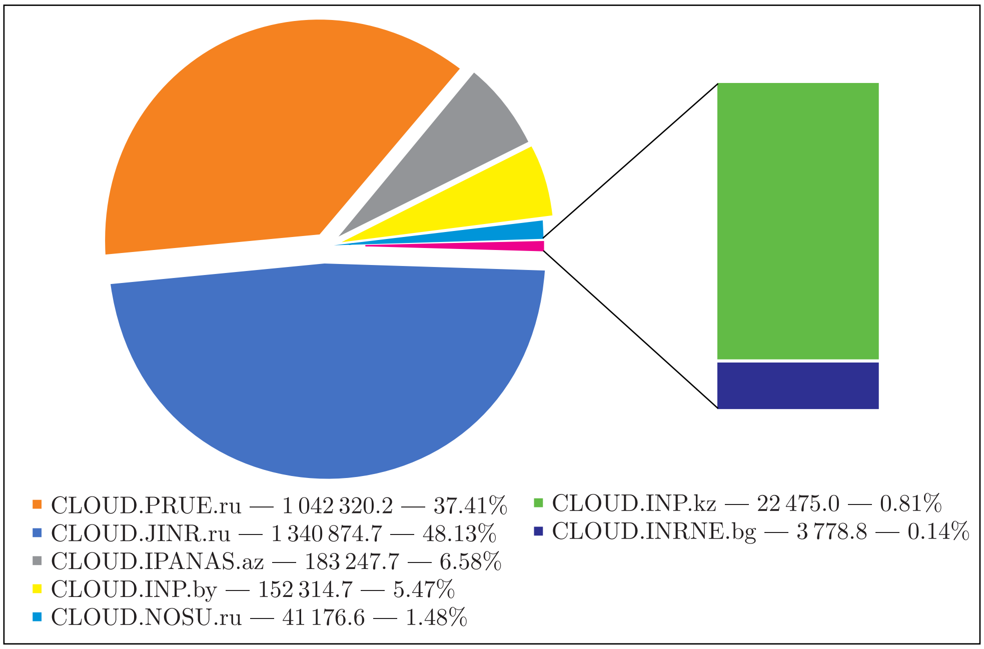

Fig. 7. Distribution of contributions of the DICE participants to the study of the SARS-CoV-2 virus via the Folding@Home platform in CPU HS06 hours

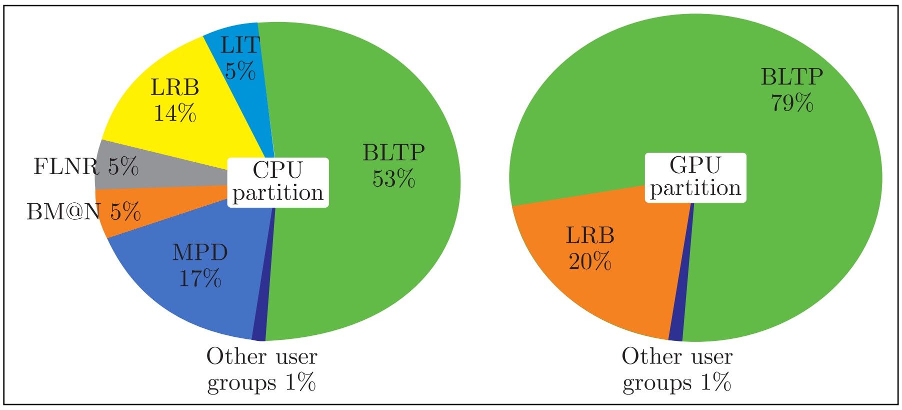

Fig. 8. Distribution of the resources of the "Govorun" supercomputer by user groups

In 2020, to increase the efficiency of solving user tasks, as well as to expand the efficiency of the utilization of both computing and data storage resources on the "Govorun" supercomputer, an approach to their management, i.e., resource orchestration, was elaborated and implemented [3]. This notion means software disjunction of a compute node, i.e., the separation of compute nodes and data storage elements (SSDs) with their subsequent integration in accordance with the requirements of user jobs. Thus, the computing elements (CPU cores and graphics accelerators) and data storage elements (SSDs) form independent fields. Due to orchestration, the user can allocate for his job a required number and type of compute nodes (including graphics accelerators), as well as a required volume and type of data storage systems. After the job is completed, the compute nodes and storage elements are returned to their corresponding fields and are ready for the next use. This feature allows one to effectively solve user tasks of different types, enhance the confidentiality level of working with data, and avoid system errors that occur when crossing the resources for different user tasks.

Within 2020, 491 609 jobs were performed on all computing components by all user groups utilizing the resources of the "Govorun" supercomputer to solve tasks in the framework of 25 themes of the JINR Topical Plan. Most of the jobs (440 813) were carried out on the Cascade component, 45 411 and 5385 were performed on the KNL and DGX components, respectively. In total, in 2020, over 35 million core-hours were accumulated on the Cascade component. The average load on the computing components in 2020 was the following: Cascade — 95.7%, KNL — 89.3%, DGX — 94.1%.

The overall number of users of the "Govorun" supercomputer is currently 157, of which 118 are from the JINR Laboratories and 39 are from other organizations of the JINR Member States. Moreover, in 2020, 75 new users were registered. The distribution of the computing resources by user groups is shown in Fig. 8.

The main users of the CPU component of the supercomputer came from BLTP and the NICA megaproject, in total 75%. User groups from the other Laboratories utilize a quarter of the resources. At the same time, for the GPU component, about 80% of the resources of the "Govorun" supercomputer are used by BLTP and 20% — by LRB, which is related to the implementation of neural network approaches for the tasks of radiation biology.

In 2020, users of the platform published 65 scientific papers. The summary report is available at http://hlit.jinr.ru/users_publications/.

In 2020, the work on the development of the offline computer complex for data modeling, processing, analysis and storage within the NICA project, which was built on the basis of the JINR MICC as a distributed scalable hybrid cluster, allowing one to organize computing for the NICA project efficiently and without additional labor costs at the request of a different class of jobs and users, was in progress. The integration of distributed computing resources was essential in creating such an infrastructure. One of the middleware options is the DIRAC Interware, a product for integrating heterogeneous computing resources and data storage resources into a unified platform, based on the use of standard data access protocols (xRootD, GridFTP, etc.) and pilot jobs. At the end of 2020, all the MICC components, the clouds of the JINR Member States, as well as the cluster of the National Autonomous University of Mexico (UNAM, within cooperation on the MPD project) were integrated into DIRAC.

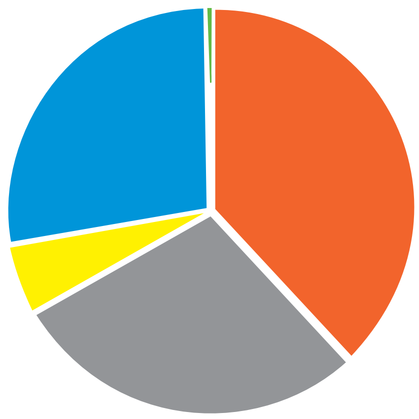

Fig. 9. Statistics on the normalized CPU time in HS06 hours used for simulation jobs within MPD on the DIRAC-based computing resources

Using the integration via DIRAC, it was possible to involve the largest amount of computing resources for centralized data generation with the Monte Carlo method for the MPD experiment. The "Govorun" supercomputer, the Tier-1/Tier-2 clusters, the NICA and UNAM clusters participated in the calculations. More than 500 000 jobs were successfully completed, and the amount of generated data exceeded 130 TB. All data is registered in the DIRAC file directory and stored in the EOS file system. Figure 9 illustrates the statistics on the normalized CPU time in HS06 hours used for simulation jobs within MPD on the DIRAC-based computing resources.

A software complex that enables the simulation of a distributed computing system for acquiring, storing and processing data from the BM@N experiment of the NICA project under different scenarios for launching jobs for the next run, which is planned to be held in 2021, was developed. The purpose of the modeling was the optimal distribution of the flows of primary data processing for the BM@N experiment to the compute nodes in order to minimize hardware downtime during job execution. Based on the simulation results, one can predict the load of the compute nodes and telecommunication channels.

Monitoring System. The developed integrated monitoring system of the MICC allows one to receive information from different components of the computing complex: the engineering infrastructure, networks, compute nodes, job launch systems, data storage elements and grid services, which guarantees a high level of reliability of the MICC. In 2020, the cloud infrastructure was connected to the common monitoring system. The Litmon monitoring system is modular and distributed. Thus, the addition of new nodes of the monitoring system entails the installation of a new node of the load distribution for the monitoring system. At present, the monitoring system comprises four servers [4]: the central control server litmon-01 and three load distribution nodes (Fig. 10).

A number of works on the development and current maintenance of the "Dubna" electronic document system (EDS) were completed. In particular, a module for maintaining the procurement plan was worked out, the ability to sign invoices for payment using an enhanced electronic signature was implemented, a subsystem for the automated formation of supply contracts on the basis of standard forms was developed, a module for monitoring, electronic archive storage and search for supply contracts was elaborated.

The work on the current maintenance and development of the APT EVM project management system for NICA was in progress. Specifically, the integration of Cost Book data with the procurement plan in EDS "Dubna" was implemented.

A new version of the CERN DB information system for registering business trips at CERN, managing accommodation and accounting financial expenses was developed and put into operation.

The ongoing maintenance and development of the following information systems upon users' requests were performed: HR LHEP, ADB2, PIN, ISS, Document Base and Electronic Photo Archive.

In 2020, a personal account with the possibility of online payment for tenants of the Institute's housing stock was developed and put into operation. Together with the electronic document system, a system for processing invoices in an electronic form, for the signing of which an internal certification center was implemented, was created. In the personnel system, a subsystem for accounting electronic employment record books was created, and the system for special job assessment was completely revised.

The Institute's management reporting was improved; as part of the development of project management, a corresponding module, which al-

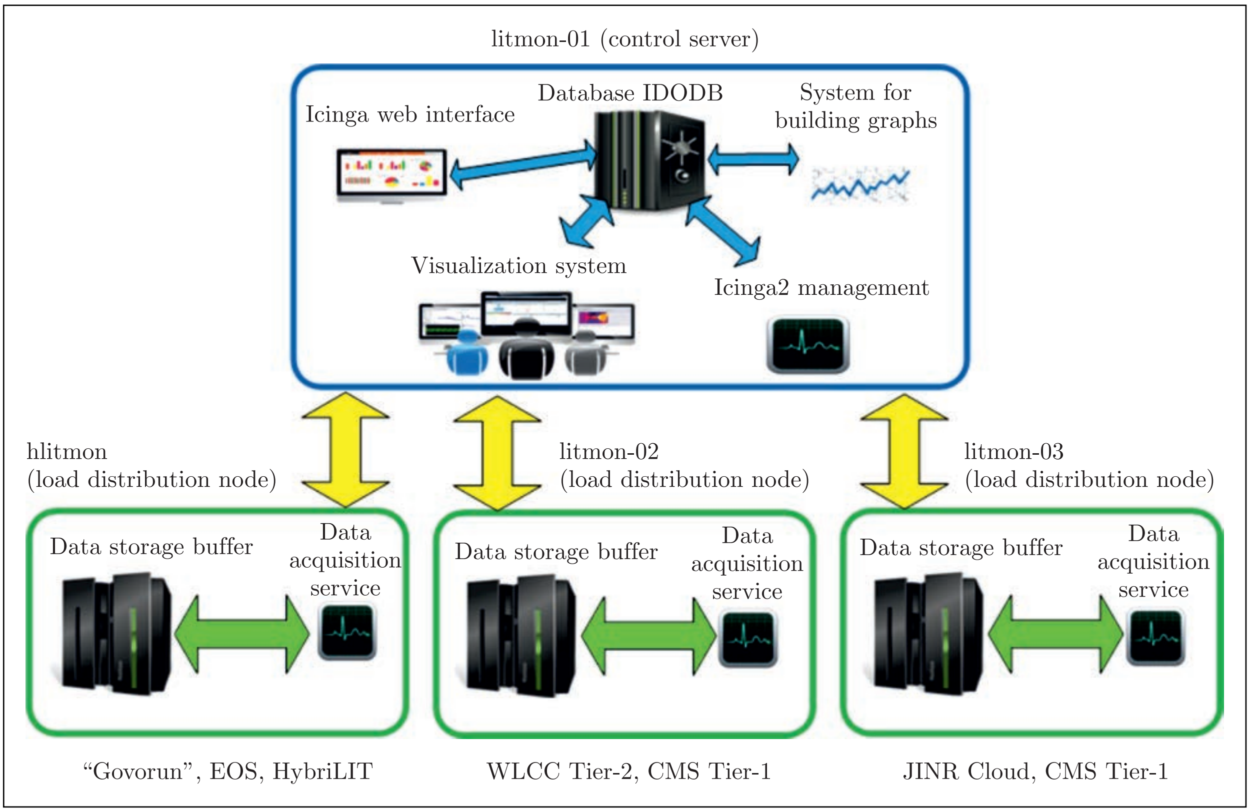

Fig. 10. Scheme of the Litmon monitoring system

lows one to track the work progress, to draw a Gantt chart and assign financial resources, was elaborated in the 1C program.

The ongoing training and support of users, as well as the maintenance and modernization of 1C programs, were carried out. The work on the creation of a system for accounting trip tickets to the "Dubna" Resort Hotel started; a new accounting methodology for the "Dubna" Resort Hotel was worked out and tested together with other services.

In 2020, the JINR Information System for Scientific Certification (ISSC) (https://dissertations.jinr.ru/) and the "Visit Centre" portal (https://visitcentre.jinr.ru/) were maintained. The modernization and support of the web site of the journals "Physics of Elementary Particles and Atomic Nuclei" (PEPAN) and "Physics of Elementary Particles and Atomic Nuclei, Letters" (PEPAN Letters) (http://pepan.jinr.ru) continued. The traditional development, creation and maintenance of web sites of conferences, symposia at the request of the Laboratories and other JINR subdivisions were in progress.

The maintenance of the following servers and systems of general use was conducted: the infrastructure of site hosting (www.jinr.ru, flnph.jinr.ru, flerovlab.jinr.ru, micc.jinr.ru, mpdroot.jinr.ru, etc.), the infrastructure of administrative servers (pin.jinr.ru, adb2.jinr.ru, sed.jinr.ru, etc.), the automated project management system (pm.jinr.ru) and the cloud storage service for the JINR staff (disk.jinr.ru).

METHODS, ALGORITHMS AND SOFTWARE FOR MODELING PHYSICAL SYSTEMS, MATHEMATICAL PROCESSING AND ANALYSIS OF EXPERIMENTAL DATA

One of the main activities of LIT is to provide mathematical, algorithmic and software support for experimental and theoretical research underway at JINR. A summary of prominent results is presented below.

A prototype of the platform for streaming analytics using Big Data technologies was deployed [5]. The platform was tested on the example of network traffic analysis in the distributed network.

Geometry and software models for different configurations of the inner tracker system of the BM@N experiment, which comprises the coordinate GEM, Forward Silicon and STS detectors, were developed. Algorithms for realistic simulations of the passage of charged particles through the sensitive planes of the tracker system detectors were implemented. The required characteristics of the gas mixture planned for use as a working medium in the gas-filled chambers of the GEM detector were calculated for future configurations in 2021–2022.

A software module for simulating data reconstruction in the drift chambers (DCH) of the BM@N experiment was elaborated. The required similarity of the process of reconstructing simulated and experimental data was obtained. The software was implemented in the BMNROOT software package. The DCH reconstruction chain was unified and automated for processing all types of data from the BM@N experiment.

Neural network models RDGraphNet and TrackNETv2, developed for the BM@N experiment with a fixed target, were successfully adapted for the cylindrical CGEM detector of the BESIII collider experiment (IHEP, Beijing). The training on simulated data and subsequent testing of the RDGraphNet model showed promising results, namely, 98% completeness and 86% accuracy, as well as 99% completeness and 77% accuracy for TrackNETv2 [6].

A further extension of the Monte Carlo generator of heavy-ion collisions DCM-SMM, which is used to simulate tens of millions of events for BM@N and MPD (NICA) on the HybriLIT cluster, was performed [7].

The impact of varying parameters in three GEANT4 hadronic physics models on the agreement with thin-target datasets was investigated, and using the Professor model tuning framework the correspondence to these datasets was described [8]. It was found that varying parameters produced a substantially improved agreement with some datasets; however, more degrees of freedom are required for full agreement.

A test server for the new version of the EventIndex system being developed was created as part of the project development to prepare the ATLAS experiment for RUN3. Services for calculating the matrix of intersection of trigger chains were implemented. The creation of a new Event Picking Service within the ATLAS EventIndex project was started. The operational monitoring system of the TDAQ system was adapted for the new versions of the Grafana product. The data visualization service for the network traffic monitoring system in ATLAS (NETIS) was modernized.

The magnetic field modeling involved: intense research concerning three-dimensional computer simulation of magnetic systems in the framework of the NICA project for the validation of the magnetic field uniformity in the working areas of new physical magnets, as well as the improvement of design tools for new medical cyclotrons, computed on the “Govorun” supercomputer.

In 2020, the JINRLIB library was supplemented with programs developed by the LIT specialists for general use: EORP 2020, a program for computing closed equilibrium orbits (http://wwwinfo.jinr.ru/programs/jinrlib/eorp/index.html); Split, a parallel implementation of the numerical solution of a system of algebraic equations with a tridiagonal matrix using the partition algorithm and MPI technology (http://wwwinfo.jinr.ru/programs/jinrlib/split/index.html); SIR-model, the simplest epidemic process model (http://wwwinfo.jinr.ru/programs/jinrlib/sir-model/index.html). The SAS program, devoted to primary processing of small-angle scattering spectra (http://wwwinfo.jinr.ru/programs/jinrlib/sas/index.html), was updated.

In cooperation with the Joint Institute of High Temperatures of RAS, a model that describes the passage of a multicomponent gas-condensate mixture through a porous medium in the depletion mode was formulated [9]. A quantitative agreement of the numerical results with experimental data on the dynamics of hydrocarbon recovery depending on pressure was obtained. The parallel implementation of the algorithm enables a 6-fold acceleration of computations on the HybriLIT cluster.

The influence of the inelastic channel and the choice of a model for the distribution density of nucleons in ^{12,14}Be nuclei on the agreement with experimental data was investigated [10]. For the density of ^{12,14}Be nuclei in the form of the symmetrized Fermi function, parameters that improve the agreement of $^{12,14}\mathrm{Be} + {}^{12}\mathrm{C}$ differential scattering cross sections with experimental data were obtained. The calculations were performed on the HybriLIT cluster.

A hybrid MPI + OpenMP model for parallelizing the multiple precision Taylor series method was proposed, implemented and tested [11]. With the help of this model, a trajectory for the Lorenz attractor was calculated in a rather long time interval [0, 7000].

To study strongly interacting nuclear matter, in particular, in neutron star nuclei, the extended sigma–omega model was investigated by means of the Bayesian analysis method. The most probable values of the physical parameters of the model were found using state-of-the-art multimessenger astronomical observations [12].

The Lagrange problem of finding all approximate solutions of the three-body problem on the plane, for which the distances between the bodies remain constant, was formulated. Two theorems that reduce the problem to the study of the midpoint scheme properties for a system of coupled oscillators were proved [13]. It was shown that in the case when the bodies formed a regular triangle the approximate solution inherited the periodicity property of the exact Lagrange solution.

The problem of the quantum-mechanical description of the near-barrier fusion of heavy nuclei, which occurs at a strong coupling of their relative motion to surface vibrations, was analyzed [14]. To this end, an efficient finite element method was proposed for the numerical solution of a system of coupled Schrödinger equations with boundary conditions corresponding to total absorption. It was found that the experimental data could be reproduced with a Woods–Saxon potential, without introducing repulsive cores. It was shown that the fusion cross sections at deep sub-barrier energies were sensitive to the potential pocket profile.

The interaction of pulsed ion beams with metal targets was modeled by the molecular dynamics method [15]. A numerical study of the dependence of the dynamics of thermal and structural processes in irradiated targets when changing the size and inhomogeneities of the structure was performed using the averaged values of the parameters of ion beams.

The basic parameters and wave functions determining the structure and properties of light nuclei with $A = 6$ (^{6}Li and ^{6}He) in the $\alpha + NN$ cluster model, which takes into account dibaryon resonances in the nucleon–nucleon interaction, were obtained [16].

An original three-center wave function was constructed by means of the irreducible representations of the D_{3h} point group, which characterizes the symmetry of the planar equilateral triangular H_3^+ molecule [17]. The results of this work and the implementation of computational methods pave the way for further studies of complex three-center systems.

Numerical simulation of laser ablation of the material under the action of ultrashort laser pulses was performed. The dependence of the maximum temperature on the sample surface and the thickness of the ablation layer on the radiation dose of the incident laser pulse was obtained. Numerical calculations were carried out using the finite difference method [18].

A method of ultrafast polarization switching in ferroelectrics was proposed and numerically studied using the self-acceleration effect of the polarization dynamics through a feedback field [19].

A new algorithm for representing polynomials in problems of computing involutive and Gröbner bases of systems of nonlinear polynomial equations was proposed [20]. The new approach enables the delegation of some parts of this computational task to GPUs, which opens up new opportunities for solving more complex problems.

The parameters on a conjugacy class in the Lie group $SL(n)$ and the parameters on a coadjoint orbit in the space $sl^*(n)$ dual to the Lie algebra $sl(n)$ were found. In this way the trivialization problems for the foliations of the $SL(n)$ group and the space $sl^*(n)$ were solved [21].

Three-loop computations of the renormalization group function γm, which determines the behavior of the effective mass of fermions in gauge theories, were carried out [22]. Dimensional regularization and the ‘t Hooft minimal subtraction scheme were used. The values of the anomalous dimensions of fermions for quantum chromodynamics and electrodynamics were obtained.

A new universal symbolic-numerical algorithm, which was implemented as the first version of $O(5) \times SU(1,1)$ in Wolfram Mathematica for computing the orthonormal basis of the Bohr–Mottelson collective model and which can be implemented in any computer algebra system, was elaborated [23]. This kind of basis is widely used to calculate the spectra and electromagnetic transitions in solid, molecular and nuclear physics.

Algorithms for algorithmic verification of linearizability for nonlinear (ordinary) differential equations were developed. The first algorithm is based on the construction of the Lie point symmetry algebra and calculation of the derived algebra; the second algorithm uses the differential Thomas decomposition and allows one not only to verify linearizability but also to generate a system of nonlinear partial differential equations that determine the point transformation and the coefficients of the linearized equation [24].

In the framework of constructive quantum mechanics, the problem of the emergence of geometry from entanglement in composite quantum systems was investigated. It was shown that the second Rényi entanglement entropy could be useful when applying polynomial computer algebra to model metric structures in quantum systems with geometry [25].

Using the negative property of the Wigner function, a global indicator of nonclassicality of the state space of an N-level quantum system in the Hilbert–Schmidt distribution was introduced, and its value for $N \to \infty$ was given [26].

The dependence of the global indicator of classicality on the geometry of the space of quantum states for a whole family of representations of Wigner quasiprobability distributions was investigated using the example of the Hilbert–Schmidt, Bures and Bogoliubov–Kubo–Mori ensembles of qubits and qutrits [27].

The robustness of entanglement in two qubits with maximally entangled mixed states was studied under quantum decoherence channels [28].

An algorithm for quantum teleportation of two-qubit maximally entangled Bell states on different five-qubit processors was implemented. To reduce arising errors, several modifications of the original teleportation protocol were proposed. The comparison of the dynamics of the results of measuring the output probabilities, performed on the IBM Q Yorktown processor, demonstrates significant progress in improving the characteristics of IBM's quantum hardware [29].

APPLIED RESEARCH

Two tasks of image recognition were considered: plant disease detection on 25 classes of five different crops (grape, cotton, wheat, cucumbers and corn — a total of 935 images) and moss species identification (5 types, 599 images). A neural network architecture based on a Siamese network with a triplet loss function and MobileNetV2 as a base network was proposed. The given model showed impressive results in accuracy for both tasks. The average accuracy for plant disease detection amounted to over 98.1%, and 97.6% for moss species classification [30]. The results illustrate a huge potential of this approach when solving the tasks of image recognition in a small training sample.

In 2020, an information system (IS) for the tasks of radiation biology was developed within a joint project of LIT and LRB using the ML/DL/HPC ecosystem of the HybriLIT platform (Fig. 11). The IS is aimed at storing experimental data and analyzing changes in the central nervous system of mammals on the basis of molecular, pathomorphological and behavioral changes in the mammalian brain when exposed

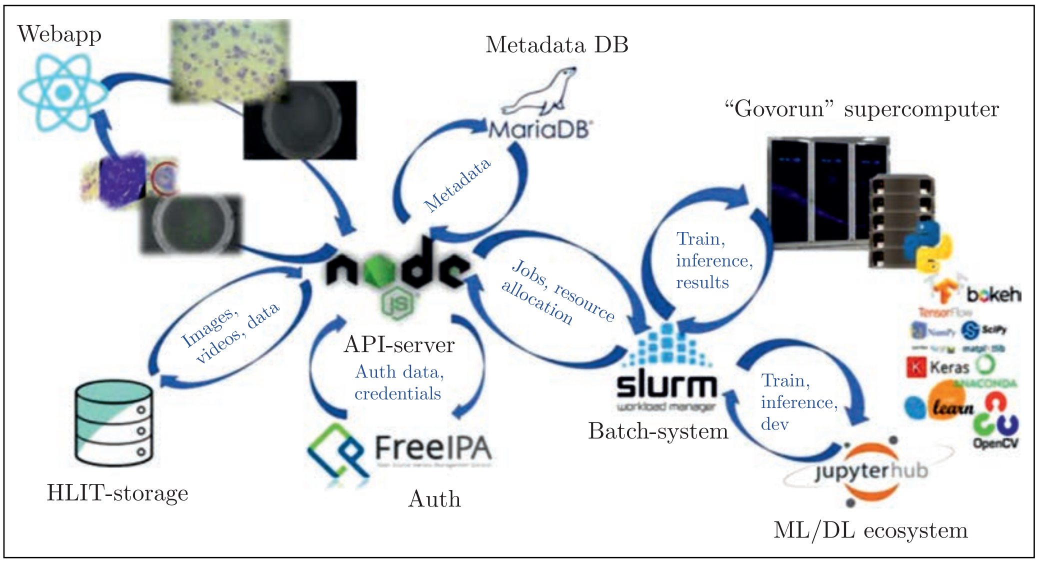

Fig. 11. Architecture of the information system

to ionizing radiation and other factors. Algorithms for experimental data processing based on machine and deep learning were implemented into the developed system. The IS comprises reliable modern means of authentication and hierarchical delimitation of access to data, a data storage system, as well as components for convenient work and visualization of data analysis results [31].

A Geometry Information System (GIS), which is configurable during deployment, was developed for use in all experiments of the NICA project. The general object model and architecture of the Geometry Database (DB) were designed. The GIS comprises central (PostgreSQL-based) and local (SQLite replica) Geometry Databases. The central DB is available on the Apache web server and provides all the functions required for detector geometry management. The local DB, being part of the software for the NICA experiments on the basis of the ROOT environment, is used primarily for loading the detector geometry in the jobs of modeling, reconstruction and physical data analysis. Application programming and web interfaces common for all NICA experiments were elaborated.

INTERNATIONAL COOPERATION

In 2020, within the cooperation agreement between JINR and DESY in collaboration with the partners of the $JOIN^2$ (Just anOther INvenio Instance) project (https://join2-wiki.gsi.de/cgi-bin/view), the work on the development of the JINR Document Server information system based on the $JOIN^2$ software platform (https://lt-jds-join2.jinr.ru/) was in progress. Bibliographic records were downloaded and verified, and authority records, namely, Topical Plan, Personalities, Subdivisions, Experiments, Grants, were downloaded and updated. This makes it possible to link publications with relevant funding sources, experiments with JINR's participation, etc. User authorization based on the Single Sign-On technology was implemented for the JINR staff [32].

An international research group, including scientists from LIT (O. Chuluunbaatar) and BLTP (Yu. V. Popov), conducted a kinematically complete experimental measurement of the characteristics of Compton scattering at free atoms using the highly efficient method of COLd Target Recoil Ion Momentum Spectroscopy (COLTRIMS). A theoretical description of this phenomenon is based on the calculations performed on the "Govorun" supercomputer [33].

In collaboration with colleagues from Poland, the "horn" effect in the K^+/π^+ ratio at a collision energy of ~ 8 GeV was studied within a $2+1$ flavor PNJL model. In parallel, to interpret the behavior of bound states in a dense and hot medium, the mean-field approximation (Breit–Wigner) and the Beth–Uhlenbeck approach were considered [34]. It was shown that the best agreement with the experimental data was obtained when the non-equilibrium chemical potential was involved in the calculations, and the absence of a critical end point in the phase diagram had no critical effect on the position and magnitude of the "horn".

EDUCATIONAL PROGRAM ON THE EDUCATION AND TESTING POLYGON

An important aspect of the activity that involves the resources of the HybriLIT platform is the educational direction related to conducting both training courses for JINR employees and practical classes for students of Dubna State University, Tver State University and other universities. In 2020, tutorials and master classes were remotely held for students from the Czech Republic and Armenia.

In 2020, tutorials and practical classes were held on the HybriLIT platform for more than 1000 students within the following courses: "Architecture of Computing Systems", "Technologies of High-Performance Computing", "Modern Methods of Analyzing Complex Systems", "Machine Learning and Data Mining", "Languages and Technologies of Data Analysis", "Mathematical Apparatus and Tools for Data Analysis" — using the ML/DL/HPC ecosystem, which allows students to master state-of-the-art technologies for developing parallel algorithms on novel computing hybrid architectures and tools (libraries and frameworks) for the tasks of machine and deep learning [35]. The platform resources were also actively used to train IT specialists within the International School of Information Technologies “Data Science” [36], whose students are engaged in real scientific projects of JINR (the results are presented in a collection of scientific and project activity reports: http://itschool.jinr.ru/other/Reports_ITSchool_eng.pdf). In 2020, three PhD theses and more than 15 Master’s and Bachelor’s theses were prepared using the resources of the HybriLIT platform.

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LABORATORY OF RADIATION BIOLOGY

In 2020, the Laboratory of Radiation Biology (LRB) continued research under themes 04-9-1077-2009/2023 "Research on the Biological Effect of Heavy Charged Particles of Different Energies" and 04-9-1112-2013/2022 "Research on Cosmic Matter on the Earth and in Nearby Space; Research on the Biological and Geochemical Specifics of the Early Earth". Based on the results of the meeting of the Executive Committee of the International Biophysical Collaboration (INFN, Rome, February 20–21, 2020), programs of biomedical research at the world's largest accelerator centers have been published [1]. The list of the Collaboration's programs includes LRB's research on the mechanisms of radiation action on the central nervous system.

RADIATION GENETICS AND MOLECULAR RADIOBIOLOGY

Research on Clustered DNA Double-Strand Breaks (DSBs) Induced by Ionizing Radiation of Different Quality. In cooperation with Czech and German scientists, a new method of ultra-high resolution analysis of the fine structure of clustered DNA DSBs has been developed based on single-molecule localization microscopy. Using this method, the structure of clustered DNA DSBs induced by accelerated ^{15}N ions (the U-400M cyclotron, the Flerov Laboratory of Nuclear Reactions) has been studied, and a comparative analysis of the kinetics of their repair in human normal (fibroblasts) and tumor (U87 glioblastoma) cells has been carried out (Fig. 1). The proposed approach can yield a new insight into the nature of radioresistance of a number of tumors [2].

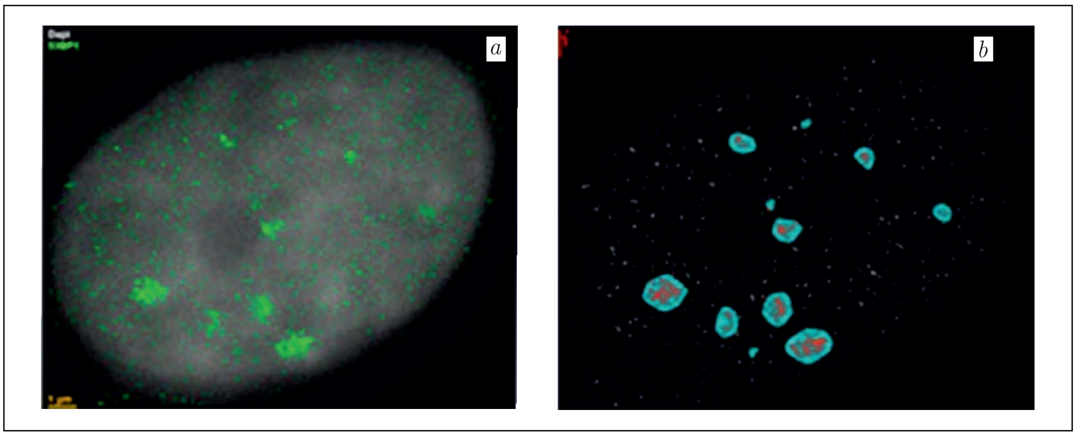

Fig. 1. A visualization of the structure of 53BP1 repair protein clusters in nuclei of human U87 glioblastoma cells 24 h after exposure to 13 MeV/nucleon ^{15}N ions at a dose of 1.3 Gy: *a*) microscope images, *b*) software post-processing

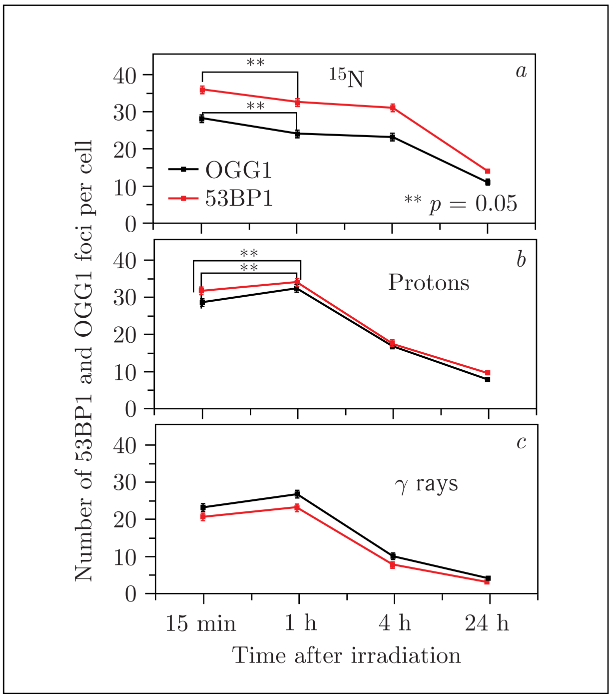

Fig. 2. Kinetics of OGG1 and 53BP1 foci formation and elimination in nuclei of normal human skin fibroblasts after exposure to 13 MeV/nucleon ^{15}N ions, spread-out Bragg peak protons, and ^{60}Co γ rays at a dose of 1.25 Gy

For the first time, analysis has been performed of the formation and elimination kinetics and structure of clustered 53BP1/OGG1 foci induced by spread-out Bragg peak protons, accelerated nitrogen ions with LET of 181 keV/μm, and ^{60}Co γ rays (Fig. 2). The use of specific fluorescent antibodies made it possible to visualize the repair marker proteins for DNA DSBs and damaged bases (53BP1 and OGG1, respectively). The sites of colocalization of marker proteins are sites for the formation of clustered DNA DSBs containing modified bases. The data obtained indicate that the repair of a clustered DNA lesion occurs in a complex manner, that is, the repair systems eliminate the clustered lesion as a single complex, rather than repair different types of damage separately, which is confirmed by a similar shape of the kinetic curves of the formation and elimination of 53BP1 and OGG1 foci [3].

Research on DNA DSB Formation and Elimination in Primary Culture Cells of the Hippocampus and Cerebellum of Rats after Exposure to ^{60}Co γ Rays, Protons, and ^{15}N Ions. Patterns of the formation of clustered DNA DSBs in rat brain cells in primary cultures of the hippocampus and cerebellum after exposure to ionizing radiations of different quality have been identified and analyzed using the DNA DSB repair markers γH2AX and 53BP1 (Fig. 3). It has been found that in the post-radiation period the yield of radiation-induced γH2AX/53BP1 foci increases and reaches its maximum 1 h after irradiation [4].

Cytogenetic Analysis of Chromosomal Damage in Mammalian and Human Cells. In collaboration with researchers from the University of Szczecin, Poland, a chemically caused premature chromatin condensation (PCC) study of the induction and repair of chromatin breaks in human normal and tumor cells has been conducted [5]. Earlier, the induction of chromosomal aberrations by radiations with different LET was simulated [6, 7]. Chromatid and isochromatid breaks in G2-phase human lymphocytes were examined immediately (t_0) and 12 h (t_{12})

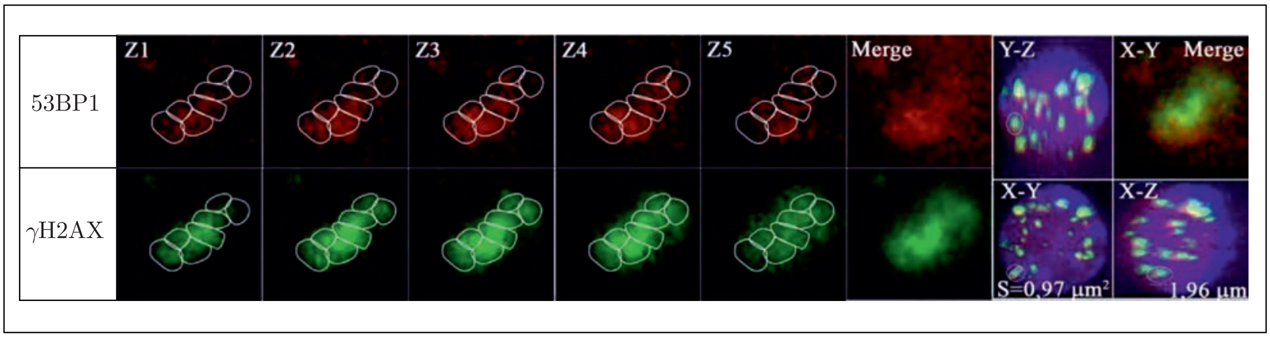

Fig. 3. Clustering of γH2AX/53BP1 foci in the nucleus of a cell of a rat hippocampal neuronal culture 1 h after proton irradiation. Images $Z1-Z5$ show individual optical sections in the $X-Y$ planes obtained along the Z axis with a step of 0.3 μm, illustrating changes in the number of individual γH2AX and 53BP1 foci in the cluster. The complex γH2AX/53BP1 cluster consists of 7 individual γH2AX and 53BP1 foci. The pictures entitled "Merge" show the resulting image of the γH2AX and 53BP1 foci of the cluster, obtained by superimposing the focal planes $Z1-Z5$. The γH2AX/53BP1 focus area in the $X-Y$ projection is 0.97 μm^2; the length of the focus along the Z axis is 1.96 μm

after irradiation with 150-MeV and spread-out Bragg peak protons, 22-MeV/nucleon boron ions, and ^{60}Co γ rays. Irradiation was performed at the medical beam of the Phasotron (JINR DLNP), at DLNP's ^{60}Co γ-ray Rocus-M facility, and at the U-400M cyclotron (JINR FLNR). In all cases, linear quadratic dependences of the chromatid break yield on the dose were observed, boron ions being much more efficient than γ rays and protons (Fig. 4). For γ-ray and proton irradiation, the PCC break distribution in cells at t_0 and t_{12} obeyed the Poisson statistics. After boron ion exposure, an excessive variance was observed, and the PCC break distribution in cells was described by Neyman type A statistics, which is a combination of two independent Poisson distributions: the probability of n ions hitting the cell nucleus and the probability of the formation of k aberrations.

Research has continued on the action of sparsely and densely ionizing radiation on primates [8]. A cytogenetic analysis of chromosome aberrations in blood lymphocytes of *Macaca mulatta* monkeys was carried out after complex exposure simulating space flight conditions, which included synchronous combined action of antiorthostatic hypokinesia and prolonged exposure to ^{137}Cs γ rays (the Institute of Biomedical Problems, Moscow), followed by irradiation of monkey heads with ^{12}C ions at a dose of 1 Gy (the Institute of High Energy Physics, Protvino). The control animal group showed a low level of chromosomal aberrations. Most of the observed chromosomal lesions (up to 70%) were chromatid-type aberrations. The number of cells with dicentrics and centric rings found in the analysis of control samples did not exceed 0.3 per 100 cells. 24 h after irradiation with ^{12}C ions (on the 9th day after irradiation with ^{137}Cs ions), the total yield of dicentrics and centric rings increased 14 times compared with the control. Over time, their number decreased, and on the 45th day of the study it was still 3.5 times higher than the unirradiated control values. 454 days after the termination of the complex exposure course, the total number of chromosomal aberrations decreased, but still did not reach the control values and exceeded the control level by 3 times (Fig. 5).

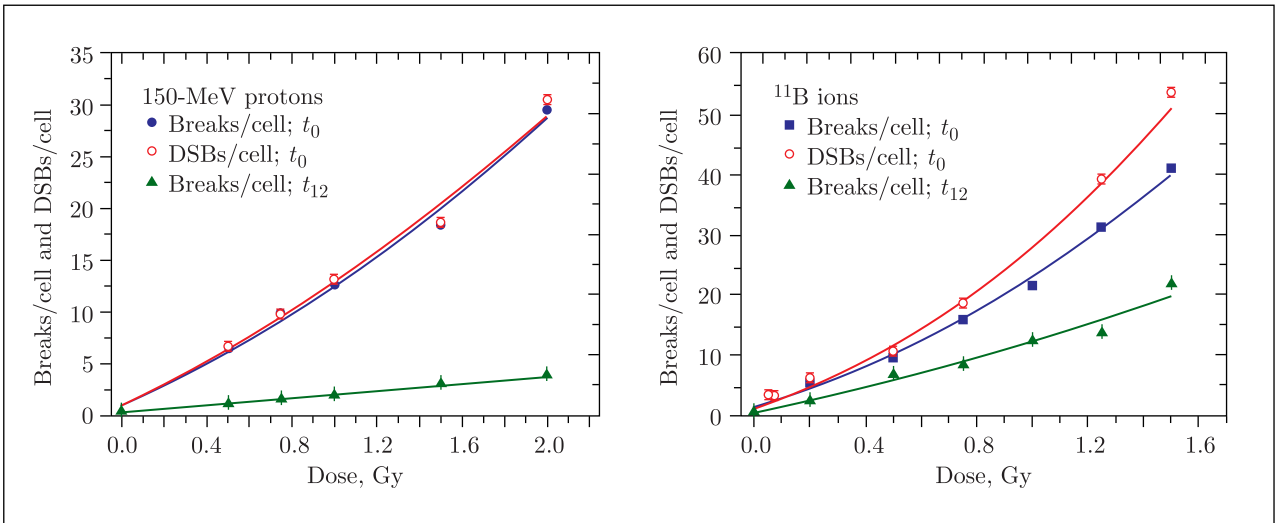

Fig. 4. PCC breaks detected immediately (t_0) and 12 h (t_{12}) after irradiation with 150-MeV protons and 22-MeV/nucleon boron ions. At t_0, the breaks were converted to DNA DSBs

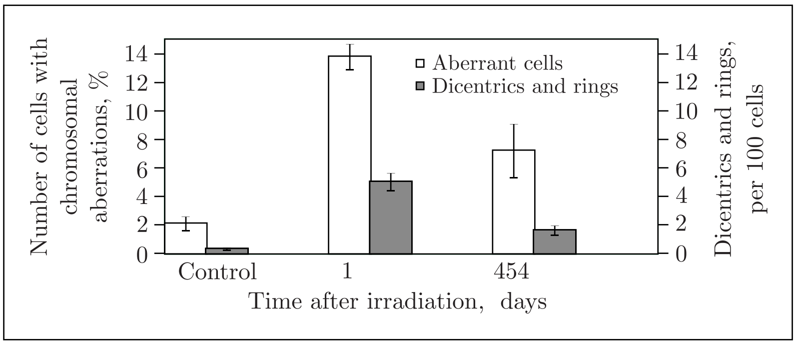

Fig. 5. The yield of cells with chromosomal aberrations (light columns) and cells with dicentrics and rings (gray columns) 1 and 454 days after the termination of the complex exposure course simulating space flight conditions (hypokinesia + prolonged γ irradiation + irradiation with accelerated ^{12}C ions)

Genetic Effects Induced by Ionizing Radiation in a Model Unicellular Eukaryotic Organism (the Yeast *Saccharomyces cerevisiae*). The distribution of non-synonymous mutations inactivating the CAN1 enzyme has been studied. The mutation spectrum is influenced not only by the features of the gene's nucleotide sequence but also by protein-level selection. The arginine permease CAN1 belongs to the evolutionarily conserved superfamily of transporters that carry amino acids through cell membranes. Despite the dissimilarity of the sequences, they have a similar structure and consist of 12 transmembrane helices flanking a hydrophilic tail directed to the cytoplasm.

The analysis of the nucleotide sequence of 3773 Can^R mutations that emerged spontaneously and after irradiation with ultraviolet light, γ rays, or accelerated ions has been performed. Part of the mutation collection was kindly provided by R. D. Kolodner (the University of California, San Diego, the U.S.) and D. A. Gordenin (the National Institute of Environmental Health Sciences, North Carolina, the U.S.). The enzyme was inactivated by 308 single non-synonymous mutations (single nucleotide polymorphisms) causing the substitution of 154 out of 590 amino acid residues. The analyzed mutations are found both in transmembrane helices and between them [9].

RADIATION PHYSIOLOGY AND NEUROCHEMISTRY

Research on Morphofunctional Indicators and Behavioral Responses in Animals Exposed to Ionizing Radiations of Different Quality. The radioprotective effect has been studied of the officinal drug piracetam on behavioral responses and morphological changes in the brain of laboratory rats after total fractionated exposure to ^{60}Co γ rays (the Rocus-M facility, the Dzhelepov Laboratory of Nuclear Problems). For 10-day irradiation at a dose of 0.5 Gy per fraction (5 Gy in total), it has been found that radiation exposure leads to reduction of passive defensive behavior in rats. These changes are observed against the background of a decrease in the cross section of the granular layer of the dentate gyrus of the hippocampus and an increase in the number of positive cells in brain slices with Fluoro Jade B staining. Parenteral administration of 0.5 ml of piracetam at the dose of 100 g per kg of body weight after each irradiation fraction was marked by the normalization of the passive defensive behavior of the animals, the conservation of morphometric parameters of the granular layer of the dentate gyrus at the level of intact animals, and a decrease in neurodegenerative changes in the central nervous system. Thus, piracetam can be considered a promising drug for the relief of central nervous system disorders due to radiation therapy, radiation accidents, and manned space missions [10].

Research on the Generation of Reactive Oxygen Species and Action Mechanisms of Antioxidants. Research has continued on the modifying effect of the antioxidant TEMPOL on the induction of chromosomal aberrations in CAL51 breast carcinoma cells for different dose ranges of exposure to ^{60}Co γ rays (the Rocus-M facility, the Dzhelepov Laboratory of Nuclear Problems). A preliminary assessment of the yield of reactive oxygen species (ROS), which is an indicator of the oxidative stress level, revealed a paradoxical fact: TEMPOL did not decrease, but increased ROS generation in irradiated cells. It has been found that TEMPOL reduces the number of aberrant cells for irradiation at doses of 1–2 Gy and increases the genotoxicity of radiation at low doses of the order of several cGy. The mechanism of TEMPOL's protective action under radiation exposure is not associated with ROS detoxification. On the contrary, their level increases in the presence of this modifier. Thus, in irradiated cells, TEMPOL itself acts as an oxidant/electrophile. It has been found that at a low dose of 0.1 Gy, TEMPOL enhances the activation of the NRF2 protein, regulator of the main pathway of the Nrf2-ARE antioxidant system. However, this increase is not accompanied by an increase in the activity of NQO1, which is under its control. At a high dose of 1 Gy, TEMPOL has no significant effect on Nrf2 expression. It is assumed that the protective effect of TEMPOL at high doses may be due to the expression of the NQO1 protein, which regulates cellular redox homeostasis and stabilizes the main DNA repair proteins P21 and P53. The concentration of this protein increased in the presence of TEMPOL at a dose of 1 Gy, but not at 0.1 Gy.

MATHEMATICAL MODELING OF RADIATION-INDUCED EFFECTS

A biophysical model of the interaction of ionizing radiation with cell structures of the brain has been developed [11]. Based on the model, it is shown that irradiation with iron ions with a fluence of $3.2 \cdot 10^5$ cm^{-2} results in high local doses (> 100 Gy) in the dendritic spines of hippocampal neurons, which is not achieved with exposure to low- and intermediate-LET charged particles. For exposure to accelerated protons and carbon and iron ions at a dose of 0.1 Gy, damage to spines 35, 268, and 524 has been predicted. After irradiation with iron ions at relatively low doses (0.1 Gy), approximately 11% of progenitor cells and 9% of immature hippocampal neurons were observed to have at least more than one clustered DNA double-strand break, which indicates a high radiosensitivity of these cell structures.

Molecular modeling has been performed of the human inosine triphosphate pyrophosphohydrolase (hITPA) enzyme, which regulates the nucleotide pool and protects cells from DNA damage. With the use of programs that identify potential sites of chemical modification, the sites of phosphorylation, ubiquitination, and sumoylation have been determined [12]. Their localization on a 3D structure shows that they are positioned on the surface of the protein and are potentially available to modifying enzymes. The results obtained allow planning further experimental verification of the existence of hITPA modified forms and modeling the effect of chemical modifications on its activity.

RADIATION PROTECTION PHYSICS AND RADIATION RESEARCH

The U-400M cyclotron-based Genome facility for irradiation of different biological samples has been upgraded. Distributions of linear energy transfer for nuclei in radiobiological experiments at the U-400M cyclotron have been calculated [13]. The design of a radiobiological channel has continued, and work has begun on the development of a space radiation simulator at the Nuclotron, the Veksler and Baldin Laboratory of High Energy Physics (VBLHEP). Prediction of the radiation conditions and radiation doses received by astronauts inside a spacecraft beyond Earth's magnetosphere has continued [14, 15], as well as processing data from radiobiological experiments on laboratory animals for space radiobiology [16, 17].

At the suggestion of the VBLHEP Directorate, the necessary calculations were made, and documents entitled "Radiation Safety Justification for the Design of the NICA Booster" and "Radiation Safety Justification for the Operation of the NICA Complex" have been prepared [18]. Calculations have been carried out and materials have been prepared for the project of the sanitary protection zone of the NICA complex in terms of the radiation factor, including the calculation of the annual effective dose from radioactive emissions into the atmosphere from the collider, booster, and Nuclotron and the justification of the 400-m zone around the Nuclotron for the proton sessions of the complex. Neutron flux density at the location of the ZDC electronics of the SPD detector has been estimated.

Neutron spectra have been measured with a multisphere spectrometer at two points at the IREN facility, the Frank Laboratory of Neutron Physics, and the spectrometer has been calibrated in open geometry [19]. Within the framework of cooperation with the Institute of Space Research, a session was conducted at the proton beam of the Phasotron, the Dzhelepov Laboratory of Nuclear Problems, to refine the tagged proton method [20]. At the DAN stand with radionuclide neutron sources and neutron generators, ADRON instruments were tested with a planetary soil model.

STUDYING COSMIC MATTER ON THE EARTH AND IN NEARBY SPACE

In cooperationn with scientists from Italy and the Czech Republic, the formation of complex prebiotic compounds under 170-MeV proton irradiation of simple organic compounds in the presence of meteorite matter as a catalyst has been studied. As a result of the exposure, a complex mixture of oxygen-containing and oligomeric derivatives was obtained, which included polyhydroxy derivatives, isomeric dimers containing benzofuran and benzopyran frame-

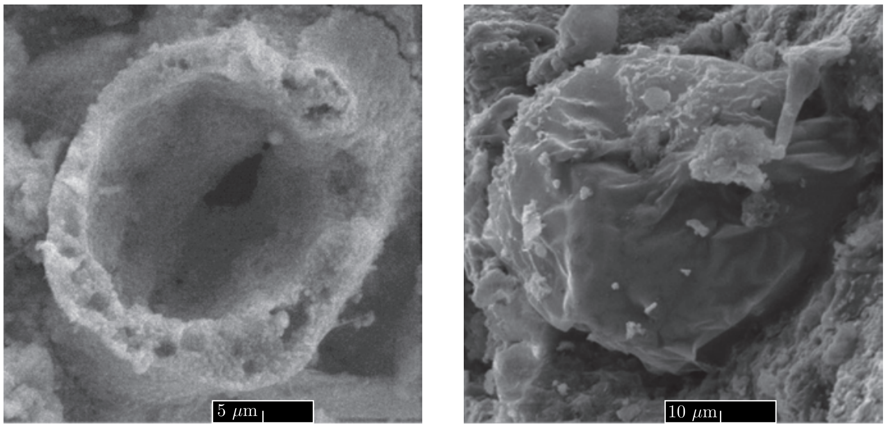

Fig. 6. Images of fossilized microorganisms in the Orgueil meteorite

works, and derivatives of quinones and perylene. A new mechanism has been suggested that promotes the formation and processing of insoluble organic matter in meteorites and during prebiotic processes [21].

In the course of scanning electron microscopy-based micropaleontological studies of the Orgueil, Murchison, Aguas Zarcas, Sutter's Mill, and other meteorites, various microfossils have been found on fresh cleavages (Fig. 6). The first illustrated atlas of microfossils in the Orgueil meteorite has been published [22]. Some aspects of prebiological evolution (the chronology of the formation of molecules in the early stages of the existence of the Universe) and the transfer of life in space (the theory of panspermia), as well as the diversity of microfossils in carbonaceous chondrites and the problem of contamination, have been considered [22, 23].

CONFERENCES AND EDUCATION

In 2020, the Laboratory's staff participated in ten online scientific conferences.

Academic activity has continued at the Department of Biophysics, Dubna State University. The Department's current enrollment includes 40 students and seven postgraduates. Four students successfully completed their education programs and got their Master's degrees in physics.

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UNIVERSITY CENTRE

In 2020, all training at the JINR UC was mainly carried out remotely both due to the COVID-19 prevention measures introduced in Russia and worldwide and so as to follow the JINR Order on the suspension of all educational events.

JINR-Based Education. In 2020, the educational process for BSc's, MSc's, and PhD's of the JINR-based departments of Russian technical universities was organized online.

Over 2020, 23 applicants from Belarus, Kazakhstan, the Russian Federation, Ukraine, and Vietnam were attached to JINR to prepare their PhD theses without studying at PhD courses. Out of 23, 8 students chose the specialty "Physics of charged particle beams and accelerator technology"; 6 students — "Physics of the atomic nucleus and elementary particles". The distribution of applicants by laboratories is as follows: VBLHEP — 8 people, DLNP — 5, FLNP — 4, FLNR — 3, BLTP — 2, LIT — 1.

Laboratory works developed by the UC Scientific and Engineering Group for undergraduate and postgraduate students from the JINR Member States, as well as for school students, are available on the UC website (uc.jinr.ru), now also in English.

New All-Year-Round Programme INTEREST. The onsite format of participation in JINR student events became temporarily impossible — the International Student Practice did not take place, and the participants of the Summer Student Programme approved by the Organizing Committee in 2020 were invited to come to JINR in 2021.

However, in September 2020, a new all-year-round programme INTEREST (INTErnational REmote Student Training) was launched by the JINR UC. It allows students to get acquainted with the main areas of the Institute research, helps to find a scientific supervisor for one's thesis, as well as raises chances of participants to get selected for JINR onsite internships in the future. Each stage of the Programme called Wave lasts for 4–6 weeks given for remote implementation of projects developed by the Institute staff members. The event programme includes an introductory lecture and optional online tours to the Institute laboratories. Active work is underway to improve the website http://interest.jinr.ru and attract project supervisors who could develop new projects to be implemented online.

Wave 1 was attended by 24 students from Egypt, India, Cuba, Poland, Russia, Romania, Uzbekistan, France, and the Czech Republic. The projects for the participants were offered by the staff members of BLTP, VBLHEP, FLNR, FLNP, LIT, and DLNP.

Twenty-six students from Belarus, Brazil, Great Britain, Egypt, India, China, Mexico, Poland, Russia, Romania, Uzbekistan, and Ukraine took part in Wave 2 of the Programme. Participants included students who had previously participated in the Summer Student Programme and International Student Practice. Students were offered 18 projects, for which 103 applications from 43 people had been received. The rules allow students to participate in the Programme more than once, provided they choose another project, the research area of which corresponds to their field of interest. Three participants used this opportunity.

Wave 3 of INTEREST was scheduled for February 2021.

The new online student programme INTEREST was presented at the regular 19th session of the RSA–JINR Joint Coordinating Committee, as well as on the virtual platform of the second Russian–German scientific and educational virtual exhibition organized in the fall of 2020 within the framework of the Russian–German Year of Scientific and Educational Partnerships 2018–2020.

JINR–RSA School at iThemba LABS. On 9–30 January 2020, representatives of JINR took part in the second JINR–RSA SAINTS@tlabs Physics Summer School hosted by iThemba LABS. Eight employees of BLTP, VBLHEP, DLNP, and UC delivered lectures on the JINR fields of research and gave master classes. The School was organized by the Southern African Institute for Nuclear Technology and Sciences. Thirty-two undergraduate and postgraduate students from 13 South African universities were selected from 66 applicants.

Events. The JINR University Centre promotes science by drawing attention to the work of scientists and demonstrating the results of the Institute research.

The UC Social Communications Group represented JINR at various outreach events for school and university students and a wider audience of different ages and occupations:

• Forum “Start of a Career” at NRNU MEPhI (7–8 April);

• MIPT job fair held online (4–6 June);

• Science and Technology Festival “Geek Picnic” (27 July, 6–8 August);

• The 5th Summer School “Physics. Mathematics. Informatics” for high-school students held at Dubna State University (5–30 July);

• Science Festival NAUKA 0+ in Samara; online week “Physics of the Nucleus” (21–26 September);

• Science Festival NAUKA 0+ in Moscow, “Expocenter” (10–11 October), online lectures from the MSU Library (10–11 and 17–18 October);

• MIPT “Career Day” (30 October – 2 November);

• Open Day at Dubna State University (7–8 November);

• Forum “Start of a Career: Autumn” at NRNU MEPhI (9–13 November).

Live Streaming — Online Excursions. Due to the new online format, the scenario of online excursions launched by the UC last year had to be updated in order to create immersive virtual tours. Video excursions were made from the video footage filmed at the JINR Laboratories. After the excursions participants viewed the video materials, the researchers of the Institute answered the questions of the audience in real time.

As before, excursions are aimed at school and university students, as well as mentors of science clubs. This allows the target audience not only to learn important scientific news but also to see the facilities, the access to which is restricted most of the time.

In 2020, filming and editing the video tours to the following basic facilities of the JINR Laboratories were completed:

• LRB Sector of Radiation Physiology;
• LRB Martian soil pavilion;
• VBLHEP Superconducting Magnets Hall;
• LIT Computing Center;
• FLNP REGATA facility;
• FLNR (in English).

Social Networks. The UC Social Communications Group continues to post JINR news on Vkontakte, Facebook, Instagram, Twitter. In order to raise interest in science and increase the awareness of the target audience of the opportunities to start a scientific career at JINR, the JINR UC youth information channel “Dubnium” is available.

Among the significant events, it is worth mentioning: rebroadcasting of live streams of the Nuclear Physics Week as part of the Samara regional platform of the 15th All-Russian Science Festival; rebroadcasting of lectures from the forum “Start of a Career: Autumn” by NRNU MEPhI; a short video review of the JINR exhibition stand at the 10th annual “Geek Picnic” festival, and broadcasting of the online excursion (in English) to the Flerov Laboratory of Nuclear Reactions for 125 participants of the Governor’s School for the Sciences and Engineering (GSSE) held at the University of Tennessee (Knoxville, USA).

In 2020, 19 videos were made and uploaded to the “Dubnium” sites by the efforts of the UC Social Communications Group.

Development of Brochures and Information Materials. Updating visual materials about the Institute is always relevant. To popularize fundamental and applied research, achievements and discoveries of JINR in 2020, the following materials were developed and printed:

• brochure about JINR for students (in Russian);

• JINR banner with the dates of world-scale discoveries made at JINR;

• motivational videos for students and graduates of science and engineering faculties on how to start a career at JINR (in Russian).

Development of the Content for the JINR Outdoor Interactive Digital Billboard. At the end of 2020, as part of the all-Institute group, the employees of the UC Social Communications Group took part in the development of content for the JINR outdoor interactive digital billboard. As a result, through joint efforts, a 20-minute video was made to be shown to Dubna residents during the New Year holidays.

Summer School "Physics. Mathematics. Informatics". On 25–30 July 2020, the V Summer School "Physics. Mathematics. Informatics" was held online. Sixty-three school students from Volgograd, Yekaterinburg, Krasnodar, Nizhny Novgorod, Nizhny Tagil, Penza, Ufa, and 20 more Russian cities passed the competitive selection in order to take part in it.

The event programme consisted of popular science lectures and teamwork on the projects. The topics of the projects were developed by university lecturers, researchers and engineers of JINR. The participants had to tackle at real professional tasks in electronics, physics, neural networks, and programming.

JINR and Dubna State University support talented school students who further on will be able to study the unique curricula of the International School of Engineering and the School of Big Data Analytics.

The website teachers.jinr.ru, which coordinates the organisation of programmes for teachers and school students and is used by thousands of teachers from theJINR Member States, is currently being upgraded. An extensive archive of presentations and videos accumulated over 10 years of running scientific schools for teachers will be restructured. This will make it easier to find the required materials and will attract new users and participants to the UC teacher programmes.

Tournament "CyberDubna-2020". On 14–16 February, the IX Open Robotics Tournament "CyberDubna-2020" was held in Dubna. About 80 students of 4–11 grades took part in the tournament, as well as students of secondary vocational education from Dmitrov, Dolgoprudny, Dubna, Korolev, Likino-Dulyovo, Protvino, Pushkino, Moscow, St. Petersburg, Eldigino and Pravdinsky villages (Pushkino district of the Moscow Region).

Organizers of the tournament were JINR, MIPT sports robotics club, Interregional Computer School (Dubna), and "Citadel" Information Technology Center (Yakhroma).

International Computer School 2020. On 19 July – 2 August 2020, the 32nd International (interregional) Computer School was held online. The School was attended by 23 students from Dmitrov, Dolgoprudny, Dubna, Moscow and 13 mentors. The first half of the day was devoted to a general discussion of the projects performed, the second — to individual work. At the final conference, video reports on all conducted studies were presented and discussed.

Yandex.Lyceum. The first year of studies at the Yandex.Lyceum came to its end. Twenty-five students who graduated with good and excellent results will start their second year. They will continue to learn Python under the programme "Basics of Industrial Programming" and implement individual creative projects. Students of 8–9 grades, who successfully passed the entrance tests, began their first-year studies in 2020–2021. Classes in Dubna are supported by JINR and are held twice a week at the Flerov Lyceum No. 6. Yandex.Lyceum classes are held in more than 160 cities in Russia and Kazakhstan.

Interschool Phys&Maths Open Classroom. In 2020/21, the Interschool Phys&Maths Open Classroom offered school students of 10–11 grades classes in experimental physics and preparation for the Unified State Exam in Physics.

The winners and prize-winners of the XXVIII Open Olympiad in Physics and Mathematics for students of 6–7 grades organized by the Interschool Phys&Maths Open Classroom in September were students of Lyceum No. 6, Gymnasium No. 11, and School No. 9.

Lectorium. The year 2020 made changes to the usual format of JINR UC interactions. For school students, the "live" format of lectures delivered by JINR staff members in the framework of the UC Lectorium was updated with online elements. It made it possible to attract a new audience not only from Russia but also from other countries. One of the tools for popularizing science and JINR achievements is the UC Lectorium for school students "COOL Science — Science at s'COOL". The Lectorium gives students the opportunity to learn about the advanced scientific and technical discoveries and achievements of JINR first-hand. In 2020, within the framework of this project, about 400 school students attended 8 lectures by JINR specialists, as well as popular science lectures at the events and festivals for a wider audience.

Visits. In January – March, JINR UC organized excursions for groups of school and university students (160 people) from Vladimir, Vologda, Moscow, Tambov, Pushkino, and Zelenograd.

Skill Improvement. JINR-based training was organized for 10 students of Dubna University College and MRATC.

108 JINR staff members were trained and certified by the JINR central qualification commission in the basics of fire safety under the programme “Basics of fire safety for workers performing gas welding and other hot works”. Ten staff members responsible for the safe execution of the works related to using lifting devices completed their training.

Online foreign language groups comprised 82 JINR employees: English — 57 people, French — 9, German — 8, Russian — 8 foreign specialists.

At the request of DLNP, JINR UC staff members have developed an English course for the personnel of the DLNP Design Department involved in the international collaborations between JINR and CERN. The course covers grammar, translation, mastering the necessary minimum of special technical terminology, and making presentations.

JINR is developing as a large multidisciplinary international scientific centre incorporating basic research in the field of modern nuclear physics, development and application of high technologies, and university education in the relevant fields of knowledge.

JOINT INSTITUTE FOR NUCLEAR RESEARCH

JINR

The Bogoliubov Laboratory of Theoretical Physics.
Junior researcher E. Mardyban,
a winner of a grant of the President of the Russian Federation in 2021–2023 for young scientists and graduate students

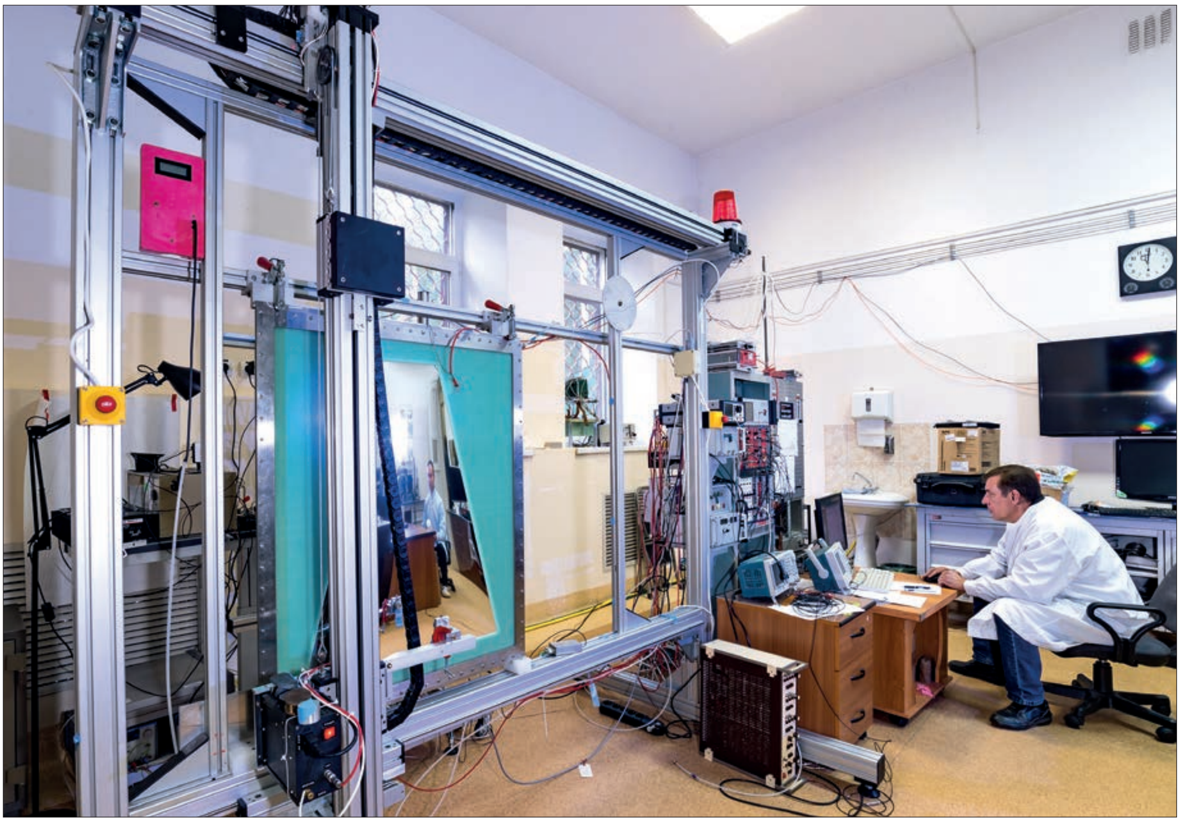
The Bogoliubov Laboratory of Theoretical Physics.
The laboratory staff discussing the renormalization group approaches in high energy physics

The Veksler and Baldin Laboratory of High Energy Physics. The NICA complex construction site

Dubna, 24–26 February. The first meeting of the NICA Cost and Schedule Review Committee

Dubna, 29 July. The 5th meeting of the Supervisory Board of the NICA Complex project via videoconference

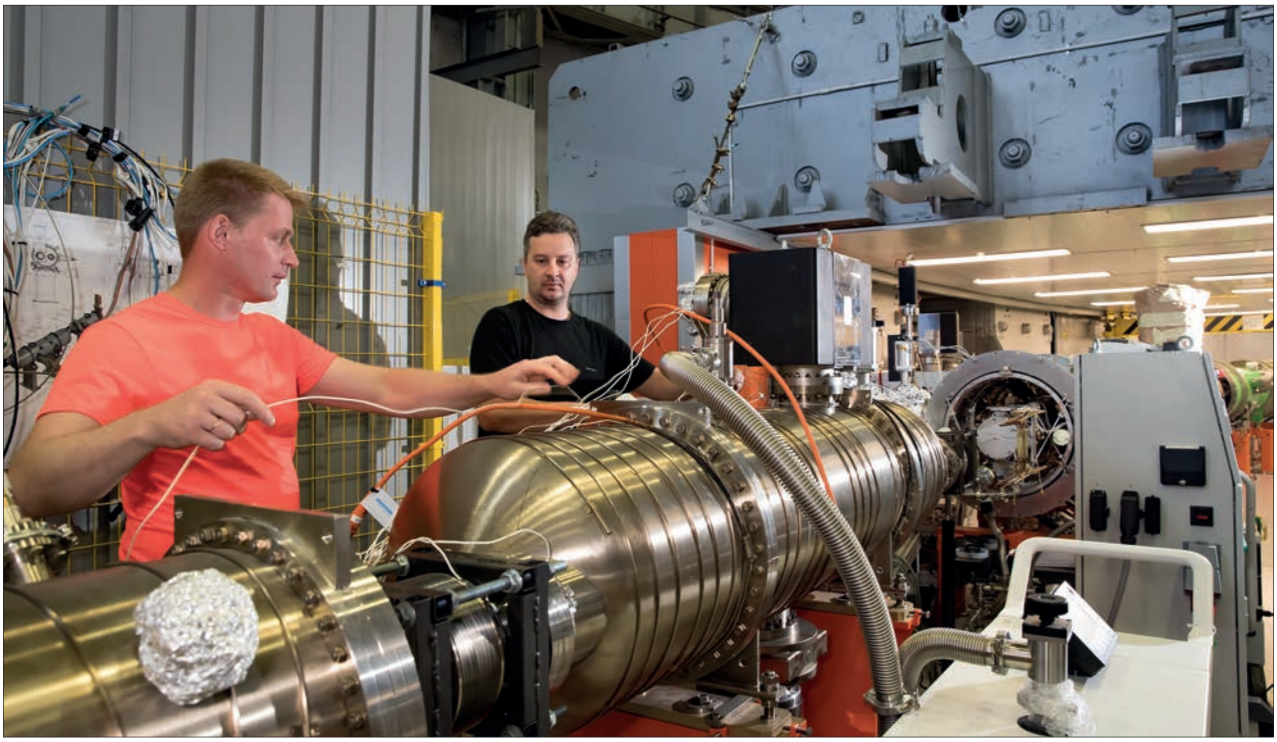
Dubna, 15 September. The opening of the SPD Days in Dubna via videoconference



The Veksler and Baldin Laboratory of High Energy Physics. A general view of the automated stand for testing the time projection chamber of the MPD facility

The Veksler and Baldin Laboratory of High Energy Physics, July.
Participants of the assembling of the MPD detector magnet

Dubna, 6 November. The superconducting magnet for the MPD detector has been delivered to the construction site of the NICA project

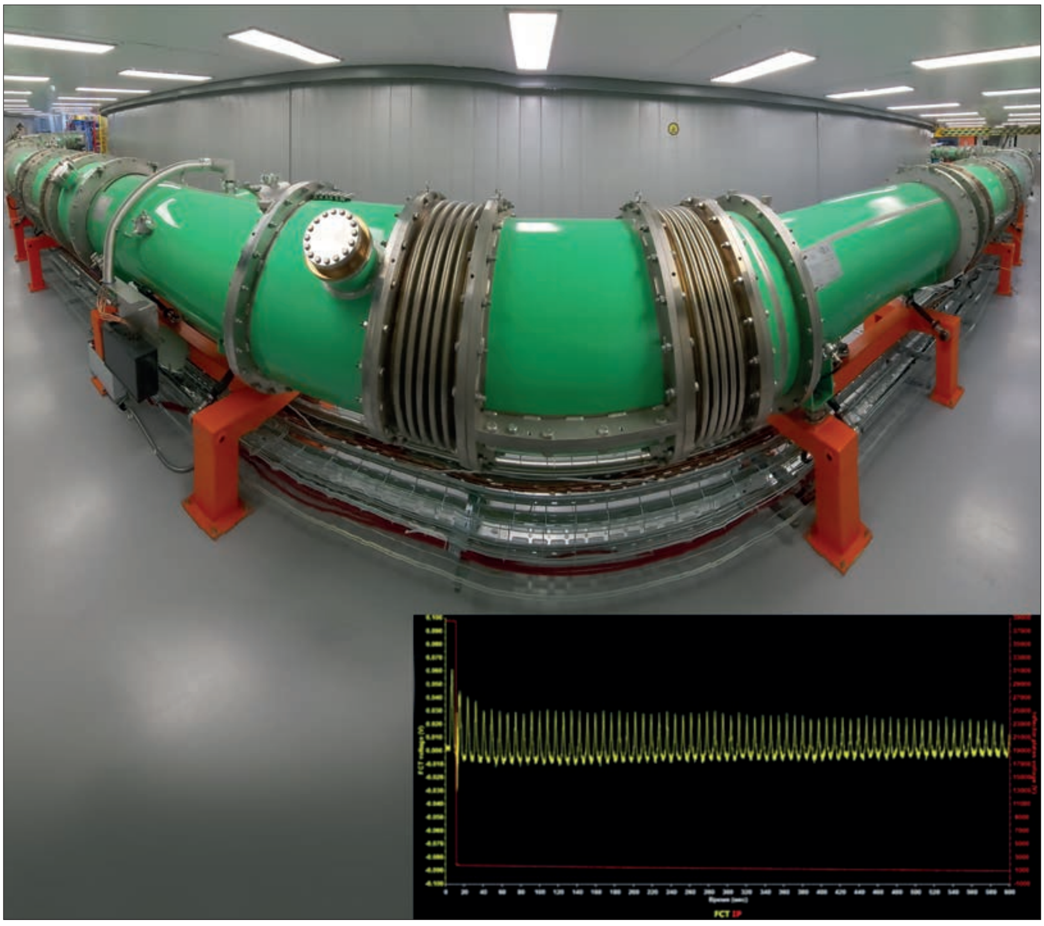


The Veksler and Baldin Laboratory of High Energy Physics. The assembling of the electrostatic septum of the system of beam injection into the NICA collider Booster

The Veksler and Baldin Laboratory of High Energy Physics, 30 December.
Part of the team of the accelerator department on the day of completing the launch session of the NICA Booster

The Veksler and Baldin Laboratory
of High Energy Physics, 20 November.
Prime Minister of the Russian Federation
M. Mishustin launched the Booster

The Veksler and Baldin Laboratory of High Energy Physics.
The Booster of the NICA collider and a diagram of the beam circulation

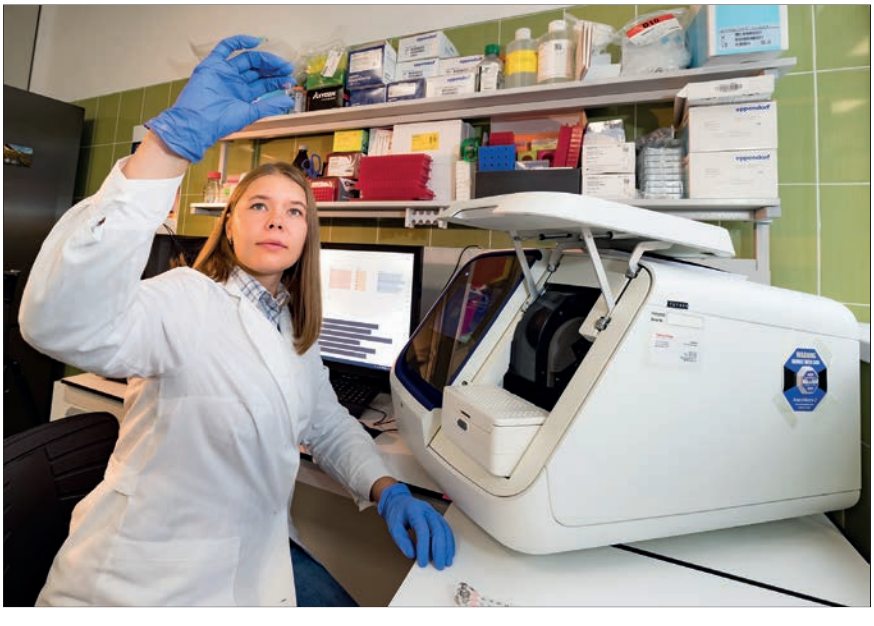


Lake Baikal (Russia). Mounting the central part of the new, seventh cluster
of the telescope Baikal-GVD

Participants of the 2020 expedition to develop
the deep-water neutrino telescope Baikal-GVD (*photo by B. Shajbonov*)

Dubna, October. Photo exhibition “Baikal. Neutrino Hunters”. The author of photos is B. Shajbonov, a participant of the Baikal international collaboration

The Dzhelepov Laboratory of Nuclear Problems. Setting up sequencing reactions to determine the DNA sequence of the 16S RNA gene in new extremophilic species of microorganisms found in the underground hot spring of the Baksan Neutrino Observatory

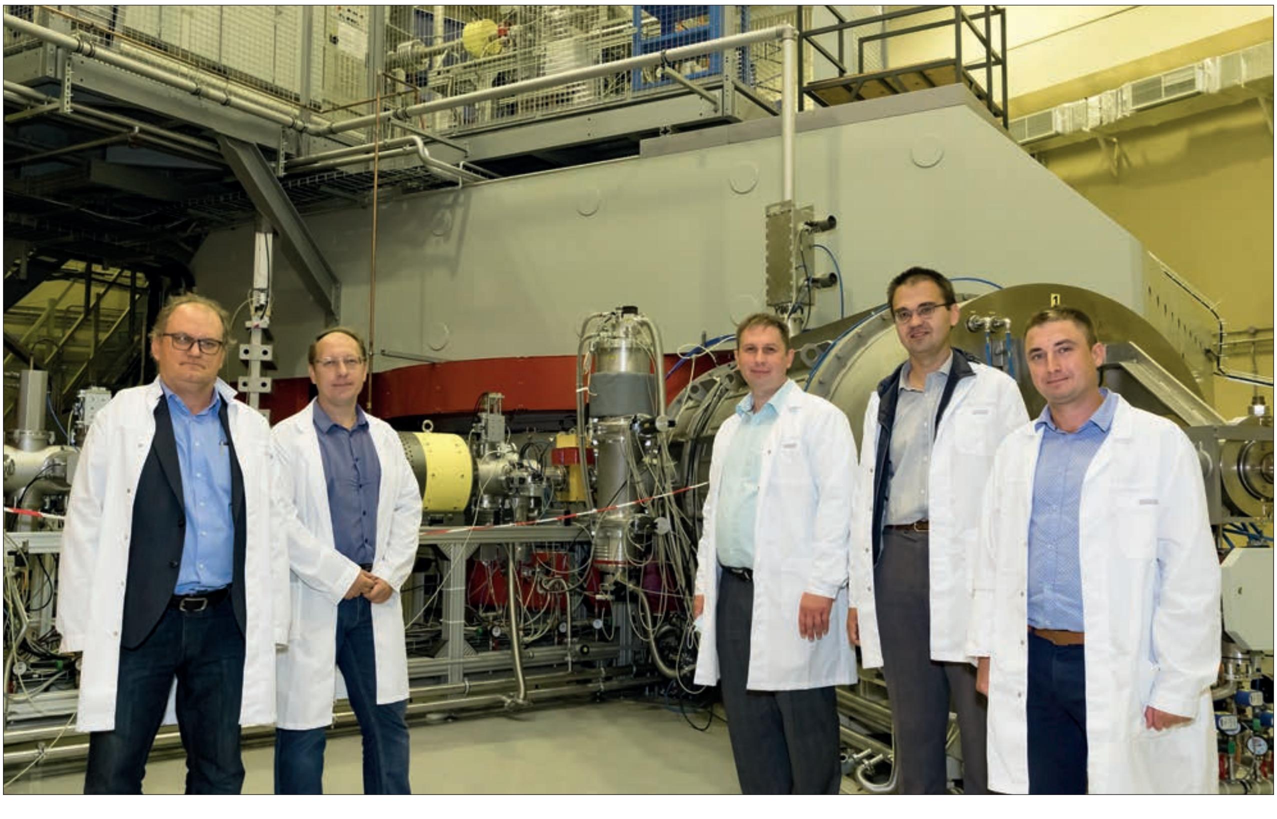


The Dzhelepov Laboratory of Nuclear Problems. The Precision Laser Inclinometer (PLI) — an innovative device for measuring the inclinations of the Earth surface in time with a sensitivity of $2.4 \cdot 10^{-11}$ rad/Hz$^{1/2}$ in the frequency range of $10^{-3} - 12.3$ Hz. The PLI is currently used at the VIRGO interferometric gravity antenna and at the LHC

The Dzhelepov Laboratory of Nuclear Problems.
Preparation of the read-out panel before the assembling of the Micromegas detector for the ATLAS experiment

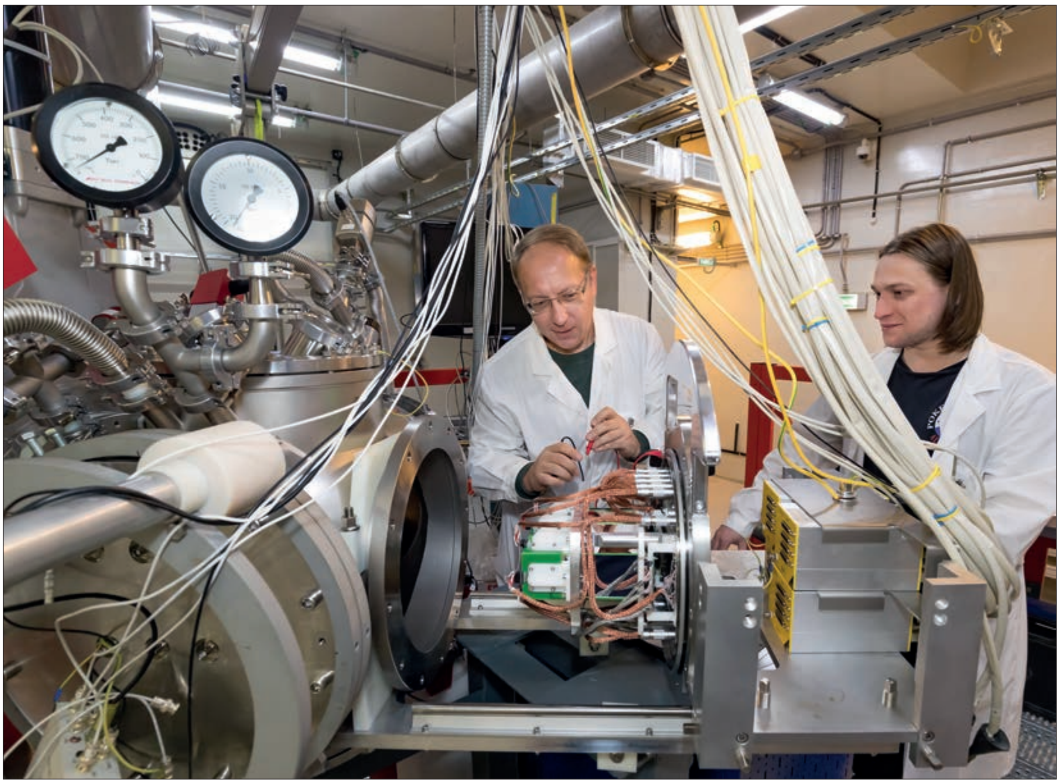
Dubna, 29 January. Chairman of the Presidium of the Far East Branch of RAS Academician V. Sergienko on a visit to JINR. The meeting with FLNR Scientific Leader Academician Yu. Oganessian

Dubna, 15 July. Vice-Rector of MIPT and Acting Director of the Landau Phystech School A. Voronov (centre) on an excursion at the Flerov Laboratory of Nuclear Reactions



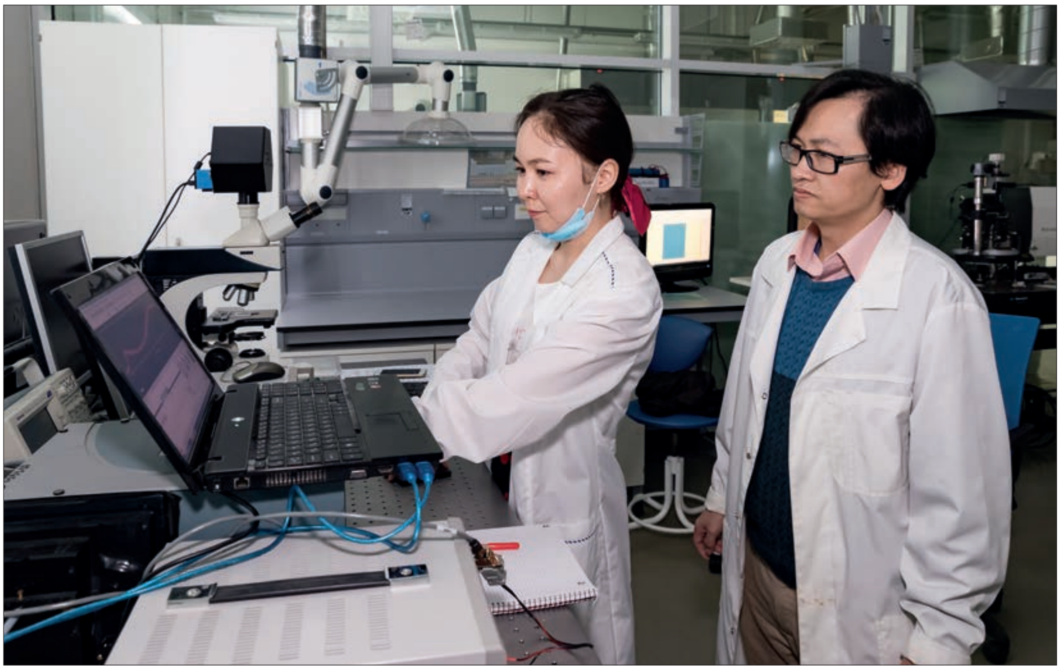
The Flerov Laboratory of Nuclear Reactions. A scientific seminar of Academician of RAS Yu. Oganessian

The Flerov Laboratory of Nuclear Reactions. The transmission electron microscope Talos F200i
for the study of radiation effects in solids and nanotechnological applications



The Flerov Laboratory of Nuclear Reactions. The installation and testing of the assembly of semiconductor detectors for GFS-2

The Flerov Laboratory of Nuclear Reactions. Measurement of photoluminescence spectra of samples of LiF and Al_2O_3 crystals after heavy-ion irradiation



The monument to I. Frank and F. Shapiro near the administration building
of the Frank Laboratory of Neutron Physics


The Frank Laboratory of Neutron Physics, 23 June. The all-laboratory memorial seminar "The 60th Anniversary of the IBR Reactor Start-Up"

Dubna, 5 February. Counsellor of the Embassy of the Republic of India in RF Dr Sh. Shrotriya (2nd from left) on an excursion to FLNP during his visit to JINR

The Frank Laboratory of Neutron Physics, 21 September. The participants of the scientific seminar with leading employees of the Skolkovo Institute of Science and Technology A. Oganov and D. Semenok

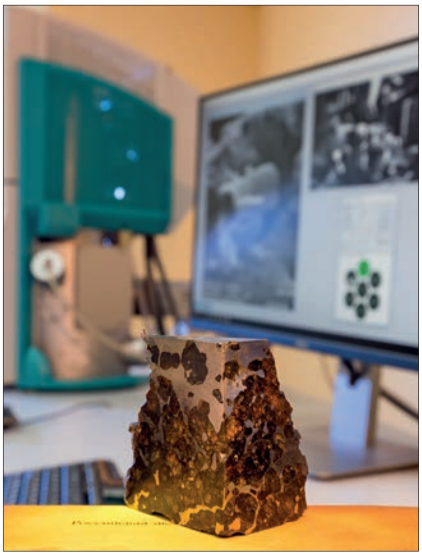
Dubna, 22–23 September. Representatives of the Rosatom State Corporation on an excursion to the Frank Laboratory of Neutron Physics during their visit to JINR

The Laboratory of Information Technologies, 16 September. The scientific and memorial seminar dedicated to the 90th anniversary of the birth of N. Govorun

Dubna, 14 October. A presentation of classrooms of the IT School in the Dubna State University to train specialists in the field of information technologies and for megascience projects of JINR

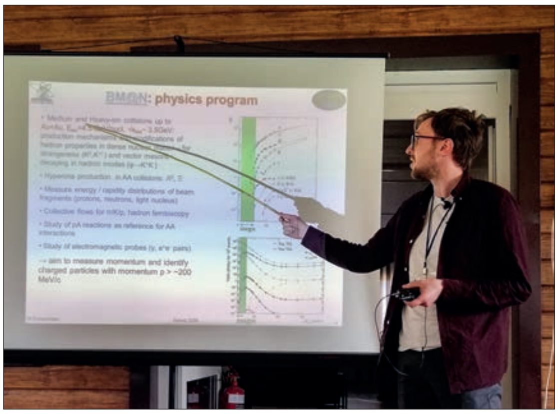
The Laboratory of Information Technologies. The assembly operations on the “Govorun” supercomputer

The Laboratory of Radiation Biology. Analysis of chromosome aberrations using the mFISH method



The Laboratory of Radiation Biology. A stand for studies of the petrified microorganisms in meteorites

The Laboratory of Radiation Biology. Carrying out the histological studies



Lipnya Island, 24–26 July. XXIV Summer School for Young Scientists and Specialists (Lipnya-2020)

Johannesburg (RSA), 9–30 January. Participants of the second JINR–RSA School

Moscow, October. The JINR stand at the jubilee All-Russian Science Festival NAUKA 0+

2020

CENTRAL SERVICES

PUBLISHING DEPARTMENT

In 2020, the Publishing Department issued 43 titles of publications and 35 titles of official documents.

The Proceedings of the XXVII International Seminar on Interaction of Neutrons with Nuclei (ISINN-27) (Dubna, 10–14 June 2019), the Proceedings of the student poster session of the VIII International Pontecorvo Neutrino Physics School (Sinaia, Romania, 1–10 September 2019) and the Book of Abstracts of the international conference “Condensed Matter Research at the IBR-2” (Dubna, 12–16 October 2020) were issued. The JINR Annual Report for the year 2019 (Russian and English versions) and the JINR Long-Term Development Strategy up to 2030 and beyond (in English) were published.

Among the publications issued in 2020 are the collection “Articles on Modern Particle Physics” edited by V. A. Matveev and I. A. Golutvin, the second edition of the book of memories “F. L. Shapiro: A Scientist and a Man”, the book “Vadim Vasilievich Volkov: Warrior. Citizen. Scientist” edited by Yu. Ts. Oganessian and S. N. Dmitriev, the book by Yu. E. Penionzhkevich and E. M. Molchanov “Exotic People and Nuclei. EXON: 30 Years of History”, and a booklet by Yu. A. Shitov, V. B. Brudanin and M. V. Fomina “Amazing Neutrino Transformations”.

In 2020, six issues of the journal “Physics of Elementary Particles and Atomic Nuclei” (brief name “Particles and Nuclei”) that included 125 papers came out. Issue 4 comprises the Proceedings of the international Bogolyubov conference “Problems of Theoretical and Mathematical Physics” (Moscow–Dubna, 9–13 September 2019). Seven issues of the journal “Physics of Elementary Particles and Atomic Nuclei, Letters” (brief name “Particles and Nuclei, Letters”) that included 150 papers were published. Issue 4 comprises the Proceedings of the XIII International Scientific Workshop on Problems of Charged Particle Accelerators in Memory of Professor V. P. Sarantsev (Alushta, Crimea, Russia, 3–8 September 2019).

The information bulletin “JINR News” was continued to be published in Russian and English.

Fifty issues of the JINR weekly newspaper “Dubna: Science, Cooperation, Progress” were published in 2020. A series of booklets “Library of Weekly Newspaper ‘Dubna’ ” was started. Two booklets were issued: “Discovery of Antisigma-Minus Hyperon” by A. A. Kuznetsov and “A. A. Tyapkin: ‘Through the Iron Curtain’. From the History of International Cooperation”.

In the framework of exchange of scientific publications, the organizations in over 40 countries of the world that cooperate with JINR received the following JINR publications: JINR preprints and communications, the information bulletin “JINR News”, JINR Annual Reports, the journals “Particles and Nuclei” and “Particles and Nuclei, Letters”.

The Publishing Department forwarded 62 papers and reports on the results of research conducted by JINR scientists to the editorial boards of journals, to various conferences, symposia, meetings and schools held both in the JINR Member States and in other countries. Papers by JINR staff members were submitted to the journals “Nuclear Physics”, “Bulletin of the Russian Academy of Sciences: Physics”, “Instruments and Experimental Techniques”, “Nuclear Physics and Engineering”, “Crystallography”, “Journal of Surface Investigation. X-Ray, Synchrotron and Neutron Techniques”, and other periodicals.

To keep readers of the Science and Technology Library (STL) timely informed about new publications received, express bulletins of STL are issued by the Publishing Department. “The Bibliographic Index of Papers Published by JINR Staff Members in 2019” was issued. Publication of express bulletins of the Licensing and Intellectual Property Department was continued. The Publishing Department continued uploading the periodical and nonperiodical publications issued at JINR in the database of the Russian Science Citation Index (RSCI) on the platform of Scientific Electronic Library.

At the request of the laboratories and other departments of JINR, the Publishing Department performed binding services and photocopying of scientific-technical and engineering-design documentation. Over 118 thousand various forms were printed.

The printing equipment base was updated. The book sewer SMYTH FX-30, which allows for high durability of issued publications, was put into operation. The following new equipment was purchased: the ROWE engineering system for photocopying and printing large-format documents, Es-Te Fold 3000 folder, as well as monochrome and color A3 MFP.

SCIENCE AND TECHNOLOGY LIBRARY

In 2020, the JINR Science and Technology Library (STL) rendered services to 2000 readers. An electronic loan system has been implemented. 2700 copies of publications were given out. As of 1 January 2021, the library stock amounted to 430 465 copies, 194 686 of them being in foreign languages. 138 publications ordered by readers were received via the interlibrary loan system. 141 requests from other libraries were completed. On the whole, the library received 1640 copies of books, periodicals, preprints and theses from all acquisition sources, including 631 publications in foreign languages. All the new publications were registered in the central catalogues, branch catalogues and in the information system "Absotheque".

128 issues of the express bulletins "Books", "Articles", "Preprints" were published including 6749 titles. Electronic versions of the bulletins are distributed among 100 addresses via e-mail. Subscription is available via the scientific library web site in the section "Services" http://lib.jinr.ru/ntb_mail/newslist.html. The exhibitions of new acquisitions of books, preprints, periodicals and theses were arranged regularly, where 1263 publications were displayed. Five topical exhibitions were organized.

The electronic catalogues of books, journals, articles, preprints and theses are accessible in Internet at the address: http://lib.jinr.ru:80http://lib.jinr.ru:8080/OpacUnicode/80/Opac Unicode. The total number of requests to the electronic catalogues was 15 500. In the electronic catalogue in the personal account the readers can order requested literature and look through their reader's register forms.

"The Bibliographic Index of Papers Published by JINR Staff Members in 2019" (1554 titles) was prepared by the JINR STL and published by the JINR Publishing Department. The Index is available on the library website in the section "Services" http://lib.jinr.ru/buk/2016/bibl_uk.php. One biobibliographic index has been prepared. The database of papers of JINR scientists is Internet accessible.

2400 JINR preprints and communications have been scanned and added to the electronic catalogue.

The STL received 109 titles of periodicals. Due to the Library subscription to the foreign journals, JINR scientists have access to full-text electronic versions of these journals.

Scientific Electronic Library is used by the readers very actively. The total number of requests to the electronic journal versions through Scientific Electronic Library and sites of foreign publishing houses was 150 000. Due to the national electronic subscription of the RFBR, JINR scientists are provided with the electronic access to the full-text versions of journals of the following publishing houses: Elsevier, Springer, American Physical Society, American Institute of Physics, Wiley, IEEE Digital Library as well as journals "Nature", "Science" and information retrieval databases Web of Science, MathSciNet and Scopus.

Within the framework of the project "History of JINR and Dubna in Books, Journals and Central Newspapers", 76 new bibliographic records have been introduced. The information system "Literature about JINR Scientists" (959 records) was put into service which is available on the page of the site of JINR STL "Publications about JINR" http://who-is-who.jinr.ru/catalog3/main.html.

In 2020, in exchange for JINR publications printed by the JINR Publishing Department, the Library received 294 publications from 13 countries. Among them 27 issues were from Russia, 13 from Romania, 5 rom Ukraine, 35 from Moldova, 149 from Germany, 8 from France, 19 from Japan, and 12 from CERN.

In 2020, within the framework of the information system “Absotheque”, the input of documents to electronic catalogue was for: books — 215 titles, journals — 1307 numbers, preprints — 3014 titles, theses and author’s abstracts — 60 titles, book articles – 371 titles, and journal articles — 6698 titles.

As of 1 January 2021, the total number of records in the information system “Absotheque” was 318 579.

On requirements of the JINR Directorate, briefing notes and statistics of indicators of publications activity of JINR scientists and their coauthors from other countries with the usage of Web of Science, Scopus, RSCI have been prepared.

Bibliometric Factors of Publication Activity of JINR Staff Members (by Web of Science Database on 29.01.2021)

JINR publication statistics in 2020 was as follows:

- Total number of publications: 1 260;
- Total number of citations: 1 424;
- Excluding self-citations: 1 084;
- Average citations per article: 1.13;
- h-index: 12.

Joint publications of JINR authors and authors from different countries are presented in Tables 1–3.

Table 1. Joint publications with authors from JINR Member States

State *	Number of publications
Armenia	201
Azerbaijan	160
Belarus	209
Bulgaria	183
Cuba	46
Czech Republic	315
Georgia	170
Kazakhstan	81
Moldova	21
Mongolia	51
Poland	362
Romania	222
Slovakia	185
Ukraine	203
Uzbekistan	28
Vietnam	32

* In alphabetical order.

Table 2. Joint publications with authors from JINR Associate Members

State *	Number of publications
Egypt	122
Germany	451
Hungary	243
Italy	369
Serbia	180
South Africa	144

* In alphabetical order.

Table 3. Joint publications with authors from other states and regions

State / Region *	Number of publications	State / Region *	Number of publications
USA	385	Israel	91
France	341	Ecuador	90
China	315	Lithuania	90
England	308	Estonia	89
Switzerland	290	Ireland	89
Turkey	257	Malaysia	89
Brazil	245	Latvia	88
India	234	New Zealand	88
Austria	224	Qatar	88
Spain	220	Argentina	79
Greece	215	Slovenia	78
Japan	191	Morocco	75
Taiwan	188	Sri Lanka	72
Portugal	187	UAE	71
Sweden	181	Montenegro	65
Australia	175	Palestine	46
Pakistan	170	Indonesia	43
Colombia	168	Peru	43
Netherlands	168	Saudi Arabia	30
South Korea	158	Venezuela	10
Croatia	152	Tajikistan	9
Finland	148	Algeria	3
Mexico	139	Wales	3
Norway	137	Lebanon	2
Thailand	135	Uganda	2
Denmark	122	Bangladesh	1
Canada	113	Botswana	1
Belgium	112	Cameroon	1
Scotland	101	Iraq	1
Iran	94	Laos	1
Chile	93	Nepal	1
Cyprus	93	North Macedonia	1
		Uruguay	1

* In order of decreasing number of publications.

LICENSING AND INTELLECTUAL PROPERTY DEPARTMENT

In 2020, the activities of the Licensing and Intellectual Property Department (LIPD) were conducted in the following areas.

Industrial Intellectual Property Protection. In this area, in cooperation with the Federal Institute of Industrial Property (FIIP) of the Federal Service of the Russian Federation for Intellectual Property (Rospatent), work was done on applications for JINR patents that had undergone the formal FIIP expertise of Rospatent in 2018–2020. Arrangements were done; changes, alterations and clarifications were agreed upon and included in the application documents according to the comments rendered by FIIP experts. Expert evaluation was conducted for a number of project elaborations of JINR staff members for the purpose of patentability, which included objects of legal protection and their classification according to the International Patent Classification (IPC); analogues and prototypes were searched. Reports on patent studies were prepared jointly with laboratory staff; for nine elaborations, in collaboration with the authors, packages of submission documents were prepared and forwarded to RF Rospatent for patents on inventions:

— "Gas-filled detector for small-angle scattering of thermal neutrons" by A. Bogdzel, V. Milkov, Ts. Panteleev;

— "Hybrid pixel detector of ionizing radiations" by D. Kozhevnikov, G. Shelkov, P. Smolyanskij;

— "Method of forming equilibrium trajectories of particles in a cyclic accelerator with a constant radius of an orbit" by G. Dolbilov;

— "Induction synchrotron magnetic system with magnetic field constant in time" by G. Dolbilov;

— "Method for prediction of risk of developing diseases associated with level of immunoglobulin E (IgE) in human blood serum" by A. Ivanova, A. Rusakovich, E. Kravchenko;

— "Solid-state capacitor-ionistor with dielectric layer made of dielectric nanopowder" by A. Doroshkevich, A. Shilo, T. Zelenyak, T. Konstantinova, A. Lyubchik, A. Tatarinova, E. Gridina, N. Doroshkevich;

— "Device for measuring angles of inclination of surface" by Yu. Budagov, M. Lyablin;

— "Device for resonance charge of capacitor" by S. Dolya, V. Smirnov.

Three computer programs were registered in Rospatent:

— "Structural nanopowders analyzer based on small-angle scattering data" by A. Nezvanov;

— "Control system of the cryogenic moderator of the IBR-2 reactor" by T. Petukhova;

— "Program of adjusting neutron reectometers ICE" by A. Kirilov, I. Gapon.

In 2020, 80 JINR patents were supported.

Patents and Information. In 2020, 36 issues of the bulletin "Inventions. Utility Models" of the federal state institution "Federal Institute of Industrial Property" were received at JINR. The information published in the bulletin was processed according to JINR topics. The processing results were presented in 12 issues of the LIPD bulletins "Patents", which were sent to subscribers of the Institute in both electronic and paper format. The electronic database of LIPD bulletins is also available on the department website (https://oliis.jinr.ru/).

Information lists of LIPD are produced on obtaining new patents by the Institute and state registration of objects of industrial intellectual property. This information is regularly included in the chapter "Patents" on the JINR website (http://www.jinr.ru/posts/category/patents-ru/). The LIPD page on the JINR website is updated.

Standardization. Standard library was supplemented: 21 new intergovernmental and state RF standard documents, 12 GOST directories and standard information directories for 2020; directories of national standards and technical conditions, guidelines, recommendations and regulations issued in 2020. Twenty-five alterations were introduced in relevant documents of the standard library files and subscribers' copies on the basis of these norm documents (NDs). Thirteen GOST official copies were distributed in departments for permanent use. Information about new NDs and alterations in them was regularly distributed to departments.

The database and automatic search for NDs, which is in the collection of the LIPD library, was updated. The access is supported to the database of the standards library that contains about 11 600 positions on the LIPD internet page.

"The Index of Norm Acts and Norm Documents Used by the Joint Institute for Nuclear Research to Exercise Activities in Use of Atomic Energy" (JINR Index AE-2017) was updated as of 1 January 2021. The current version is posted on the LIPD site.

Information on technical regulations in force in Russia, intergovernmental standard documents (GOST), Russian National Standard (GOST R) and other regulatory and technical documentation in force at the Joint Institute for Nuclear Research were updated as of 2020.

2020

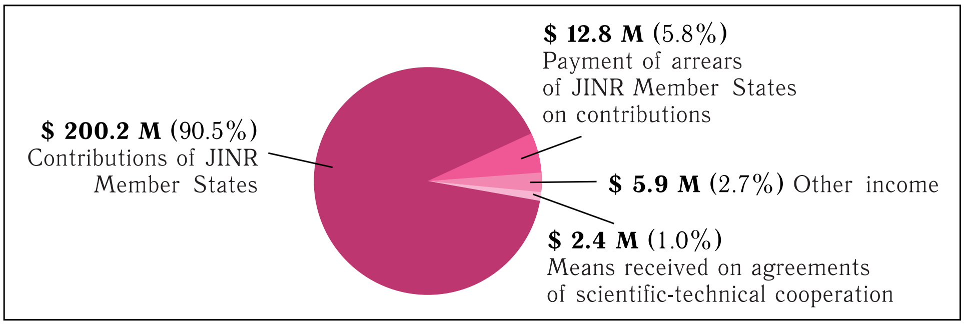
ADMINISTRATIVE ACTIVITIES

JINR

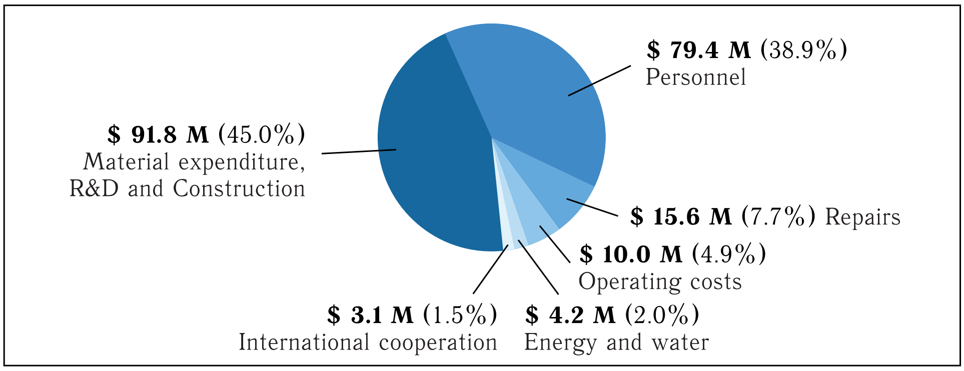
JOINT INSTITUTE FOR NUCLEAR RESEARCH

FINANCIAL ACTIVITIES

Execution of the JINR budget in 2020 in incomings in total **221.3 million US dollars**



Execution of the JINR budget in 2020 in expenditure in total **204.1 million US dollars**



Scale (in %) of contributions of JINR Member States in 2020

State	%	State	%
Republic of Armenia	0.13	Republic of Moldova	0.07
Republic of Azerbaijan	0.35	Mongolia	0.09
Republic of Belarus	0.83	Republic of Poland	5.01
Republic of Bulgaria	0.80	Romania	1.69
Republic of Cuba	0.64	Russian Federation	80.86
Czech Republic	2.73	Slovak Republic	1.59
Georgia	0.16	Ukraine	1.72
Republic of Kazakhstan	1.51	Republic of Uzbekistan	0.58
Democratic People's Republic of Korea	0.25	Socialist Republic of Vietnam	0.99
		Total:	100.00

STAFF

As of 1 January 2021, the total number of the staff members at the Joint Institute for Nuclear Research was 5215.

Working at JINR are: RAS Academicians V. Matveev, I. Meshkov, Yu. Oganessian, M. Ostrovsky, G. Trubnikov, B. Sharkov; RAS Corresponding Members V. Aksenov, L. Grigorenko, D. Kazakov, V. Kekelidze, E. Krasavin, A. Starobinsky, G. Shirkov; Members of other state Academies of Sciences I. Zvara, G. Zinoviev, B. Yuldashev, O. Chuluunbaatar; 50 Professors, 26 Assistant Professors, 236 Doctors of Science, and 620 Candidates of Science.

In 2020, 372 people were employed and 333 people were discharged because of engagement period expiry and for other reasons.

AWARDS

For the services for JINR and international cooperation the Honorary Diploma of RAS was awarded to 1 staff member; the Honorary Diploma of the Mayor of the Dubna city was awarded to 7 staff members; the JINR Honorary Diploma was awarded to 5 staff members; the JINR Honorary Certificate was awarded to 7 staff members; the title “Honorary JINR Staff Member” was conferred on 1 staff member.

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2021-10

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