2019

JOINT INSTITUTE FOR NUCLEAR RESEARCH

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 2019 in the life of the Joint Institute for Nuclear Research will be remembered for many bright events and achievements. By all accounts, the last year was most successful in modern history of JINR. The Institute took an active part in the celebration of the International Year of the Periodic Table of Chemical Elements that further strengthened the prestige of JINR in the world and confirmed its leading position in the field of synthesis of superheavy elements. Activities in priority topics of the Seven-Year Plan were conducted according to the plans. They are the megaproject of the research complex NICA, commissioning of the Factory of Superheavy Elements, the development of the neutrino telescope Baikal-GVD, and the launch of the second phase of the "Govorun" supercomputer. There are also other projects whose success was achieved by the international community of the Joint Institute.

This success would be impossible without an important component of the BLTP activities in theoretical support of experimental research at JINR and other research centres with the participation of JINR, that is a major part of studies conducted by theoreticians of the Institute. The research resulted in about 480 publications in peer-reviewed journals and proceedings of international conferences and four monographs. Most of the results were obtained in cooperation with scientists from the JINR Member States and other countries.

In the implementation of the flagship scientific projects of JINR, in particular, the megascience project "The NICA complex", considerable progress was achieved in the development of the basic configuration of the complex. With the assembling finished, step-by-step testing and launch are performed of the superconducting ring accelerator — the Booster. It is one of the most important phases, as not only the development of the accelerator is discussed but also the work-out of essentially new technologies, design solutions and engineer approaches. All elements of the magnetic-cryostat system are produced at JINR according to a unique technique that is acknowledged in Europe. A complex of high-technology systems manufactured with participation of leading Russian and foreign companies and institutes will provide the operation of the accelerator and high-quality beam shaping.

First physical results on the production of hyperons ("strange" baryons) were obtained at the BM@N facility in the experiment aimed at studying properties of superdense nuclear matter in collisions of high-energy heavy ions, whose beams will be provided by the Booster and Nuclotron complex accelerators (NICA megascience project).

The experiment is represented by the international collaboration of 11 countries, including Germany, France, the United States, and Israel. During the run, hundreds of millions of interactions of carbon, argon and krypton ions with targets from carbon to lead were collected on the extracted Nuclotron beams.

A unique accelerator complex "Factory of Superheavy Elements" (SHE Factory) was commissioned in 2019. The preparations for the first experiment on the synthesis of the isotopes of element 115 (moscovium) were finalized. The experiment summarizes the results of JINR's long-standing work in creating and commissioning the SHE Factory and aims at showing the complex ready for the long-term research programme on the synthesis of elements 119 and 120 — the first elements of the 8th row of the Mendeleev Periodic Table — and the study of the nuclear and chemical properties of new elements.

Another achievement of 2019 is the construction of the fourth and fifth clusters of the deep underwater detector in Lake Baikal as the next step to full-scale Baikal-GVD detector. With their introduction, the effective volume of the Baikal-GVD telescope achieved the value of 0.25 km^3 in the task of registration of showers from high-energy neutrino of astrophysical origin that is about 0.6 of the effective volume of the IceCube detector in the Antarctic. Preliminary data analysis for 2016–2018 and, partially, for 2019 years for the search allows one to select first six events with energies above $\sim$ 100 TeV, where astrophysical neutrino flux exceeds background atmospheric one. The work to develop the telescope is conducted in cooperation of our Institute, institutes of the Russian Academy of Sciences and foreign scientific centres.

The Institute staff members developed a unique device — Precision Laser Inclinometer — to monitor the angular microseismic activity. Its construction is based on the application of the most modern elements of physics — laser radiation, quantum phenomenon, and gravitation interaction. It is in high demand for the search of gravitation waves. In 2019, in the European megaproject VIRGO on the search of gravitation waves first successful results were obtained of the efficient application of the Precision Laser Inclinometer.

The international user programme was continued to be implemented at neutron beams of the pulsed reactor IBR-2. It should be mentioned that the success of this programme opens a wide opportunity of joint work in the world and determines the quality of neutron spectrometers of JINR whose fleet is regularly upgraded.

In 2019, IBR-2 completed eight cycles that comprised 2680 h of work for experiment. The new cryogenic moderator and reactivity modulator were installed in the proper location. Work was finished to develop a unique facility — the magnet on the basis of high-temperature superconductivity with the closed-loop cryocooler cooling. The IREN facility reached the level above 100 MeV. Studies of objects of cultural heritage with nuclear physics methods are conducted at it, and these studies fall in with world trends. Besides, the project of a new neutron pulsed source of the fourth generation is continued to be developed. The partnership with leading scientific organizations, in particular, with ROSATOM, is very important here.

Nowadays it is impossible to solve most complex resource-intensive tasks without the development of high-productive capabilities and modern computer architectures that allow one to considerably accelerate the work with big volumes of experimental data. In this direction one more important step is made at the Institute — the second phase of the supercomputer "Govorun" was commissioned. The modernization lead to an increase in capacity by three times that put the supercomputer in the tenth place in the list of TOP 50 most powerful supercomputers in CIS countries.

In the field of advanced radiobiological research, a group of specialists from JINR and A. F. Tsyb MRRC performed pre-clinical *in vivo* studies of a new method of increasing the biological effectiveness of accelerated protons in the treatment of tumors. The patent has been obtained for a new method of enhancing the radiation effect on living cells. A method of obtaining neuron cultures of different parts of the rat brain has been developed, whereby it is possible to study the formation of ionizing radiation-induced DNA damage in neurons. The use of a neuron culture allows modeling the interactions and reactions of cells of different types in response to radiation exposure. In experiments with proton and γ-ray exposure, DNA double-strand break formation in cerebellar and hippocampal neurons has been studied using immunohistochemical methods.

The considerable progress in the development of the educational programme of the Institute and in the field of the training of specialists should not go unnoticed thanks to the fruitful work of the JINR University Centre with young scientists, students and postgraduates from many countries, as well as students and teachers of physics. In 2019, about 500 students of the JINR-based departments of MSU, MIPT, MEPhI, Dubna State University and universities of the JINR Member States were trained at the University Centre. Students from the universities of Armenia, Azerbaijan, Belarus, Bulgaria, Cuba, Egypt, Italy, Kazakhstan, Mexico, the Netherlands, Poland, Romania, the Russian Federation, Serbia, Slovakia, Ukraine and Uzbekistan took part in summer training programmes and industrial practices.

From 1 September 2019, Dissertation Councils were launched at JINR operating due to the right to award academic degrees independently in the Russian Federation. A specialized international competition for JINR fellows has been launched. These actions will undoubtedly contribute to further attracting young scientists from the JINR Member States and other countries to the Institute — specialists who are ready to bring fresh ideas and suggest new approaches to the ongoing research and create a new atmosphere of scientific search.

A revolutionary new stage has been achieved in the development of the long-term partnership between the Institute and the Rosatom State Corporation. In December, the joint meeting of the Presidium of the Science and Technology Council of Rosatom and the dilated JINR Directorate took place. During this meeting, a Cooperation Agreement on partnership interaction in some issues of leading scientific projects, including the development of the NICA collider complex, the SHE Factory, the use of the IBR-2 pulsed reactor and the development of a new pulsed reactor facility in Dubna, was signed.

Among the significant results of the year, it is necessary to note the expansion of the international relations and prospects of the JINR cooperation with the line ministries of the Republic of Armenia, the Republic of Poland, the Republic of Cuba, the Republic of Serbia, with the National Academy of Sciences of the Republic of Belarus, scientific organizations of the Socialist Republic of Vietnam, the People's Republic of China and the Republic of Korea, joining partners from the United Mexican States to the NICA project, as well as the strengthening of partnership relations with the Federal Republic of Germany.

The last year was also remembered for a number of significant anniversaries that play an important role in the history of the development of not only the Institute but also the world science as a whole. The international Bogoliubov conference "Problems of Theoretical and Mathematical Physics" was dedicated to the 110th anniversary of the birth of Academician Nikolai Bogoliubov (1909–1992), an outstanding scientist, mathematician and physicist. The Institute cel-

ebrated the 110th anniversary of the birth of Vaclav Votruba (1909–1990), a member of the Czech Academy of Sciences, the first Vice-Director of JINR.

On 20 December, in the ceremonial meeting dedicated to the 70th anniversary of the first launch of the JINR Synchrocyclotron, heroic creators of the Synchrocyclotron and all veterans of the Dzhelepov Laboratory of Nuclear Problems were honored. The history of JINR establishment, all achieved and world-recognized results of its scientific staff, considerable experience accumulated in the fields of nuclear physics, high-energy physics, condensed matter physics — all this is closely connected with the launch and long-term successful operation of the Synchrocyclotron in Dubna.

Another glorious event was the 70th anniversary of the Blokhintsev Universal Public Library of JINR, which completely confirms the fact that cities grow and develop around libraries and universities.

The planned programme for the development of JINR infrastructure, solving social issues, improving the employees' living conditions of the Institute and visiting colleagues was carried out. In particular, the reconstruction of the dormitory in Moscovskaya St., 2, which is one of the symbols of the JINR side of Dubna, is in progress at full pelt.

On behalf of the JINR Directorate, I would like to express my deep gratitude to the Russian Government, which completely fulfills its responsibilities to JINR, and to the Governments of the JINR Member States for supporting the Institute. In store, there is very large and important work on the most important tasks of the Institute in the JINR Seven-Year Plan; on the implementation of its ambitious megascience projects; on the development of a Strategy for Long-Term Development of JINR till 2030 and on; on the obtaining new scientific results in breakthrough areas of fundamental physics — this is the work on which the future of our international centre largely depends.

V. MATVEEV
Director
Joint Institute for
Nuclear Research

2019

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 25–26 March. It was chaired by the Plenipotentiary of the Government of the Russian Federation, M. Kotyukov.

Based on the report presented by JINR Director V. Matveev, the Committee of Plenipotentiaries (CP) noted with satisfaction the achievement of important milestones in the development of JINR's flagship programmes, in particular:

— the formation of managing bodies of the MPD and BM@N international collaborations established for conducting research at the NICA accelerator complex, organization of a targeted competition by the Russian Foundation for Basic Research for the best projects on "Megascience–NICA", and holding of the third meeting of the Supervisory Board of the NICA complex project established under the Agreement between the Government of the Russian Federation and JINR;

— the completion of one of the most important stages of construction of the Factory of Superheavy Elements associated with the commissioning of the DC-280 cyclotron and with the production of the first beam of accelerated heavy ions at this new basic facility of JINR;

— the adoption of measures aimed at improving the coordination of the JINR Neutrino Physics Programme in terms of implementing priorities between the ongoing neutrino experiments, as well as the continuation of construction of two new clusters of the Baikal-GVD detector;

— the formation of two possible concepts for the future neutron source at JINR along with the maintenance of the operational conditions of the IBR-2 reactor and the continuous improvement of the spectrometers within the FLNP User Programme;

— the update of the JINR external network infrastructure and the start of the active use of the "Govorun" supercomputer by JINR Laboratories.

The CP also noted:

— the significant level of JINR's representation in the cornerstone programme of the International Year of the Periodic Table of Chemical Elements, which contributes to enhancing the awareness of the international community about JINR's achievements in the field of the synthesis of superheavy elements;

— the efforts of the JINR Directorate aimed at implementing JINR's right to independently confer academic degrees, the organization of a specialized international competition for JINR fellows, and the establishment of the Dubna School of Engineering based at Dubna State University;

— the work carried out by the JINR Directorate to prepare a Regulation on research and educational programmes for JINR's cooperation with scientific organizations and universities of the JINR Member States;

— the signing of the Roadmap for scientific cooperation between the Federal Republic of Germany and the Russian Federation, as well as the readiness of German partners to continue their participation in the construction of the NICA complex;

— the signing of the framework agreement on cooperation between GSI, FAIR and JINR, as well as of the Roadmap for the development of the cooperation between the Arab Republic of Egypt and JINR; the expansion of scientific and technological ties with the French Republic and the Republic of Korea;

— the relevance of the objective to elevate the status of the Italian Republic and the Republic of Serbia in JINR.

The CP endorsed the inclusion of the task of constructing the basic configuration of the NICA accelerator complex in the Russian national project "Science" and took note of JINR's obligations related to participation in this project.

The CP commissioned the JINR Directorate to present a draft Strategic Plan for the Long-Term Development of JINR at the CP's session in November 2019,

aa well as to prepare and submit to the CP's session in March 2020 a report on the progress of implementation of the Seven-Year Plan for the Development of JINR for 2017–2023 and the proposals for its update.

The CP supported the measures proposed by the JINR Directorate for the innovative development of JINR. It commissioned the Directorate, within the framework of the JINR innovation policy, to prepare a project for the use in the interests of the JINR Member States of new innovative tools, including innovation science and technology centres proposed by the Russian Federation in the national project "Science", the State Programme for the Development of Science and Technology and in other regulatory acts.

The CP granted JINR Director V. Matveev the right to extend the terms of office or to assign temporary duties of JINR Vice-Directors, including to other persons, until their official approval by the Committee of Plenipotentiaries. It commissioned the JINR Director to report at the CP's session in November 2019 on the measures taken to form the JINR Directorate in accordance with the established procedure.

Regarding the report "Implementation of the JINR budget for 2018 and draft of the revised budget of JINR for 2019" presented by M. Vasilyev, Deputy Head of the JINR Finance and Economy Office, the CP took note of the information on the implementation of the JINR budget for 2018, approved the consolidated final adjustment of the JINR budget expenditure for 2018 and the revised budget of JINR for 2019 with the total income and expenditure amounting to US$289 790.2 thousand.

Regarding the report "Construction and exploitation of the NICA complex of superconducting rings for heavy-ion colliding beams, implementation of the budget within the framework of the Agreement between the Government of the Russian Federation and JINR, and draft of the revised budget for 2019" presented by VBLHEP Director V. Kekelidze, the CP took note of the analysis of implementation of the schedule of the NICA complex project. The Committee noted that work was being carried out actively and was continuously monitored by the Directorates of VBLHEP and JINR. It welcomed the achievement of the first goal of the project — the launching of the BM@N experimental setup with extracted beams.

The CP endorsed the report on the use of the budget funds of JINR and of the special-purpose funds of the Russian Federation, provided 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 period until 2018 inclusive, and approved the revised budget for the use of these special-purpose funds for 2019 in the amount of 3 711 471.1 thousand rubles.

As recommended by the Supervisory Board of the NICA complex project, the CP approved the scheme of distribution of the basic financial expenses for the realization of the basic configuration of the NICA complex project, taking into account the funding from the federal project "Development of Advanced Infrastructure for Research and Development in the Russian Federation" of the national project of the Russian Federation "Science", allocated in 2019 from the budget of Russia.

The Committee noted the need to intensify the work on the NICA complex project in order to fully and timely accomplish its goals, taking into account the requirements of the federal project "Development of Advanced Infrastructure for Research and Development in the Russian Federation".

Regarding the report "Results of the meeting of the JINR Finance Committee held on 22–23 March 2019" presented by A. Khvedelidze, Plenipotentiary of the Government of Georgia to JINR, the CP approved the Protocol of this meeting. It commissioned the JINR Directorate and the Working Group under the CP Chairman for JINR Financial Issues to submit for consideration at the meeting of the Finance Committee and for approval at the CP's session in November 2019 an updated draft Procedure for the offset of costs of supplies of equipment, instruments, materials, services and individual work on the Institute's orders against payments of JINR Member States' contributions, as well as a new version of the Regulation for the JINR staff.

The CP commissioned the JINR Directorate to prepare an updated draft Regulation on research and educational programmes for the JINR's cooperation with scientific organizations and universities of the JINR Member States, taking into account the comments and suggestions to be made by members of the Working Group, for consideration at the meeting of the Working Group in October 2019.

Regarding the report "Proposals of the Finance Committee for the selection of an organization for auditing JINR's financial activities for 2018" presented by A. Khvedelidze, the CP approved the plan for auditing JINR's financial activities for 2018 as presented by the JINR Directorate. The Committee approved the LLC AC "Korsakov and Partners" as JINR's auditor for 2018, authorizing it to conduct an audit of the Institute's financial activities for the specified period and to analyze the implementation by the JINR Directorate of the Plan of measures on the follow-up of the audit of JINR's financial activities for 2017.

Regarding the report "Status of the Baikal-GVD project" presented by D. Naumov, Deputy Director of the Dzhelepov Laboratory of Nuclear Problems, the CP took note of the progress of work for the project "Baikal neutrino telescope" which is under way according to schedule. Noting the installation of three clusters with a total number of 864 optical modules during 2016–2018, which has made this facility the largest neutrino telescope in the Northern Hemisphere, as well as the continuous work to update the infrastructure of the experiment, the Committee welcomed DLNP's plans to

install two more clusters in 2019 and to commission the first phase of the Baikal neutrino telescope in 2021.

Regarding the report "Status of the Factory of Superheavy Elements" presented by S. Dmitriev, Director of the Flerov Laboratory of Nuclear Reactions, the CP took note of the progress of work on the Factory of Superheavy Elements (SHE) which is proceeding according to schedule, noted the obtaining from the Federal Environmental, Industrial and Nuclear Supervision Service of the Russian Federation of a certificate of compliance of the constructed object with the requirements of technical regulations, and congratulated the FLNR staff on the production and extraction of the first beam of heavy ions at the DC-280 cyclotron.

The CP endorsed FLNR's most important tasks for the SHE Factory as follows: production of heavy-ion beams with design parameters, commissioning work and start-up of the GFS-2 gas-filled recoil separator, preparation and conduct of first-day experiments on the synthesis of moscovium isotopes in the ^{48}Ca + ^{243}Am reaction as well as of experiments on the synthesis of new element 120 in the ^{50}Ti + $^{249-251}$Cf reaction.

In connection with the inauguration of the experimental building of the Factory of Superheavy Elements at FLNR and with the launching of the Factory's main facility — the DC-280 cyclotron, the CP highly appreciated the successful completion of the major stage in the construction of this unique accelerator complex aimed at obtaining breakthrough results in the field of the synthesis and study of properties of new superheavy elements as well as the scientific and technological quality of the realization of the project to build the DC-280 cyclotron and the participation in it of most Member States of JINR. The CP congratulated the JINR Directorate and staff on the launching of this new basic facility at the Institute.

The CP commissioned the JINR Directorate to study the issue of establishing a Prize of the JINR Committee of Plenipotentiaries to award creative teams of JINR staff for ideas of conceiving, developing and implementing large-scale projects of the Institute, executed at the highest world standards.

The CP supported the proposal by the JINR Directorate and the Plenipotentiary of the Government of the Socialist Republic of Vietnam to conduct the next meeting of the Finance Committee and the next session of the CP in Hanoi (Vietnam).

A regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States was held in Hanoi on 25–26 November. It was chaired by the Plenipotentiary of the Government of the Russian Federation, M. Kotyukov.

Having heard the report presented by JINR Director V. Matveev, the CP took note of the recommendations of the 126th session of the JINR Scientific Council, of the information presented by the JINR Directorate on the progress of implementation of the JINR Plan of Research and International Cooperation in 2019 and on the plans for JINR activities for 2020.

The CP commended the work done by the JINR Directorate on implementing the megascience project "NICA complex". It noted, in particular:

— the completion of the main systems of the Booster synchrotron and of the fabrication of the yoke of the solenoidal magnet for the MPD detector;

— the commissioning of the updated computer cluster at VBLHEP for the challenges of the NICA complex;

— the first physics results produced in the BM@N experiment at the NICA complex;

— the holding of the meetings of the MPD and BM@N Collaborations of the NICA complex, which discussed the physics programmes of the MPD and BM@N experiments, and progress in detector subsystems work and in the analysis of experimental data.

The CP commissioned the JINR Directorate to establish an International Committee for the analysis of the expenditure and schedule for implementing the NICA complex project and to submit the results of the accomplished analysis of the project's implementation including recommendations to the JINR Directorate at the CP session in March 2020.

The CP took note of the obtaining of the permission issued by the Ministry of Housing Policy of Moscow Region to commission the experimental building of the Factory of Superheavy Elements (SHE) and of the Sanitary and Epidemiological Conclusion on the compliance of the Factory's facilities with radiation safety requirements. It also endorsed the plans of first experiments at the SHE Factory.

The CP acknowledged an active participation of JINR in the cornerstone events dedicated to the International Year of the Periodic Table of Chemical Elements.

The CP took note of the successful continuation of work on the construction of the Baikal deep underwater neutrino telescope, Baikal-GVD, in particular, the commissioning of two new clusters of the neutrino detector, the effective volume of which has now reached ~ 0.25 km^3. It welcomed the preparation of a draft Agreement between the Ministry of Science and Higher Education of the Russian Federation and JINR on cooperation and joint work on the construction of the Baikal-GVD neutrino telescope, and on participation in experimental studies in the fields of high-energy neutrino astrophysics, neutrino astronomy, and neutrino physics.

The CP endorsed the further development of the JINR neutrino experiments at the Kalinin Nuclear Power Plant. It also acknowledged the new results achieved in condensed matter physics studies with the IBR-2 spectrometer complex, as well as the development of the concept of a new, fourth-generation neutron source for JINR.

Taking note of the information about the decision of the Government of the Republic of Uzbekistan to resume full participation in JINR and its readiness to

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	– M. Kotyukov
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

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
P. Fré	– Italian Republic
S. Galès	– French Republic
P. Giubellino	– Federal Republic of Germany
B. Grynyov	– Ukraine
M. Hnatič	– Slovak Republic
M. Jeżabek	– 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
Trần Đức Thiệp	– 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
Not appointed	– Democratic People's Republic of Korea

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
Vice-Director M. Itkis
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 E. Krasavin

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. Dmitriev

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

fully implement its obligations in accordance with the JINR Charter, as well as about the appointment of the Plenipotentiary of the Government of the Republic of Uzbekistan to JINR, the CP recommended that the Plenipotentiary of the Government of the Republic of Uzbekistan submit, for consideration at the CP session in March 2020, his proposals on financial terms for resuming the full participation of the Republic of Uzbekistan in JINR.

The CP welcomed the enactment at JINR of new dissertation councils on the basis of JINR's right to independently confer academic degrees, as well as the launch of a specialized international competition for JINR fellows, which will contribute to further attracting young scientists to JINR from the JINR Member States and other countries.

The CP welcomed the strengthening of partnership with the Federal Republic of Germany, the signing of the Roadmap for cooperation with the Ministry of Education, Science and Technological Development of the Republic of Serbia, and the efforts of the JINR Directorate towards enhancing international cooperation, in particular, the accession of partners from the United Mexican States to the NICA project.

The Committee commissioned the JINR Directorate to study the possibility of associate membership in JINR and to submit relevant proposals for consideration at the CP session. For the preparation of a draft document, it was proposed to establish a Working Group of representatives of the Republic of Bulgaria, the Czech Republic, the Republic of Kazakhstan, the Republic of Poland, Romania, and the Russian Federation as well as to invite a CERN representative as a consultant.

Based on the report "Draft Budget of JINR for the year 2020, draft contributions of the Member States for the years 2021, 2022, and 2023" presented by M. Vasilyev, Deputy Head of the JINR Finance and Economy Office, the CP resolved, prior to revising the JINR budget for 2020 at the CP session in March 2020, taking into account the proposals of the JINR Directorate for amending the remuneration system, to set the personnel costs at the budget level of 2019 in the amount of US$84.8 million. The variation between the personnel costs in the draft budget for 2020 and in the JINR budget for 2019 in the amount of US$10.7 million is carried forward to the expenses under the consolidated item "Material costs" of the budget for 2020. The CP also commissioned the JINR Directorate when revising the budget to submit proposals for modifying approaches to the budgeting process for consideration at the Finance Committee meeting and the CP session, taking into account the forecasting of results of cash execution of the budget and ensuring the uniformity of expenditure.

The CP approved the JINR budget for 2020 with the total income and expenditure amounting to US$218 713.9 thousand, the scale of contributions and the contributions of the JINR Member States for 2020, as well as the repayment of contributions arrears of Member States to the JINR budget for 2020.

The CP commissioned the JINR Directorate to submit for consideration at the CP session in March 2020 an analysis of the salaries by personnel category and proposals to ensure a competitive level of remuneration for JINR's highly qualified staff, providing for the dependence of salary payments on employees' performance.

The CP determined the provisional volumes of the JINR budget in income and expenditure for the year 2021 amounting to US$212.24 million and for the year 2022 amounting to US$217.33 million, as well as the provisional amounts of the Member States' contributions for 2021 and 2022. The Committee took note of the provisional volume of the JINR budget in income and expenditure for the year 2023 amounting to US$222.67 million and of the provisional amounts of the Member States' contributions for 2023.

The CP endorsed the consolidated adjustment of the JINR budget for the year 2019 over nine months. It also allowed the JINR Directorate to index the salary and tariff parts of the compensation package of the staff members, taking into account the opportunities afforded by the JINR budget in 2020, in accordance with the JINR Collective Bargaining Agreement for 2017–2020.

Following the report "Draft budget for the use of the special-purpose funds of the Russian Federation provided 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 2020" presented by VBLHEP Director V. Kekelidze and JINR Vice-Director R. Lednický, the CP approved the budget for the use of the special-purpose funds of the Russian Federation allocated in accordance with this Agreement in the amount of 5 003 911.0 thousand rubles.

Following the report "Draft Strategic Plan for the Long-Term Development of JINR" presented by JINR Director V. Matveev and Vice-Director B. Sharkov, the CP commissioned the JINR Directorate to prepare and submit for consideration at the CP session in March 2020 a single, integrated document based on the materials presented by the thematic subgroups describing the overall strategy with its flagship projects and partnership priorities.

Following the report "Results of the meeting of the JINR Finance Committee held on 21–22 November 2019" presented by S. Harizanova, Chair of the Finance Committee, the CP approved the Protocol of the meeting and the Procedure for setting off the costs of procurement of equipment, instruments, materials, services and individual work on JINR's orders against the payment of contributions of the JINR Member States.

Based on the discussion of the issue "Draft Staff Regulations of JINR", the CP commissioned the JINR Directorate to prepare and submit for consideration at the Finance Committee meeting and at the CP session in March 2020 the Staff Regulations of JINR, taking into account the proposals of the JINR Directorate for ensuring a competitive salary level for JINR's highly qualified staff. If necessary, it commissioned to submit proposals for appropriate adjustments to the JINR budget for consideration at the Finance Committee meeting and at the CP session.

Regarding the issue "Results of the audit of JINR's financial activities performed for the year 2018", the CP approved the Auditors' Report and the Accounting Report of JINR for the year 2018.

Based on the information "Changes proposed to the membership of the JINR Scientific Council" presented by JINR Director V. Matveev, the CP took note of the inclusion in the Scientific Council of B. Yuldashev (Academy of Sciences of the Republic of Uzbekistan), appointed the Plenipotentiary of the Government of the Republic of Uzbekistan, and invited U. Bassler (IN2P3 CNRS, France and CERN, Switzerland) and A.-I. Etienvre (IRFU CEA, Saclay, France) to become members of the JINR Scientific Council.

Having heard the information "Measures being taken for staffing the JINR Directorate" presented by JINR Director V. Matveev, the CP took note of the search for promising candidates to be recruited as members of the JINR Directorate with a view to rejuvenating it and being more prepared for active work to implement the ambitious goals of the Seven-Year Plan for the Development of JINR for 2017–2023, including in the context of the preparation of the Strategic Plan for the Long-Term Development of JINR until 2030. The Committee accepted the proposal by JINR Director V. Matveev to put into practice scheduling the election of the JINR Director at the CP March session of the year preceding the year of completion of the office of the current Director.

The CP supported the proposal by JINR Director V. Matveev to invite the First Deputy Minister of Science and Higher Education of the Russian Federation, G. Trubnikov, to the position of the First Vice-Director of JINR with the assignment to him of the mandate and responsibility for preparing the programme for the future development of the Institute, for heading the management of the NICA megaproject, and for implementing the coordination functions of JINR Administrative Director until his approval for this position in accordance with JINR's rules by the JINR Committee of Plenipotentiaries in March 2020.

The CP took note of the proposal by JINR Director V. Matveev on the readiness of the JINR Directorate to promote the nomination of G. Trubnikov for the position of JINR Director in the next election of the Director taking into account his knowledge and experience, as well as the statement of the Plenipotentiary of the Government of the Russian Federation, M. Kotyukov, about his readiness, in accordance with the JINR Charter, to nominate G. Trubnikov to the position of Director of JINR in the next election.

The CP heard the report "Current status of R&D in the atomic energy field and the project of a research reactor in Vietnam" presented by Trần Chí Thành, President of the Vietnam Atomic Energy Institute (VINATOM), and supported the proposal by the JINR Director to establish a Working Group to develop a plan of cooperation between VINATOM and JINR for implementing the project of a new research reactor in Vietnam.

The CP also heard the report "Vietnam Academy of Science and Technology today and tomorrow" presented by Trần Tuấn Anh, Vice-President of the Vietnam Academy of Science and Technology.

SESSIONS OF THE JINR SCIENTIFIC COUNCIL

The 125th session of the JINR Scientific Council took place on 21–22 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 recent highlights of JINR development, the progress in implementing JINR's flagship programmes, the decisions of the latest session of the JINR Committee of Plenipotentiaries (November 2018), and events in JINR's international cooperation.

The Scientific Council took note of the analysis of implementation of the schedules of realization of JINR's flagship projects presented in the reports by VBLHEP Director V. Kekelidze (NICA), FLNR Director S. Dmitriev (SHE Factory), and by DLNP Deputy Director D. Naumov (Baikal-GVD). The Scientific Council heard information presented by FLNP Director V. Shvetsov about the progress of the joint work being done by the Jagiellonian University in Kraków (Poland) and the Frank Laboratory of Neutron Physics to develop the concept for and establish a Laboratory for Structural Research of Macromolecules and New Materials (SOLCRYS) at the SOLARIS National Synchrotron Radiation Centre of the Jagiellonian University.

The Scientific Council also heard the report "Exawatt science" presented by the President of the Russian Academy of Sciences, A. Sergeev.

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 award of the V. Dzhelepov Prize took place at the session, and diplomas were presented to the winners of JINR prizes for the year 2018. The Jury's recommendation on the award of the B. Pontecorvo Prize was approved. The Scientific Council heard the best reports by young scientists as recommended by the PACs.

The appointments of Deputy Directors of DLNP and LIT were endorsed. Vacancies of positions in the Directorates of JINR Laboratories were announced.

General Considerations of the Resolution. The Scientific Council took note of the comprehensive report by JINR Director V. Matveev and appreciated the milestones achieved in the development of JINR's flagship programmes, in particular:

— the establishment of international collaborations for the MPD and BM@N experiments, organization of two meetings of these collaborations, and holding of a targeted competition on "Megascience–NICA" for grants of the Russian Foundation for Basic Research, which contributes to attracting a wide international community, including Russian institutions, to the realization of the NICA project;

— the production of the first beam of accelerated heavy ions at the DC-280 cyclotron, which indicates the emergence of JINR's new basic facility as the core part of the Factory of Superheavy Elements;

— the implementation of priorities between all ongoing neutrino experiments aimed at improving the coordination of the JINR Neutrino Physics Programme and the continuing development of the Baikal-GVD detector;

— the maintenance of the operational conditions of the IBR-2 facility and the continued upgrade of its instruments within the FLNP User Programme; the in-progress development of two possible concepts for the future neutron source at JINR;

— the start of the active use of the "Govorun" supercomputer being a promising part of JINR's IT infrastructure.

The Scientific Council congratulated the Directorate and staff of JINR on the opening of the International Year of the Periodic Table of Chemical Elements (IYPT), noting with satisfaction the numerous dedicated events with JINR's participation.

The Scientific Council recognized the efforts being taken by the JINR Directorate towards strengthening cooperation with JINR partners as well as extending the general horizons of international cooperation. The Scientific Council appreciated, in particular, the signing of the framework agreement on cooperation between GSI, FAIR and JINR, and of the Roadmap for the development of the JINR–Egypt cooperation, and also welcomed broadening ties with France and the Republic of Korea.

The Scientific Council welcomed the Directorate's initiative to establish a JINR Science and Innovation Centre.

Analysis of Implementation of JINR's Flagship Projects. The Scientific Council took note of the analysis of implementation of the schedules of realization of JINR's flagship projects.

NICA. The analysis of the implementation of the schedule of the NICA complex project was presented in the following main aspects: accelerator complex, experimental facilities, and infrastructure. Work is being carried out actively in all these areas and is continuously monitored by the Directorates of VBLHEP and JINR.

The first goal of the project has been achieved — the launching of the BM@N experimental setup with extracted beams and the successful collection of first data within the experimental physics programme during the 55th run of the Nuclotron.

The ongoing installation of the Booster synchrotron corresponds to the plans for its commissioning (end of 2019). There is progress in building the first experimental facility at the collider — the MPD detector. The project management has taken measures to eliminate the delay in developing MPD elements caused by force majeure and to continue the work in accordance with the plan.

The preparation of the conceptual and technical reports of the second experimental facility, the SPD detector, continues.

Work on the construction of the accelerator infrastructure and other facilities of the NICA complex is well underway.

SHE Factory. The work on the Factory of Superheavy Elements is proceeding according to schedule. In 2018, a certificate of compliance of the constructed object with the requirements of technical regulations by the Federal Environmental, Industrial and Nuclear Supervision Service of Russia (Rostekhnadzor) was obtained. Complex commissioning work was conducted at the DC-280 cyclotron. On 26 December 2018, the first beam of accelerated krypton ions was produced inside the DC-280 cyclotron; on 17 January 2019 it was successfully extracted from the cyclotron.

The most important tasks for FLNR to focus on in the current year are the following: production of heavy-ion beams with design parameters (first quarter, 2019); commissioning work and startup of the GFS-2 gas-filled recoil separator (first quarter, 2019); preparation and conduct of first-day experiments on the synthesis of moscovium isotopes in the $^{48}\mathrm{Ca} + {}^{243}\mathrm{Am}$ reaction (second quarter, 2019); preparation for experiments on the synthesis of new element 120 in the $^{50}\mathrm{Ti} + {}^{249-251}\mathrm{Cf}$ reaction (second half, 2019).

Baikal-GVD. The implementation of the project "Baikal Neutrino Telescope" is underway according to schedule. Three clusters with a total number of 864

optical modules were installed during 2016–2018. This facility has become the largest neutrino telescope in the Northern Hemisphere. All three clusters are operating normally. Data analysis is in progress.

A good deal of work has been done to update the infrastructure of the Baikal neutrino telescope. A laboratory complex for the assembly and testing of optical modules, including long-term tests, for testing electronics, deep-water connectors, cables and other equipment, was built at DLNP. On the site of the experiment, new residential premises, a data collection centre, a coastal centre, a canteen and a hostel were put into operation; a laboratory for the assembly of deep-water cables was constructed in Baikalsk.

Within the 2019 campaign, two more clusters will be installed, bringing the total number of optical modules to 1440. According to the plan, the first phase of the Baikal neutrino telescope will be commissioned in 2021. The number of optical modules will reach 2592.

The Scientific Council highly appreciated the ongoing efforts to implement these major projects of the current Seven-Year Plan for the Development of JINR; however, considering the existence of competitive projects in several research centres elsewhere, it emphasized the importance of strict observance of the approved timelines. The Scientific Council recommended that the JINR Committee of Plenipotentiaries give an overall positive assessment to the analysis presented.

Status of the Establishment of the SOLCRYS Laboratory at SOLARIS. The Scientific Council took note of the information presented by FLNP Director V. Shvetsov about the progress of the joint work being done by the Jagiellonian University in Kraków (Poland) and the Frank Laboratory of Neutron Physics to develop the concept for and establish JINR's new research infrastructure — a Laboratory for Structural Research of Macromolecules and New Materials (SOLCRYS) at the SOLARIS National Synchrotron Radiation Centre of the Jagiellonian University.

The Scientific Council welcomed the start of tendering activities for the supply of equipment and installation of SOLCRYS workstations. At the same time, the Scientific Council noted the need for progress in resolving the issue of constructing a superconducting wiggler capable of providing maximum radiation intensity at an energy of at least 20 keV, as indicated in the Agreement between the Jagiellonian University and JINR concerning the establishment of SOLCRYS.

The Scientific Council took note of the possibility to explore a future collaboration with the CERIC-ERIC consortium.

Recommendations in Connection with the PACs. The Scientific Council took note of the recommendations made by the PACs at their meetings in January 2019. 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 2020.

Particle Physics. The Scientific Council shared the concern of the PAC for Particle Physics about the series of delays (mainly in civil construction), which affect the overall schedule of the NICA project, and urged the NICA management to critically scrutinize the current schedule of the entire project to ensure that no further delays occur. The Scientific Council noted with satisfaction the successful implementation of the plan for the renewal of heating, water and drainage networks (12 km of networks already renewed) and the efforts of the Laboratory's management to eliminate the backlog from the plans to build a compressor station.

The Scientific Council was pleased to note the official establishment of the international experimental collaborations MPD and BM@N after their 2nd Collaboration Meeting. The Scientific Council welcomed the admission of new institutions to the collaborations and congratulated the elected Spokespersons and Institutional Board Chairpersons, the appointed Project Managers and Deputy Spokespersons, and wished them very fruitful work at the NICA facility. The Scientific Council supported the plans for the formation of organizational structures of the Collaborations.

The Scientific Council noted the steady progress in constructing the main subsystems of the MPD detector: the superconducting magnet, TPC and ToF. It supported the plans for the installation of the BM@N transport line and the vacuum beam pipe through the experimental setup, which are necessary for operation with heavy-ion beams. The Scientific Council concurred with the PAC's reiterated recommendations for the BM@N team to focus efforts on the physics analysis of the large data sets collected both in the BM@N research programme and in the study of short-range correlations.

The Scientific Council supported the PAC's recommendations on the approval of new projects and the continuation of ongoing projects in particle physics within the suggested time scales, as outlined in the PAC recommendations. In particular, it endorsed the PAC's recommendations to start the preparation of a Conceptual Design Report (CDR) for the Spin Physics Detector (SPD) at the NICA collider, followed after its acceptance by a Technical Design Report. The CDR must contain a full concept which should guarantee much better spin physics results than those that could be achieved with MPD at NICA. The Scientific Council supported the PAC's recommendations to approve the project until the end of 2021 with first priority.

The Scientific Council endorsed the PAC's recommendations for the continuation of the JINR's participation in the BES-III project until the end of 2022 with second priority. The JINR group has made many significant contributions in the BES-III experiment since 2005, and the Scientific Council agreed with the PAC that the experiment has reached most of the aimed at

goals and further studies could be conducted with a commensurate lower effort.

The Scientific Council considered JINR's participation in the R&D project for the PHOS detector as an important contribution to the upgrade of the ALICE photon spectrometer and supported the PAC's recommendation for continuation of JINR's participation in the R&D project until the end of 2020 with first priority.

The Scientific Council recognized the important results achieved by the JINR group in the LHC experiments: the analysis of ultraperipheral Pb + Pb and p–Pb collisions and the study of kaon femtoscopy in the ALICE experiment; the observation of the Higgs boson decay into a pair of b-quarks, recent results on searches for new physics in $\gamma + Z/W/H$ final states and the progress in the mass production of micromegas chambers for the Phase-1 upgrade of the ATLAS detector; the results on the search for high-mass resonances decaying into dilepton pairs, the measurements of asymmetries and cross sections of Drell–Yan pair production and the progress in the R&D work for a new hadron calorimeter of the CMS detector.

Nuclear Physics. The Scientific Council thanked the PAC for Nuclear Physics for its initiative to follow up on the construction work for the Factory of Superheavy Elements (SHE Factory) and noted the significant progress achieved by FLNR in this major project.

The Scientific Council recognized the efforts made by the Laboratory in order to prepare for the commissioning of the SHE Factory as well as the progress in constructing new facilities for the SHE Factory, in particular, the GFS-2 gas-filled separator, appreciated this work and supported its continuation. In the first quarter of 2019, it is planned to continue the work at DC-280 to obtain heavy-ion beams of design parameters, to complete the commissioning work for the GFS-2 separator, and to initiate the implementation of the experimental programme on the synthesis and study of the properties of superheavy elements at the Factory.

A set of test experiments will be carried out at the first stage with a view to achieving the design parameters of the GFS-2 separator, using fusion reactions of rare-earth elements with ^{40}Ar, ^{48}Ca, ^{50}Ti ions accelerated at the DC-280 cyclotron. In this set of experiments, it is necessary to study the transmission of GFS-2 at different thicknesses of the target, the resistance of targets to an increased beam intensity and accumulated dose, the clearing of background reaction products, etc.

The first commissioning experiments at SHE will concern the synthesis of moscovium isotopes in the ^{48}Ca + ^{243}Am reaction and at a later stage the study of chemical properties of Fl and Cn. The programme will further be focused on preparing and conducting experiments on the synthesis of elements 120 and 119 in the reactions of ^{50}Ti beam with $^{249-251}$Cf and ^{249}Bk targets, respectively.

The Scientific Council congratulated the FLNR staff on the successful startup of the DC-280 cyclotron and recommended that the Directorates of JINR and FLNR concentrate their efforts to complete all commissioning work, including the DC-280 cyclotron and the GFS-2 separator, and to prepare for the test experiments. The Scientific Council endorsed the programme of first experiments at the SHE Factory.

Neutrino Physics. The Scientific Council congratulated the PAC for Particle Physics and the PAC for Nuclear Physics on the careful evaluation, at the joint session of the two PACs on 22 January 2019, of all projects and research themes carried out at JINR in the areas of neutrino physics, astrophysics and Dark Matter. There are currently 13 such projects, seven of them are regularly evaluated by the PAC for Particle Physics whereas the other six by the PAC for Nuclear Physics. In order to achieve "a better coordination of the neutrino physics programme therefore allowing implementation of priorities in a more concerted and efficient manner" as outlined in the Resolution of the Scientific Council's previous session, all 13 projects were jointly evaluated by both PACs with the ultimate goal to classify them into three categories: A, B or C, based on the scientific merit of the project and the performance of the JINR group involved.

The Scientific Council endorsed the recommendations of the PACs, noting that the recommendations and the classification developed would be useful for the DLNP and the JINR Directorates in their efforts towards concentration of resources in the selected directions and strengthening the research programme.

Condensed Matter Physics. The Scientific Council took note of the information on the current state of the IBR-2 facility as well as on the results of theoretical and experimental studies of the reactor's dynamical characteristics considered by the PAC for Condensed Matter Physics. The Scientific Council supported the efforts of the FLNP Directorate to secure the operational conditions of the IBR-2 facility and welcomes the plans for its maintenance and upgrade.

The Scientific Council appreciated the quality and the interdisciplinary character of the scientific results produced at IBR-2 instruments and the instrumentation developments in 2018. The Scientific Council agreed with the PAC that continuous upgrade of the IBR-2 instruments should be provided together with a more detailed analysis of the research outcome for each particular instrument and of its potential for improvement.

The Scientific Council took note of the results of implementing the FLNP User Programme in 2018 and of the recent efforts to improve the process of collection and evaluation of research proposals. The Scientific Council was pleased to note that the IBR-2 facility had been operating stably according to the User Policy Programme since 2012 with calls for proposals being

issued twice a year. In 2018, however, due to technical reasons at the reactor, fewer than originally scheduled number of cycles was assigned for experiments within the User Programme. The Scientific Council also welcomed the PAC's request to provide detailed statistics for each particular instrument with relation to this Programme.

The Scientific Council was satisfied with the assessed current state of the Fourier stress diffractometer (FSD) at the IBR-2 facility, concurring with the PAC that FLNP's achievements in developing correlation diffractometry were particularly successful for the IBR-2 research programme.

The Scientific Council noted the strengthening of cooperation between JINR and the SOLARIS National Synchrotron Radiation Centre of the Jagiellonian University in Kraków (Poland) towards developing a laboratory for structural research using synchrotron X-rays. The Scientific Council expects that this joint activity will extend the variety of experimental approaches to the condensed matter research pursued at JINR. The Scientific Council shared the PAC's recommendation calling for more technical details on potential scientific use of this new laboratory at the SOLARIS Centre.

The Scientific Council took note of the general endorsement by the PAC of FLNP's intents to open two new themes: "Development of the critical design report for a new Dubna Neutron Source (DNS-IV)" and "Construction of a Laboratory for Structural Research of Macromolecules and New Materials at the SOLARIS National Synchrotron Radiation Centre of the Jagiellonian University in Kraków (Poland)", and expects the consideration of full proposals at the PAC's next meeting.

Common Issues. The Scientific Council was pleased with the present state and trends in the development of a concept for the future neutron source at JINR considered by the PAC for Condensed Matter Physics and the PAC for Nuclear Physics. The Scientific Council noted the progress in the current stage of the conceptual design process and welcomed the two principle schemes proposed for such a source: a pulsed fast reactor IBR-3 (NEPTUN) and a pulsed neutron source driven by a proton accelerator (PLUTON). The Scientific Council recommended that FLNP continue developing both concepts of the new neutron source, compare their parameters and costs between each other and with those of other existing or projected neutron sources and that the conceptual design and scientific programme of the future neutron source be evaluated at a duly held joint session of the PAC for Nuclear Physics and the PAC for Condensed Matter Physics.

Reports by Young Scientists. The Scientific Council followed with interest the reports by young scientists, selected by the PACs for presentation at this session: "East–west asymmetry effect in atmospheric muon flux in the Far Detector of NOνA", "Upgrade of the GERDA experiment", and "Clusterization aspects of fullerene C_{70} in toluene/N-methyl-2-pyrrolidone mixture according to SANS, SAXS and DLS data", and thanked the respective speakers: Olga Petrova (DLNP), Nadezhda Rumyantseva (DLNP), and Tetiana Nagorna (FLNP) — three talented scientists. The Scientific Council welcomed such selected reports in the future and looks forward to the Management enhancing the visibility of and empowering female scientists at JINR.

Scientific Report. The Scientific Council thanked A. Sergeev, President of the Russian Academy of Sciences and member of the JINR Scientific Council, for his excellent lecture on "Exawatt science".

Awards and Prizes. The Scientific Council congratulated DLNP Chief Researcher V. Komarov on the award of the V. Dzhelepov Prize for his pioneering work on the construction of the first channel for proton therapy at the JINR synchrocyclotron.

The Scientific Council approved the Jury's recommendations presented by JINR Director V. Matveev on the award of the B. Pontecorvo Prize to Professor F. Halzen (University of Wisconsin, Madison, USA) for his leading role in the construction of the IceCube detector and experimental discovery of very-high-energy cosmological neutrinos.

The Scientific Council approved the Jury's recommendations presented by Vice-Director M. Itkis on the award of JINR annual prizes for best papers in the fields of scientific research, instruments and methods, and applied research.

The Scientific Council congratulated E. Rabinovici, member of this Council, on having been awarded the 2019 Award for Science Diplomacy by the American Association for the Advancement of Science, together with other distinguished scientists: Z. Sayers, C. Llewellyn Smith, H. Schopper (member of the JINR Scientific Council during 1993–2003), and K. Toukan, for their central contributions to the founding and development of the international physics centre SESAME (Allan, Jordan).

The Scientific Council congratulated DLNP Chief Researcher J. Budagov and JINR Vice-Director M. Itkis on the award of the Jubilee Diplomas of Honour of the Presidium of the National Academy of Sciences of Ukraine for scientific achievements and on the occasion of the 100th anniversary of the Academy, presented at this session by member of the JINR Scientific Council and the Plenipotentiary of the Government of Ukraine to JINR, B. Grynyov.

Endorsement of Appointments of Deputy Directors of DLNP and LIT and Announcement of the Vacancy of the Position of the Director of FLNR. The Scientific Council endorsed the appointment of V. Glagolev, A. Kovalík, and D. Naumov as Deputy Directors of the Dzhelepov Laboratory of Nuclear Problems (DLNP), until the completion of the term of office of DLNP Director V. Bednyakov.

The Scientific Council endorsed the appointment of O. Chuluunbaatar as Deputy Director of the Laboratory of Information Technologies (LIT), until the completion of the term of office of LIT Director V. Korenkov.

The Scientific Council announced the vacancy of the position of the Director of the Flerov Laboratory of Nuclear Reactions. The election will take place at the 127th session of the Scientific Council in February 2020.

The 126th session of the JINR Scientific Council took place on 19–20 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 the recent achievements of JINR in its major research directions, the progress in developing physics facilities within JINR's large projects, the decisions of the latest session of the JINR Committee of Plenipotentiaries (March 2019), as well as events in JINR's international cooperation and in the field of training highly qualified scientific personnel.

The Scientific Council heard reports concerning the current preparation of the draft Strategic Plan for the Long-Term Development of JINR in its major sections, presented by DLNP Deputy Director D. Naumov (particle physics), VBLHEP Deputy Director R. Tsenov (relativistic heavy-ion physics and spin physics), FLNR Scientific Secretary A. Karpov (nuclear physics at low and intermediate energies), FLNP Directorate Adviser A. Ioffe (condensed matter physics and neutron nuclear physics), LRB Senior Researcher E. Nasonova (radiobiology), and by LIT Researcher N. Voytishin (information technology).

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

The Scientific Council heard the scientific report "The Bruno Pontecorvo Centre in Pisa: Status and future collaboration with JINR" presented by V. Cavasinni (Italy).

The award of the B. Pontecorvo Prize took place at the session, and diplomas were presented to the winners of JINR prizes for the year 2018. The Scientific Council heard the best reports by young scientists as recommended by the PACs.

Elections of the Directors of VBLHEP and LRB were held at the session. The vacancies of positions in the Directorates of JINR Laboratories were announced.

The participants of the session visited VBLHEP to attend the inauguration of the NICA Computing Centre.

General Considerations of the Resolution. The Scientific Council congratulated JINR Director V. Matveev for his comprehensive presentation and appreciated the emerging results which follow from choosing a good strategy and from selection of coherent priorities distinguishing JINR as a world-class international scientific research organization.

The Scientific Council supported the efforts of the JINR Directorate towards constructing the basic configuration of the NICA complex, noting the completion of the main systems of the Booster synchrotron and of the fabrication of the yoke of the solenoidal magnet for the MPD detector. The Scientific Council appreciated the first physics results produced in the BM@N experiment and the continued analysis of the data taken earlier in this experiment, and also noted the commissioning of the updated computer cluster at VBLHEP to meet the challenges of the NICA complex.

The Scientific Council took note of the holding at JINR, on 17 April 2019, of the 3rd Joint Meeting of the MPD and BM@N Collaborations, which covered the physics programmes of the MPD and BM@N experiments, and progress in detector subsystems work and in analysis of experimental data.

The Scientific Council welcomed the opening of the experimental building of the Factory of Superheavy Elements (SHE) at the Flerov Laboratory of Nuclear Reactions and the launching of the Factory's main facility — the DC-280 cyclotron, highly appreciating the scientific and technological quality of the realization of the project to build the DC-280 cyclotron and the participation of most JINR Member States.

The Scientific Council noted the holding at JINR, on 30–31 May 2019, of the international symposium "The Present and the Future of the Periodic Table of Chemical Elements", which was attended by representatives of UNESCO, IUPAC, and IUPAP together with eminent scientists from institutes and universities of the JINR Member States and other countries.

The Scientific Council noted the commissioning of two new clusters of the Baikal-GVD detector under construction, the effective volume of which has now reached ~ 0.25 km^3, as well as the further development of the neutrino experiments at the Kalinin Nuclear Power Plant.

The Scientific Council supported the efforts being taken by the JINR Directorate to train highly qualified scientific personnel. In particular, the Scientific Council welcomed the beginning of operation at JINR, from 1 September 2019, of new dissertation councils on the basis of JINR's right to independently confer academic degrees in the Russian Federation. Implementation of this right will further attract young scientists from Member States to JINR.

Preparation of the Draft Strategic Plan for the Long-Term Development of JINR. The Scientific Council took note of the reports concerning the current preparation of the draft Strategic Plan for the Long-Term Development of JINR in its major sections. The speakers presented information concerning new scientific research and experiments prepared and to be car-

ried out over the period 2023–2030 and beyond. They also suggested what scientific and technological results should be achieved, what research infrastructure should be developed, and what the future staffing needs should be. In addition, information was given about the membership of the thematic subgroups and the organization of their work (meetings, workshops, videoconferences, etc.).

The Scientific Council recommended that the international Working Group ensure the preparation of a single, integrated document based on the materials presented by the thematic subgroups describing the overall strategy with its flagship projects and partnership priorities and inform the Committee of Plenipotentiaries, at its session in November 2019, about the progress in preparing the Strategic Plan for the Long-Term Development of JINR.

Recommendations in Connection with the PACs. The Scientific Council took note of the recommendations made by the PACs at their meetings in June 2019, as reported at this session by I. Tserruya, Chairman of the PAC for Particle Physics, by JINR Vice-Director M. Itkis on behalf of M. Lewitowicz, Chairman of the PAC for Nuclear Physics, and by D. L. Nagy, Chairman 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 2020.

Particle Physics. The Scientific Council noted with satisfaction the active work on the mounting of the NICA Booster magnets and that commissioning with beam is expected to be completed by the end of 2019; supported the request to improve the diagnostics of the accelerator complex in order to deliver pure well-defined beams to the users, and acknowledged the efforts of VBLHEP to reduce the delay in the construction work schedule for the infrastructure of the collider complex.

The Scientific Council welcomed the admission of two new institutions to the MPD collaboration, the magnitude and quality of simulations being carried out, and the collaboration efforts to complete the first stage of the detector by 2021. The Scientific Council congratulated the BM@N team on the presentation of first physics results on the production of lambda hyperons and appreciated the ongoing efforts for the preparation of the BM@N setup for heavy-ion beams in 2021.

The Scientific Council supported the PAC's approach for the evaluation of the JINR's participation in the LHC experiments, in particular, the recommendation given to the JINR Directorate for each of the three LHC themes (ALICE, ATLAS and CMS) to combine the project concerning physics analysis and operations and the project concerning detector upgrade and associated R&D into one single project. Thus, better monitoring and regulating the execution of the so far distinct projects will be achieved. The Scientific Council also supported the proposal to have a thorough yearly review of all three LHC experiments at the same PAC meeting, followed by a brief status report six months later.

The Scientific Council congratulated the JINR CMS group on the quality of the work carried out in various detector subsystems with major JINR responsibilities and on the progress in physics studies with direct participation of JINR members. It also seconded the PAC's recommendations to make larger efforts towards a higher productivity in terms of physics analysis and scientific publications, commensurate with the global contribution of JINR to CMS. A physics analysis plan should be prepared, which includes subjects that would allow the group to achieve higher visibility, with identified JINR responsibilities and an increased number of young researchers and students involved. In this regard, the presence of a large number of participants with 0.1 FTE is a matter of concern.

The Scientific Council appreciated the progress in many physics analyses with JINR responsibility in the ATLAS experiment, the large number of scientific publications with direct participation of JINR members, and the consistency of the research subgroups involving several young researchers. The Scientific Council supported the PAC's recommendations to concentrate on studies for which the group could achieve a leadership role with a visible impact within the ATLAS collaboration, in terms of coordination roles, involvement of new young researchers, and presentations at major conferences.

Taking note of the involvement of the ALICE group at JINR in physics analyses, the group's contribution to the GRID–ALICE system and to the photon spectrometer upgrade, the Scientific Council shared the PAC's concern about the relatively low visibility of the JINR team working in ALICE as reflected, for example, by the lack of talks at major conferences in the field.

The Scientific Council supported the PAC's recommendations on the continuation of JINR's participation in the CMS, ATLAS and ALICE projects for the period 2020–2023, with first priority, pending the setting in place of corrective actions to address the above-mentioned concerns.

The Scientific Council supported the PAC's recommendations on the continuation of ongoing projects in particle physics. In particular, it endorsed the recommendation on continuation of the SCAN-3 project for the period 2020–2022 with first priority, making sure that it does not interfere with NICA operation. It also supported the PAC's decision to postpone any recommendation on the NA64 project till the authors present to the PAC a revised proposal where the recommendations made at the joint session of two PACs to improve the ratio of FTE to participants, to attract students and to get involved in data analysis were properly addressed.

The Scientific Council seconded the PAC's evaluation of the FASA project and the request that the authors submit an improved proposal, better focusing its scientific content, taking into account data obtained 40 years ago at Fermilab, CERN-PS, Bevatron and Bevalac, and presenting a convincing argument on how they could solve the still open question of break-up or thermalization in the multifragmentation of nuclei.

The Scientific Council drew to the attention of the leaders of the Borexino, PANDA and COMET projects to be concluded in 2019 that they should present their reports at the meeting of the PAC in February 2020.

Nuclear Physics. The Scientific Council appreciated FLNP's outstanding achievements in the research of fundamental symmetries with polarized neutrons, the wide range of excellent results in the field of applied research within international programmes, and the importance of the work for the development of the accelerator facility carried out at IREN.

The Scientific Council supported the recommendation of the PAC for Nuclear Physics to extend the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron" for 2020–2022 with first priority for further research activities in nuclear physics using FLNP's neutron facilities: the highly intense pulsed neutron source IREN and the IBR-2 pulsed reactor. The FLNP Directorate is advised to focus on the modernization of experimental halls and pavilions with beams of the IREN facility, on the construction of a polarized nuclear target for the work with polarized neutrons at IREN, and on the upgrade of the EG-5 electrostatic generator. Special attention should be given to the beam delivery systems in order to increase neutron fluxes.

The Scientific Council recognized the importance of the project "Research and development of the tagged neutron method for identification of the elemental structure of matter and studies of nuclear reactions (TANGRA)" and supported the PAC's recommendation to extend this project for 2020–2022, with first priority.

The Scientific Council commended the work under the GDH&SPASCHARM&NN project, which consists in fact of three independent experimental activities connected by the study of the nucleon spin structure in strong and electromagnetic interactions, and is technically strongly supported by the frozen spin polarized proton and deuteron targets built and maintained by JINR's group. Acknowledging the important role of the Dubna group in all the three experiments, the Scientific Council supported the PAC's recommendation to extend this project for 2020–2022, with first priority.

The Scientific Council concurred with the PAC's recommendation on the opening of a new project "Construction of a prototype of the initial section of a high-current heavy-ion linear accelerator aimed at producing intense radioactive ion beams for basic research" for the period 2020–2021. The proposed work plan aims at constructing a prototype of the initial section of the linear accelerator and at designing the LINAC-100 accelerator.

Condensed Matter Physics. The Scientific Council noted the importance of activities within the theme "Development of the IBR-2 Facility with a Complex of Cryogenic Neutron Moderators" and project "Construction of a complex of cryogenic moderators at the IBR-2 facility" and supported their extension for 2020–2022.

The Scientific Council took note of the status of the cooperation between JINR and the SOLARIS National Synchrotron Centre (Kraków, Poland) focusing on the development of a joint facility for structural research using synchrotron X-rays. The Scientific Council supported the recommendation of the PAC for Condensed Matter Physics on the opening of a new theme "Development of the SOLCRYS Structural Research Laboratory at the SOLARIS National Synchrotron Centre" for 2020–2022, noting the interest of several organizations from the JINR Member States in taking part in this activity.

The Scientific Council welcomed the results of discussion of the inelastic neutron scattering instruments at IBR-2 within the context of the current trends in neutron spectroscopy worldwide. Considering that the two spectrometers reviewed by the PAC are the only inelastic neutron scattering instruments available at JINR, the Scientific Council supported the development of new inelastic neutron scattering instruments and FLNP's intention to present a proposal for opening a new project to further develop the two existing instruments.

The Scientific Council was satisfied with the progress 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" and supported the PAC's recommendation on its continuation.

The Scientific Council appreciated the results obtained in the development of new mathematical methods, algorithms, and software packages for condensed matter physics, which are represented, on the one hand, through high-class computer support of the data acquisition and processing at IBR-2 spectrometers and, on the other hand, through important computer developments for the numerical solution of theoretical models describing either dynamic phenomena or structural properties of complex materials. The Scientific Council supported the PAC's recommendation on further extension of the theme "Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data" for 2020–2023, with the understanding that the basis for future developments within this theme will be the implementation of the opportunities offered by the heterogeneous computing platform HybriLIT through its "Govorun" supercomputer and its education and testing site.

The Scientific Council was pleased with the results achieved by DLNP's Medico-Technical Complex both in the field of clinical research on proton radiotherapy applications for the treatment of different diseases and in the field of radiobiology. The Scientific Council supported extension of the theme "Biomedical and Radiation-Genetic Studies Using Different Types of Ionizing Radiation" and the projects "Further development of methods, technologies, schedule modes and delivery of radiotherapy" and "Radiogene: Molecular genetics of radiation-induced changes at the gene, genome and transcriptome level in *Drosophila melanogaster*" for 2020–2022.

The Scientific Council agreed with the PAC's recommendation on extension of the concluding theme and project "Research on Cosmic Matter on the Earth and in Space; Research on the Biological and Geochemical Specifics of the Early Earth" for 2020–2022, expecting that research in the fields of this theme would make a remarkable contribution to astrobiology.

Common Issues. The Scientific Council looks forward to being informed of the decision concerning the Neutrino Programme evaluated by the joint session of the PAC for Particle Physics and of the PAC for Nuclear Physics in January 2019 and to knowing when and how this programme will be re-evaluated. In general, the Scientific Council recommended that better allotment of scientific themes to respective PACs be made.

The Scientific Council noted the significant progress achieved in developing a technical justification for the concept of a new neutron source at JINR and supported the recommendations made by the PAC for Condensed Matter Physics and the PAC for Nuclear Physics on the opening of the theme "Development of the Conceptual Design of a New Advanced Neutron Source at JINR" for 2020–2022. At the same time, special attention should be paid to developing the scientific programme for the new source in the field of condensed matter physics and nuclear physics as well as to defining a management structure and a time schedule, specifying milestones and expected results of this new theme.

The Scientific Council supported the development of JINR information systems aimed at providing information and software support for the JINR research and management activities within the theme "Information and Computing Infrastructure of JINR". The Scientific Council appreciated LIT's efforts to achieve development and upgrade of the JINR telecommunication and network infrastructure; modernization of the MICC engineering infrastructure, increase in performance of computing resources and data storage systems. The Scientific Council supported the recommendations of the PAC for Nuclear Physics and of the PAC for Condensed Matter Physics to extend the theme "Information and Computing Infrastructure of JINR" and the MICC project for 2020–2023, with first priority.

Reports by Young Scientists. The Scientific Council appreciated the reports by young scientists, selected by the PACs for presentation at this session: "Neutrino oscillation analysis in the NOνA experiment" and "Investigations of polystyrene-fullerene nanocomposite thin films by neutron and X-ray reflectometry", and thanked the respective speakers: L. Kolupaeva (DLNP) and T. Tropin (FLNP). The Scientific Council will welcome such selected reports in future.

Memberships of the PACs. On the proposal of the JINR Directorate presented by JINR Vice-Director R. Lednický, the Scientific Council appointed Fuqiang Wang (Purdue University, West Lafayette, USA) as a new member of the PAC for Particle Physics for a term of three years. It thanked the outgoing member Nu Xu for his successful work in this PAC.

The Scientific Council appointed M. Kozak (Adam Mickiewicz University, Poznań, Poland) as a new member of the PAC for Condensed Matter Physics for a term of three years. It thanked the outgoing member J. Wąsicki for his successful work in this PAC.

Prizes and Awards. The Scientific Council congratulated F. Halzen (University of Wisconsin, Madison, USA) on the award of the B. Pontecorvo Prize for his leading role in the construction of the IceCube detector and experimental discovery of very-high-energy cosmic neutrinos, and thanked him for his excellent presentation.

The Scientific Council congratulated the winners of JINR annual prizes for best papers in the fields of scientific research, instruments and methods, and applied research.

The Scientific Council congratulated LRB Director E. Krasavin on the award of the Diploma of Doctor Honoris Causa of the National University of Mongolia, presented at this session.

Elections and Announcement of Vacancies in the Directorates of JINR Laboratories. In the elections of the Director of the Veksler and Baldin Laboratory of High Energy Physics, the nominated candidate did not obtain the required majority of votes. As proposed by JINR Director V. Matveev, the Scientific Council will announce new elections at the 129th session in February 2021.

The Scientific Council elected A. Bugay as Director of the Laboratory of Radiation Biology (LRB) for a term of five years. The Scientific Council thanked E. Krasavin for his successful tenure as Director of this Laboratory.

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

Appreciation. The Scientific Council congratulated the Veksler and Baldin Laboratory of High Energy Physics on the commissioning of the NICA Computing Centre. This is a landmark event on the way to

realizing the NICA complex and an important element of its research infrastructure.

The Scientific Council thanked V. Cavasinni, Coordinator of the Bruno Pontecorvo Centre of the Physics Department of the University of Pisa (Italy), for his report on the status of this centre and future collaboration with JINR, and wished the Bruno Pontecorvo Centre success in its activity.

Rules of Procedure of the Scientific Council. The Scientific Council discussed the amendments proposed by JINR Director V. Matveev to the Regulations for the election of Directors and for the endorsed appointment of Deputy Directors of JINR Laboratories, which are part of the Rules of procedure of the JINR Scientific Council, and decided to continue their consideration at the next session.

MEETINGS OF THE JINR FINANCE COMMITTEE

A meeting of the JINR Finance Committee was held in Dubna on 22–23 March. It was chaired by S. Harizanova, a representative of the Republic of Bulgaria.

Based on the report presented by JINR Director V. Matveev, the Finance Committee took note of the Directorate's information on the results of the 125th session of the JINR Scientific Council, on the implementation of the JINR Plan of Research and International Cooperation in 2018 and on plans for activities for 2019. The Committee commended the efforts of the JINR Directorate and staff towards realizing JINR's major projects.

The Finance Committee recommended that the CP commission the JINR Directorate to prepare and submit to the CP's session in March 2020 a report on the progress of implementation of the Seven-Year Plan for the Development of JINR for 2017–2023 as well as proposals for its update.

The Finance Committee noted the successful cooperation between JINR and the Jagiellonian University in Kraków (Republic of Poland) in developing the concept for and establishing JINR's new research infrastructure — a Laboratory for Structural Research of Macromolecules and New Materials (SOLCRYS) at the SOLARIS National Synchrotron Radiation Centre of the Jagiellonian University. It welcomed, in particular, the start of tendering activities for the supply of equipment and installation of SOLCRYS workstations.

The Finance Committee endorsed the inclusion of the task of constructing the basic configuration of the NICA accelerator complex in the Russian national project "Science" and took note of JINR's obligations related to participation in this project.

The Finance Committee supported the plans for JINR's participation in the events dedicated to the International Year of the Periodic Table of Chemical Elements (IYPT), including the holding of large conferences and symposia in Dubna during the IYPT.

The Finance Committee welcomed the signing of the Roadmap for scientific cooperation between the Federal Republic of Germany and the Russian Federation, as well as the readiness of German partners to continue their participation in the construction of the NICA complex.

The Finance Committee took note of the signing of the framework Agreement on Cooperation between GSI, FAIR and JINR, as well as of the Roadmap for the development of the cooperation between the Arab Republic of Egypt and JINR; it also welcomed the expansion of scientific and technological ties with the French Republic and the Republic of Korea.

The Finance Committee recommended that the CP support the measures proposed by the JINR Directorate for the innovative development of JINR and that it commission the Directorate, within the framework of the JINR innovation policy, to prepare a project for the use in the interests of the JINR Member States of new innovative tools, including innovation science and technology centres proposed by the Russian Federation in the national project "Science", the State Programme for the Development of Science and Technology and in other regulatory acts.

Regarding the report "Implementation of the JINR budget for 2018 and draft of the revised budget of JINR for 2019" presented by M. Vasilyev, Deputy Head of the JINR Finance and Economy Office, the Finance Committee recommended that the CP take note of the information on the implementation of the JINR budget for 2018, approve the consolidated final adjustment of the JINR budget expenditure for 2018 and the revised budget of JINR for 2019 with the total income and expenditure amounting to US$289 790.2 thousand.

Regarding the report "Construction and exploitation of the NICA complex of superconducting rings for heavy-ion colliding beams, implementation of the budget within the framework of the Agreement between the Government of the Russian Federation and JINR, and draft of the revised budget for 2019" presented by VBLHEP Director V. Kekelidze, the Finance Committee recommended that the CP take note of the analysis of implementation of the schedule of the NICA complex project, that it note that work was being carried out actively and was continuously monitored by the Directorates of VBLHEP and JINR, and that it welcome the achievement of the first goal of the project — the

launching of the BM@N experimental setup with extracted beams.

The Finance Committee recommended that the CP endorse the report on the use of the budget funds of JINR and of the special-purpose funds of the Russian Federation, provided 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 period until 2018 inclusive, and approve the revised budget for the use of these special-purpose funds for 2019 in the amount of 3 711 471.1 thousand rubles.

As recommended by the Supervisory Board of the NICA complex project, the Finance Committee recommended that the CP approve the scheme of distribution of the basic financial expenses for the realization of the basic configuration of the project of the NICA complex of superconducting rings for heavy-ion colliding beams, taking into account the funding from the federal project "Development of Advanced Infrastructure for Research and Development in the Russian Federation" of the national project of the Russian Federation "Science", allocated in 2019 from the budget of Russia.

The Finance Committee noted the need to intensify the work on the NICA complex project in order to fully and timely accomplish its goals, taking into account the requirements of the federal project "Development of Advanced Infrastructure for Research and Development in the Russian Federation".

Regarding the report "Results of the meeting of the Working Group (WG) under the CP Chairman for JINR Financial Issues held on 20–21 March 2019" presented by T. Filatova, Chairman of the WG, the Finance Committee recommended that the CP commission the JINR Directorate to submit for consideration at the meeting of the Finance Committee and for approval at the CP's session in November 2019 an updated draft Procedure for the offset of costs of supplies of equipment, instruments, materials, services and individual work on the Institute's orders against payments of JINR Member States' contributions, as well as a new version of the Regulation for the JINR staff.

The Finance Committee also recommended that the CP commission the Directorate to prepare an updated draft Regulation on research and educational programmes for JINR's cooperation with scientific organizations and universities of the JINR Member States.

Regarding the report "Selection of an organization for auditing JINR's financial activities for 2018" presented by JINR Vice-Director R. Lednický, the Finance Committee recommended that the CP approve the plan for auditing JINR's financial activities for 2018 as presented by the JINR Directorate and that it approve the LLC AC "Korsakov and Partners" as JINR's auditor for 2018, authorizing it to conduct an audit of the Institute's financial activities for the specified period and to analyze the implementation by the JINR Directorate of the Plan of measures on the follow-up of the audit of JINR's financial activities for 2017.

The Finance Committee heard with interest the report "Applied research with neutrons" presented by FLNP Director V. Shvetsov.

A meeting of the JINR Finance Committee was held in Hanoi (Vietnam) on 21–22 November. It was chaired by S. Harizanova, a representative of the Republic of Bulgaria.

The Finance Committee heard a report presented by JINR Director V. Matveev and recommended that the CP take note of the recommendations of the 126th session of the JINR Scientific Council and of the preliminary results of implementation of the JINR Plan of Research and International Cooperation in 2019.

The Finance Committee recommended that the CP commend the work done by the JINR Directorate on implementing JINR's large scientific projects, in particular: the megascience project "NICA complex", the Factory of Superheavy Elements, the neutrino research programmes at Lake Baikal and at the Kalinin NPP, the research with the IBR-2 spectrometer complex; that the CP acknowledge the active participation of JINR in the cornerstone events dedicated to the International Year of the Periodic Table of Chemical Elements; that the CP endorse the preparation of a draft Agreement between the Ministry of Science and Higher Education of the Russian Federation and JINR on cooperation and joint work on construction of the Baikal-GVD deep underwater neutrino telescope and on participation in experimental studies in the fields of high-energy neutrino astrophysics, neutrino astronomy, and neutrino physics.

Taking note of the decision of the Government of the Republic of Uzbekistan to resume full participation in JINR, the Finance Committee suggested that the CP recommend that the Plenipotentiary of the Government of the Republic of Uzbekistan submit, for consideration at the CP session in March 2020, his proposals on financial terms for resuming the full participation of the Republic of Uzbekistan in JINR.

The Finance Committee recommended that the CP welcome the signing of the Roadmap for cooperation with the Ministry of Education, Science and Technological Development of the Republic of Serbia and that it endorse the signing of the document extending the Agreement on cooperation between JINR and the German Federal Ministry of Education and Research.

Based on the report "Draft Budget of JINR for the year 2020, draft contributions of the Member States for the years 2021, 2022, and 2023" presented by M. Vasilyev, Deputy Head of the JINR Finance and Economy Office, the Finance Committee recommended that the CP approve the JINR budget for the year 2020 with the total income and expenditure amounting to US$218 713.9 thousand. The Finance Committee also recommended that the CP approve the scale of contributions and the contributions of the JINR Member States

for 2020, as well as the repayment of contribution arrears of Member States to the JINR budget for 2020.

The Finance Committee recommended that the CP determine the provisional volumes of the JINR budget for the year 2021 amounting to US$212.24 million, for the year 2022 amounting to US$217.33 million, as well as the provisional amounts of the Member States' contributions for 2021 and 2022; and that the CP determine the provisional volume of the JINR budget for the year 2023 amounting to US$222.67 million and of the provisional amounts of the Member States' contributions for 2023.

The Finance Committee recommended that the CP endorse the consolidated adjustment of the JINR budget for the year 2019 over 9 months and that it also allow the JINR Directorate 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 2020, in accordance with the JINR Collective Bargaining Agreement for 2017–2020.

The Finance Committee recommended that the CP commission the JINR Directorate to submit, for consideration at the CP session in March 2020, proposals to ensure a competitive level of remuneration for JINR's highly qualified staff.

Following the report "Draft budget for the use of the special-purpose funds of the Russian Federation provided 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 2020" presented by VBLHEP Director V. Kekelidze and JINR Vice-Director R. Lednický, 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 this Agreement in the amount of 5 003 911.0 thousand rubles.

The Finance Committee recommended that the CP take note of the information concerning the "Draft Strategic Plan for the Long-Term Development of JINR" presented by JINR Director V. Matveev and Vice-Director B. Sharkov.

Regarding the report "Results of the meeting of the Working Group for JINR Financial Issues under the CP Chair held on 17–18 November 2019" presented by A. Khvedelidze, Plenipotentiary of the Government of Georgia to JINR, the Finance Committee recommended that the CP take note of the information on the continued work to finalize the draft Regulations for research and educational programmes of JINR's cooperation with scientific organizations and universities of JINR Member States, of the new version of the JINR Staff Regulations to be considered and approved at the CP session on 25–26 November 2019; and of the ongoing work to improve the procurement activities of JINR.

Regarding the report "Draft Procedure for setting off the costs of procurement of equipment, instruments, materials, services and individual work on JINR's orders against the payment of contributions of JINR Member States" presented by T. Naumenko, Deputy Chief Accountant of JINR, the Finance Committee recommended that the CP approve the Procedure for setting off the costs against the payment of contributions of the JINR Member States.

Based on the report "Results of the audit of the financial activities of JINR performed for the year 2018 and analysis of implementation by the JINR Directorate of the Plan of activities resulting from the audit of the financial activities of JINR performed for the year 2017" 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 2018.

MEETINGS OF THE JINR PROGRAMME ADVISORY COMMITTEES

The 50th meeting of the Programme Advisory Committee for Particle Physics took place on 21–22 January. It was chaired by Professor I. Tserruya.

The Chairman 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 124th session of the JINR Scientific Council (September 2018) and the decisions of the JINR Committee of Plenipotentiaries (November 2018).

Reports on the progress towards realization of the Nuclotron–NICA project and on corresponding infrastructure developments were presented by S. Kostromin and N. Agapov. The PAC was concerned by the series of delays, which affect the overall schedule of the NICA project. It urged the NICA management to critically scrutinize the current schedule of the entire project to ensure that it stands on solid ground and that no further delays occur. The PAC was pleased to note that 12 km of heating, water and drainage networks had been successfully renewed; this work is expected to be completed by the end of the year.

V. Kekelidze informed the PAC about the results of the 2nd Collaboration Meeting of the MPD and BM@N experiments at the NICA complex. The PAC welcomed the establishment of international collaborations of these experiments. A report on the implementation of the MPD project was presented by A. Kisiel. The Commit-

tee noted the steady progress in constructing the main subsystems of the MPD facility: the superconducting magnet, TPC and ToF. It welcomed the award of a special-purpose joint Russia–China grant for construction of the MPD ECal detector. The PAC heard with interest the report made by M. Kapishin on the preliminary results of the BM@N detector performance in Run 55 of the Nuclotron and urged the team to focus efforts on the physics analysis of the large data sets collected both in the BM@N research programme and in the study of short-range correlations. The PAC requested to see physics analysis reports at the next meeting. It also supported the plans for the installation of the BM@N transport line and the vacuum beam pipe through the experimental setup, which are necessary for operation with heavy-ion beams.

The PAC heard with interest a proposal presented by R. Tsenov for opening a project for the preparation of a Conceptual Design Report (CDR) for the Spin Physics Detector (SPD) at the NICA collider, followed after its acceptance by a Technical Design Report (TDR). The concept presented to the PAC did not look very convincing. The CDR must contain a full concept with clear physics goals and simulations showing the physics performance targeted. Technical solutions should be of the latest state-of-the-art and should not necessarily be based on in-house existing technologies. The PAC encouraged the full SPD Collaboration to be involved in the concept elaboration process and to form a permanent team of experts. After approval of the CDR, a Technical Design Report will be prepared. The PAC recommended approval of the project of preparation of the CDR and TDR until the end of 2021 with first priority.

The status of and prospects for the participation of the JINR group in the BES-III experiment at the e^+e^- collider BEPSII at IHEP in Beijing (China) were presented by A. Zhemchugov. The PAC appreciated the many significant contributions in software development and data analysis, as well as the results obtained by the JINR group since 2005. Noting that the experiment had reached most of the aimed at goals and that further studies could be conducted by the proponents with a commensurate lower effort, the PAC recommended continuation of this activity until the end of 2022 with second priority.

The PAC took note of the report presented by A. Vodopyanov on the R&D project, which is aimed at improving the performance and reliability of the PHOS detector, and recommended continuation of JINR's participation in the R&D project for the ALICE photon spectrometer upgrade until the end of 2020 with first priority.

The PAC heard with interest the reports made by B. Batyunya (ALICE experiment), S. Turchikhin (ATLAS) and V. Alexakhin (CMS) on the new results obtained by the JINR groups in LHC experiments: the study of kaon femtoscopy in Pb + Pb, p + Pb and pp collisions in the analysis of ultraperipheral Pb + Pb and p + Pb collisions in ALICE experiment; the mass production of micromegas chambers for the Phase-1 upgrade of the ATLAS Muon Spectrometer, observation of the Higgs boson decay into a pair of b quarks, recent results on searches for new physics in $\gamma + Z/W/H$ final states, as well as the framework development of the ATLAS distributed data management; the search for high-mass resonances decaying into dilepton pairs in the CMS experiment, the measurements of asymmetries and cross sections of Drell–Yan pair production, and the progress in realization of Phase-1 of the detector upgrade.

The PAC heard with interest the report "Description of meson production in electron–positron annihilation and tau-lepton decays within the NJL model" presented by A. Arbuzov.

The PAC heard information concerning long-range plans for JINR's development in the area of particle physics presented by N. Russakovich. It commended the JINR Directorate's efforts towards defining strategic objectives and establishing priorities in the JINR scientific policies; it also supported JINR's plans to integrate its projects and facilities into the European Research Infrastructure and to further enforce partnership relations with CERN.

The PAC reviewed 22 poster presentations in particle physics by young scientists from DLNP and VBLHEP, and selected the poster "East–west asymmetry effect in atmospheric muon flux in the Far Detector of NOνA" presented by O. Petrova to be reported at the session of the Scientific Council in February 2019.

A joint meeting of the PAC for Particle Physics and of the PAC for Nuclear Physics concerning the JINR Neutrino Programme was held on 22 January. It was chaired by Professors I. Tserruya and M. Lewitowicz.

The PAC for Particle Physics and the PAC for Nuclear Physics held a joint meeting for the assessment of all projects and research themes carried out at JINR in the areas of neutrino physics, astrophysics and Dark Matter.

The PACs thanked DLNP Director V. Bednyakov for the comprehensive overview of the JINR Neutrino Programme. There are currently 13 such projects, seven of them are regularly evaluated by the PAC for Particle Physics and six — by the PAC for Nuclear Physics. In order to achieve "a better coordination of the neutrino physics programme therefore allowing implementation of priorities in a more concerted and efficient manner" as outlined in the Resolution of the Scientific Council, all the 13 projects were jointly evaluated by the two PACs with the ultimate goal to classify them into three categories: A, B or C, based on the scientific merit of the project and the performance of the JINR group involved.

• Category A: excellent projects, which should be fully funded with adequate resources and encouraged to continue and expand their impact;

• Category B: very good projects, but with some weaknesses. They should be funded together with a strong recommendation on where improvement is needed;

• Category C: good projects which demonstrate relatively low performance.

The project leaders were requested to answer a common questionnaire prepared by representatives of the two PACs in coordination with the JINR management. Each project was reviewed by one referee from the PAC for Particle Physics and one from the PAC for Nuclear Physics. The final assignment of each project into category A, B or C was done taking into account the opinions of the two relevant referees and the subsequent discussion of the project.

The evaluation resulted in specific recommendations for each of the 13 projects, emphasizing their strengths and weaknesses as outlined in the minutes of the joint meeting, and in the following classification of the projects in the areas of neutrino physics, astrophysics and Dark Matter:

• Category A: Baikal-GVD, DANSS, Daya Bay/JUNO, NOνA;

• Category B: COMET, EDELWEISS-LT, GEMMA-III, GERDA, NA64, SuperNEMO, TAIGA;

• Category C: Borexino, Mu2e, g-2.

The 49th meeting of the Programme Advisory Committee for Nuclear Physics was held on 22–23 January. 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 M. Itkis informed the PAC about the Resolution of the 124th session of the JINR Scientific Council and about the decisions of the JINR Committee of Plenipotentiaries.

The PAC heard a report by E. Lychagin on the progress of the development of a new neutron source at FLNP. Two principle schemes were considered for such a source: a pulsed periodic reactor IBR-3 using neptunium fuel and a proton accelerator hitting a non-multiplying tungsten target supplying neutrons for a subcritical booster with a plutonium dioxide core. An estimated neutron flux is $> 10^{14}$ cm$^{-2} \cdot$ s^{-1}, a pulse length is 150–200 μs, and a repletion rate is 10 Hz.

The PAC heard reports on the status of the Factory of Superheavy Elements (SHE Factory) presented by I. Kalagin (cyclotron DC-280), by A. Popeko (separators for the SHE Factory) and by V. Utyonkov (first experiments at the SHE Factory). The PAC noted with appreciation that the construction of the experimental building of the SHE Factory had been completed and that a certificate of compliance of the constructed object with the requirements of technical regulations by the Russian Federal Environmental, Industrial and Nuclear Supervision Service (Rostekhnadzor) had been obtained. On 26 December 2018, the first beam of accelerated krypton ions was produced and transported to the finite radius of acceleration of the DC-280 cyclotron, and on 17 January 2019, the first beam of accelerated Kr ions was successfully extracted from the cyclotron.

The first experimental setup at the SHE Factory being prepared for operation with heavy-ion beams will be the GFS-2 gas-filled separator designed at FLNR and manufactured by SIGMAPHI (France). In 2018, the main assemblies of the GFS-2 separator and the power supply units were mounted, and the beam transport channel was prepared. A set of test experiments will be first carried out in order to achieve the design parameters of GFS-2, using fusion reactions of rare-earth elements with ^{40}Ar, ^{48}Ca, ^{50}Ti ions accelerated at the DC-280 cyclotron. In this set of experiments, it is necessary to study the transmission of GFS-2 at different thicknesses of the target, the resistance of targets to an increased beam intensity and accumulated dose, the clearing of background reaction products and other characteristics of GFS-2.

The first commissioning experiments at SHE will concern the synthesis of moscovium isotopes in the ^{48}Ca + ^{243}Am reaction and at the later stage — the study of the chemical properties of Fl and Cn. Further experiments to study chemical properties of superheavy elements as well as experiments on nuclear and mass spectrometry will be carried out using the GFS-3 gas-filled separator together with gas traps of reaction products. In April 2019 its installation will begin on Channel 2 of the DC-280 cyclotron; its startup is planned in the first quarter of 2020.

The programme will further be focused on preparing and conducting experiments on the synthesis of elements 120 and 119 in the reactions of ^{50}Ti beam with $^{249-251}$Cf and ^{249}Bk targets, respectively.

The PAC heard a report by S. Zemlyanoy on the progress of construction of the GALS separator of nuclear reaction products. The GALS setup, which uses a two-step separation method, based on stopping of nuclei in a gas cell, resonance laser ionization and separation in a magnetic field, will operate with beams of the U-400M cyclotron. In test experiments, it is planned to obtain Os isotopes in order to approach and synthesize isotopes in the region of the shell with $N = 126$.

The scientific report "Charged-current neutrino–nucleon reactions in the supernova neutrino-sphere" presented by A. Dzhioev was heard at the meeting.

The PAC reviewed poster presentations of new results by young scientists in the field of nuclear physics research. The best posters selected were "Upgrade of the GERDA experiment" by N. Rumyantseva, "Pygmy

and Giant dipole resonances in ^{48,50}Ca and ^{68,70}Ni" by N. Arsenyev, and "New systems based on extracting sorbents for the purification of low-background materials" by G. Marinov. "Upgrade of the GERDA experiment" was recommended for oral presentation at the session of the Scientific Council in February 2019.

The 49th meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 24–25 January. It was chaired by Professor D. L. Nagy.

The Chairman 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 124th session of the JINR Scientific Council and the decisions of the JINR Committee of Plenipotentiaries.

V. Shvetsov reported on the current state of the IBR-2 facility and the results of theoretical and experimental studies of the reactor's dynamical characteristics. The PAC appreciated the analysis of the technical conditions of the IBR-2 facility and FLNP's plans for its maintenance and upgrade; it also supported the efforts of the FLNP Directorate to secure the operational conditions of IBR-2.

D. Kozlenko presented the main scientific results in condensed matter research and instrumentation developments at the IBR-2 reactor obtained in 2018. The PAC appreciated the high scientific level of the results obtained at IBR-2 instruments and their interdisciplinary character. The PAC encouraged the continuous upgrade of the IBR-2 instruments, which will enable extension of the research areas and opportunities provided for the IBR-2 user community.

The PAC took note of the report by D. Chudoba on the statistics of the FLNP User Programme for the year 2018 and on the implementation of a new web application for the collection and evaluation of research proposals. Noting that the IBR-2 facility had been operating stably according to the User Policy Programme since 2012 and the fact that fewer than originally scheduled number of cycles was assigned for experiments in 2018 due to technical reasons at the reactor, the PAC recommended making detailed statistics and its analysis for each particular instrument with relation to the FLNP User Programme.

The PAC heard a report by G. Bokuchava about the current state of the Fourier stress diffractometer (FSD) at the IBR-2 facility. The PAC considered FLNP's achievements in developing correlation diffractometry to be particularly successful for the IBR-2 research programme; it will also welcome further suggestions for FSD potential improvements.

The PAC heard with interest the developments regarding the joint facility for structural research using synchrotron X-rays presented by N. Kučerka. Noting that the collaborative efforts taken by JINR and the SOLARIS centre of the Jagiellonian University in Kraków (Poland) will extend the variety of experimental approaches to the condensed matter research at JINR, the PAC expects more technical details on the potential scientific use of the proposed facility and on interaction with the infrastructure of the SOLARIS centre.

The PAC heard a number of reports concerning the development of a general concept for a new source of neutrons at JINR. In particular, the PAC appreciated the report on instrumentation and moderators at long-pulse neutron sources presented by F. Mezei, providing a comprehensive analysis of the main parameters of existing neutron sources and their instruments with a focus on ESS. The PAC also heard with interest the reports presented by A. Balagurov and A. Ioffe covering the present state and trends in the development of a concept for JINR's new neutron source following its discussion by the Working Subgroup (WSG) on Condensed Matter and Neutron Nuclear Physics of the Working Group for the preparation of JINR's strategic long-range development plan. The PAC noted the two proposals recommended by the WSG: the pulsed fast reactor IBR-3 (NEPTUN) and the pulsed neutron source driven by a proton accelerator (PLUTON). The PAC expects additional details on the proposals already made and for the instrumental suite of a new source.

The PAC took note of the intent to open new themes "Development of the critical design report for a new Dubna Neutron Source (DNS-IV)" and "Construction of a Laboratory for Structural Research of Macromolecules and New Materials at the SOLARIS National Synchrotron Radiation Centre of the Jagiellonian University in Kraków (Poland)", presented by V. Shvetsov, and recommended that full proposals on these themes be presented at its next meeting.

The PAC heard with interest the scientific reports: "Structure and properties of aqueous solutions of C_{60} and C_{70} fullerenes for biological applications", "Structural and functional properties of mutant NMDA synaptic receptors", and "CPT study of the Fermi surface reconstruction in the t–J model" presented by E. Kyzyma, E. Dushanov, and I. Ivantsov, respectively.

The PAC heard reports on conferences held: by M. Avdeev, on the Conference on Neutron Scattering in Condensed Matter (NSCM-2018) (Saint Petersburg, 17–21 September 2018); by A. Rogachev, on the international conference "Biomembranes-2018" (Moscow, 1–5 October 2018); and by V. Chausov, on the international conference "Modern Problems of Space Radiobiology and Astrobiology" (Dubna, 17–19 October 2018).

The PAC reviewed 16 poster presentations by young scientists in the field of condensed matter research. The poster "Clusterization aspects of fullerene C_{70} in toluene/N-methyl-2-pyrrolidone mixture according to SANS, SAXS and DLS data" by T. Nagorna was selected as the best poster at the session. The PAC also noted two other high-quality posters: "Investigation of

crystal and magnetic structure of nanostructured complex oxides of transition metals in wide temperature range" by N. Belozerova and "Isotope-identifying neutron reflectometry at the IBR-2 pulsed neutron reactor" by V. Zhaketov.

The 50th meeting of the Programme Advisory Committee for Condensed Matter Physics was held on 17–18 June. It was chaired by Professor D. L. Nagy.

The Chairman 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 125th session of the JINR Scientific Council (February 2019) and the decisions of the JINR Committee of Plenipotentiaries (March 2019).

The PAC heard a report on the concluding theme "Development of the IBR-2 Facility with a Complex of Cryogenic Neutron Moderators" and project "Construction of a complex of cryogenic moderators at the IBR-2 facility" presented by A. Vinogradov and recommended their extension for 2020–2022.

The PAC heard a proposal for the opening of a new theme "Development of the Conceptual Design of a New Advanced Neutron Source at JINR" presented by V. Shvetsov. Noting the significant progress achieved by the FLNP team in developing a technical justification for the concept of the new source and the necessity of developing a rationale for the scientific programme for the new source, the PAC recommended opening of this new theme for 2020–2022 and requested the theme leaders define a management structure, clear deliverables, milestones, and a time schedule for this theme.

The PAC heard the status and recent developments of the JINR–SOLARIS collaboration to develop the joint facility for structural research using synchrotron X-rays and a proposal for opening a new theme "Development of the SOLCRYS Structural Research Laboratory at the SOLARIS National Synchrotron Radiation Centre" presented by N. Kučerka. The PAC recommended the opening of this new theme for 2020–2022 and requested that parameters of the three proposed stations and their connections with the scientific programme and the international synchrotron landscape be reported at its next meeting.

The PAC heard a report on the concluding theme "Biomedical and Radiation-Genetic Studies Using Different Types of Ionizing Radiation" and project "Further development of methods, technologies, schedule modes and delivery of radiotherapy" presented by G. Mitsyn and recommended their extension for 2020–2022. The PAC emphasized the high importance of the results achieved both in the field of clinical research on proton radiotherapy applications for the treatment of different diseases and in the field of radiobiology. Particularly, it was stressed that the clinical research had entered a new phase, in which the statistical analysis of the treatment results became possible.

The PAC considered the report presented by K. Afanasyeva on the concluding project "Radiogene: Experimental justification of radiation genetic risk estimation according to the frequency of heritable DNA changes in human and animal structural genes" and recommended its extension for 2020–2022 with a new title "Radiogene: The molecular genetics of radiation-induced changes at the gene, genome and transcriptome level in *Drosophila melanogaster*". The PAC recognized the significant progress in the development of this project and the new fundamental data in the nature of radiation genetics of living organisms and frequency of inherited changes in the DNA of gene mutations induced by γ rays and fission neutrons.

The PAC heard a report on the concluding theme and project "Research on Cosmic Matter on the Earth and in Space; Research on the Biological and Geochemical Specifics of the Early Earth" presented by A. Rozanov and recommended their extension for 2020–2022. Thanks to the collaboration between JINR, the Russian Academy of Sciences, and other institutions, the Astrobiology Sector of LRB has become one of the leading sectors of research in this field. In 2017, a modern Tescan Vega 3 scanning electron microscope was put into operation, by which fossilized microorganisms in meteorites are searched for and studied. Eukaryotic microorganisms have been found in the Orgueil meteorite; these results have been published in the "Paleontological Journal" of the Russian Academy of Sciences.

The PAC heard a report on the concluding theme "Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data" presented by Gh. Adam and recommended its extension for 2020–2023. The PAC noted that issues of condensed matter physics addressed on this theme are represented through high-class computer support of the data acquisition and processing at IBR-2 spectrometers and through important computer developments for the numerical solution of theoretical models describing either dynamic phenomena or structural properties of complex materials of interest in JINR laboratories.

Based on the results reported by M. Avdeev, the PAC was satisfied with the progress 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".

The PAC took note of the overview of the current trends in neutron spectroscopy worldwide presented by J. Kulda. It also heard the presentation by D. Chudoba on the current state of inelastic neutron scattering instruments operating at IBR-2. The PAC supported the FLNP plans to prepare a proposal for a new project on the development of inelastic neutron scattering instruments at JINR.

The PAC took note of the information on the current activities of the Working Subgroup for Radiobiology and Astrobiology for the preparation of JINR's

strategic long-range plan presented by B. Sharkov and E. Krasavin and welcomed its efforts towards finalizing this document.

The PAC heard with interest the scientific report "Emergence of life in formamide-based origin scenario" presented by R. Saladino.

The PAC reviewed poster presentations by young scientists in fields of information technology and condensed matter physics. The poster "Investigations of polystyrene-fullerene nanocomposite thin films by neutron and X-ray reflectometry" by M. Karpets was selected as the best poster at this session and was recommended to be reported at the session of the Scientific Council in September 2019.

The 51st meeting of the Programme Advisory Committee for Particle Physics took place on 19–20 June. It was chaired by Professor I. Tserruya.

The Chairman 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 125th session of the JINR Scientific Council and the decisions of the JINR Committee of Plenipotentiaries.

The PAC heard a report on the progress towards realization of the Nuclotron–NICA project presented by S. Kostromin. The PAC supported the active work on the mounting of the Booster superconducting magnets inside the Synchrophasotron yoke, expecting the assembly and commissioning with beam to be completed by the end of 2019. It requested to improve the diagnostics of the accelerator complex in order to be able to deliver to the users well-identified beams without contaminations.

The PAC heard a report on the progress towards realization of the NICA/MPD presented by A. Kisiel. The PAC welcomed the admission of two new institutions to the MPD collaboration — the University of Warsaw and the China Institute of Nuclear Energy. It also welcomed the Collaboration's efforts to develop the detector elements as well as its computing and software infrastructure with a view to completing the first stage of the detector by 2021.

The PAC heard a report on the progress towards realization of the BM@N project presented by M. Kapishin. The PAC congratulated the BM@N team on the obtaining of first physics results on the production of lambda hyperons and encouraged it to shorten the time between data collection and release of preliminary results.

The PAC took note of the report on JINR's participation in the CMS experiment at the LHC presented by A. Zarubin. The PAC congratulated the JINR CMS group on the quality of the work carried out in various detector subsystems with major JINR responsibilities, including the forward muon station and the endcap hadronic calorimeter, which contributed to a smooth and stable running of the CMS detector throughout Run2. The Committee noted progress in physics studies with direct participation of JINR members: the study of muon pair production, including Drell–Yan processes, searches for physics Beyond the Standard Model (BSM), measurements of Higgs boson couplings and study of multiple jet production processes. It encouraged the group to better balance the detector maintenance and operation work with the physics studies.

The PAC appreciated the report on the status of the CMS detector upgrade presented by CMS Spokesperson R. Carlin and wished the Collaboration success in implementing such an ambitious plan.

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 PAC appreciated the progress in the various physics analyses with the JINR group responsibility in the ATLAS experiment, such as those defining the structure of the proton at ultrahigh energies, searching for physics BSM, searching for a valence-like nonperturbative component of heavy quarks in the proton, etc. The group members also contributed to the observation of associated production of Higgs boson with vector boson and of Higgs boson with $t\bar{t}$ quark pair, and to the search for the tH process. The PAC was pleased to note the large number of scientific publications with direct participation of JINR members and the consistency of the research subgroups.

The PAC took note of the report by V. Pozdnyakov on the involvement of the JINR group in physics analysis in the ALICE experiment at LHC which resulted in several publications. These include a new femtoscopic correlation analysis for pairs of opposite sign kaons that showed consistency with the predictions of hydrodynamic models. Event generators and software for analysis of heavy quarkonia production, developed with the participation of the JINR group, provided new results for the nuclear modification factors for $\Upsilon\,(1s)$ and $\Upsilon\,(2s)$ in Pb–Pb collisions at 5.02 TeV. The group will also contribute to the maintenance and development of the GRID–ALICE analysis at JINR and in the photon spectrometer upgrade. The PAC was concerned with the relatively low visibility of the JINR team working in ALICE as reflected, for example, by the lack of talks at the major conferences in the field. It strongly encouraged the group leader to take actions to attract young scientists and students into the project aiming at a strong impact and visibility.

The PAC recommended continuation of JINR's participation in all three LHC projects for 2020–2023, with first priority, pending the setting in place of corrective actions to address the above-mentioned concerns.

The PAC heard a report on the SCAN-3 project presented by S. Afanasiev, which is aimed at the study of highly excited nuclear matter through observation of its decay products at the Nuclotron, noted the expertise of the authors of this project, and recommended its continuation for 2020–2022 with first priority.

The PAC took note of the report on realization of the NA64 experiment at SPS presented by V. Peshekhonov. Recognizing the excellent role played by the JINR team in the design, production, test and installation of the straw tube chambers in the NA64 experiment, the PAC noted that the recommendations made at the joint meeting of two PACs in January 2019 to improve the ratio of FTE to participants, to attract students and to get involved in data analysis were not properly addressed in the presented material. The PAC postponed any recommendation on the project till the authors present to the PAC, not later than at its next meeting, a revised proposal and recommended that the JINR management provide sufficient resources to the group to allow continuation of their work and commitments.

The PAC heard a report on the development of the JINR Multifunctional Information and Computing Complex (MICC) presented by T. Strizh. The PAC was pleased to note that LIT had successfully fulfilled JINR's computing needs for all its activities both in-house and outside. It recommended continuation of the MICC project for 2020–2023 with first priority.

The PAC took note of a new project FASA at the Nuclotron presented by S. Avdeev aimed at the study of space-time characteristics of hot nuclei formed in the collisions of light relativistic ions with heavy targets. The PAC requested the authors to present an improved proposal, to sharpen the scientific case and to present details on the target thickness, the identification power of their telescopes for He and Be isotopes, and a simulation of the performance of the experiment in comparison with theoretical predictions.

The PAC reviewed 17 poster presentations in particle physics by young scientists from LIT, VBLHEP and DLNP, and selected the poster "Neutrino oscillation analysis in the NOνA experiment" presented by L. Kolupaeva to be reported at the session of the Scientific Council in September 2019.

The 50th meeting of the Programme Advisory Committee for Nuclear Physics was held on 24–25 June. 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. Additional information on the recent progress in the construction and commissioning of the Factory of Superheavy Elements (SHE) was presented by FLNR Director S. Dmitriev. JINR Vice-Director M. Itkis informed the PAC about the Resolution of the 125th session of the Scientific Council (February 2019) and about the decisions of the Committee of Plenipotentiaries (March 2019).

The PAC heard reports on the theme "Information and Computing Infrastructure of JINR" and the report on the project of the "Multifunctional Information and Computing Complex (MICC)", included in the theme, presented by T. Strizh. The PAC supported the development of JINR information systems aimed at providing information and software support for JINR's scientific research; approved the activities of LIT to develop a system for training and retraining IT-specialists based on the JINR MICC and its educational components, which is aimed at acquainting young scientists and specialists of JINR and its Member States with state-of-the-art techniques of solving applied problems on novel computing architectures. The PAC recommended extension of the theme and of the project for 2020–2023 with first priority.

The PAC heard a report on the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron" presented by E. Lychagin. The PAC was satisfied with the high-quality results obtained under the theme, the achievements in the research of fundamental symmetries with polarized neutrons, the wide range of excellent results in the field of applied research within international programmes, and the importance of the work for the development of the accelerator facility carried out at IREN. The PAC recommended extension of the theme for 2020–2022 with first priority.

The PAC heard a report on the project "Research and development of the tagged neutron method for identification of the elemental structure of matter and studies of nuclear reactions" (TANGRA) presented by Yu. Kopatch. The use of BGO crystals and HP-Ge detectors resulted in significant improvements of γ-ray energy resolution. The PAC recommended extension of the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron" and of the TANGRA project 2020–2022 with first priority.

At the meeting, two letters of intent to prepare new projects within this theme were presented. The PAC recommended that the authors prove the stability and the calibration accuracy of the detector for measurement of the neutron lifetime using the time-of-flight method and propose a realistic design of the cryostat for the construction of a facility for polarization of neutrons and nuclei.

The PAC heard information about FLNP's proposal for the opening of a new theme "Development of the Conceptual Design of a New Advanced Neutron Source at JINR" presented by V. Shvetsov. The Committee supported the need to construct a world-class neutron source at JINR to maintain its leading positions in condensed matter research and neutron physics.

The PAC heard a report on the project "GDH&SPASCHARM&NN" presented by Yu. Uzikov. The project consists of three independent experimental activities connected by the study of the nucleon spin structure in strong and electromagnetic interactions, and technically strongly supported by the frozen spin polarized proton and deuteron targets developed and maintained by the Dubna group.

The GDH experiment at MAMI-C (Mainz) is carried out with a new polarized target using a horizontal

^{3}He/^{4}He dilution refrigerator to be used with the Crystal Ball and TAPS spectrometer. The SPASCHARM experiment is under way at IHEP (Protvino), using high-energy proton and antiproton beams. The NN experiment in Prague using a polarized 14-MeV neutron beam with a polarized deuterium target aims to study the $3N$ forces in strong (nd) interactions.

The PAC acknowledged the important role of the Dubna group, noting that it should actively continue to take part in all three experiments, and recommended extension of the project for 2020–2022 with first priority.

The PAC heard a report on the project "Study of deeply subcritical electronuclear systems and their applications for energy production, SNF (NFW) transmutation and research in the field of radiation materials science" (E&T&RM) presented by A. Baldin. Emphasizing the positive aspects of the project, e.g., possibility to study recycling of the spent nuclear fuel, development of new neutron detectors, with comparison of Monte Carlo simulations with experimental results, the PAC recommended extension of the project until the end of 2020 with first priority.

The PAC heard a proposal for the opening of a new project "Construction of a prototype of the initial section of a high-current heavy-ion linear accelerator aimed at producing intense radioactive ion beams for basic research" presented by L. Grigorenko. The proposed work plan aims to construct a prototype of the initial section of the linear accelerator and a design of LINAC-100. The project was recommended to be opened for the two-year period 2020–2021.

The PAC heard a report on the first results of the experiments performed with the ACCULINNA-2 fragment-separator presented by A. Fomichev. The highly intense ^{8}He and ^{9}Li radioactive beams obtained by ACCULINNA-2, installed in the channel at the U-400M cyclotron, were used to study the production and decay of $^7\mathrm{H} \to t + 4n$ and $^{10}\mathrm{Li} \to n + {}^9\mathrm{Li}$, respectively. The preliminary results of the first experiment have been submitted for publication and the data analysis of the second experiment is still in progress.

The PAC heard with great interest the report "Transverse momentum distributions of hadrons in the Tsallis nonextensive statistics" presented by A. Parvan.

The PAC reviewed 13 poster presentations in the field of nuclear physics research by young scientists from LIT and FLNP. The best posters selected were: "T-odd angular correlations in the emission of prompt gamma rays and neutrons in the fission of uranium by polarized neutrons" presented by D. Berikov, "Measurements of gamma ray yields from (n, $x\gamma$) reactions at the TANGRA set-up" presented by N. Fedorov, and "Monte Carlo study of systematic errors in the measurement of the scattering of ^{15}N ions by ^{10,11}B" presented by I. Satyshev. The poster "T-odd angular correlations in the emission of prompt gamma rays and neutrons in the fission of uranium by polarized neutrons" was recommended for presentation at the session of the Scientific Council in September 2019.

PRIZES AND GRANTS

The ***N. Bogoliubov Prize*** was awarded 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;

— Professor 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 ***B. Pontecorvo Prize*** was awarded to F. Gianotti (CERN) for her leading contributions to the experimental studies of fundamental interactions and to the discovery of the Higgs boson.

JINR PRIZES FOR 2019

I. Theoretical Physics Research

First Prize

"Theory of groups and symmetries. Representations of Lie groups and algebras. Applications".

Authors: A. Isaev, V. Rubakov.

Second Prizes

1. "Study of multinucleon transfer reactions as a method for production of new heavy and superheavy nuclei".

Authors: A. Karpov, V. Saiko.

2. "*Ab initio* quantum-chemical approach to the study of the crystal field and quantum magnetism in transition metal oxides".

Authors: L. Siurakshina, V. Yushankhai, P. Fulde, L. Hozoi, J. van den Brink.

II. Experimental Physics Research

First Prizes

1. "Measurement of the energy spectra of reactor antineutrinos in the DANSS project".

Authors: V. Belov, V. Brudanin, I. Zhitnikov, S. Kazartsev, A. Kuznetsov, D. Medvedev, M. Fomina, E. Shevchik, M. Shirchenko, Yu. Shitov.

2. "Detailed study of the structure of ^{6}Be in the charge-exchange reaction ^{1}H(^{6}Li, ^{6}Be)n".

Authors: V. Chudoba, L. Grigorenko, M. Golovkov, A. Gorshkov, S. Krupko, S. Sidorchuk, E. Nikolskii, G. Ter-Akopian, A. Fomichev, P. Sharov.

Second Prize

"Study of rare and search for forbidden decays of charged kaons".

Authors: E. Goudzovski, V. Kekelidze, D. Madigozhin, M. Misheva, Yu. Potrebenikov, S. Shkarovskiy.

III. Physics Instruments and Methods

First Prize

"Development, construction and commissioning of the DC-280 cyclotron of the Factory of Superheavy Elements at FLNR, JINR".

Authors: B. Gikal, G. Gulbekian, S. Dmitriev, I. Ivanenko, N. Kazarinov, I. Kalagin, N. Osipov, S. Pashchenko, N. Pchelkin, V. Semin.

Second Prizes

1. "Innovative method of increasing the light collection from scintillation detectors of the Mu2e experiment veto system".

Authors: A. Artikov, Ju. Budagov, I. Vasiliev, V. Glagolev, Yu. Davydov, A. Simonenko, Yu. Kharzheev, D. Chokheli, E. Dukes, C. Group.

2. “First stage of the BM@N GEM central tracking system”.

Authors: A. Galavanov, S. Vasiliev, E. Kulish, M. Kapishin, A. Makankin, A. Maksymchuk, S. Khabarov.

IV. Applied Physics Research

First Prizes

1. “Application of neutron diffraction to study structural and microstructural transformations of Li-ion electrode materials during operation”.

Authors: I. Bobrikov, A. Balagurov, N. Samoylova, S. Sumnikov, O. Ivanshina, R. Vasin.

2. “Research on molecular damage formation in genetic structures of human and mammalian cells after exposure to low- and intermediate-energy accelerated heavy ions”.

Authors: A. Boreyko, T. Bulanova, M. Zadnepryanets, E. Krasavin, E. Kruglyakova, E. Smirnova, G. Timoshenko.

Second Prize

“Neutron radiography and tomography at the pulsed high-flux IBR-2 reactor: Development of the experimental facility and results of the interdisciplinary applied research”.

Authors: D. Kozlenko, S. Kichanov, A. Belushkin, E. Lukin, K. Nazarov, A. Rutkauskas, G. Bokuchava, B. Savenko, I. Saprykina.

V. Encouraging Prize

“Features of population of isomeric states in reactions with weakly bound nuclei”.

Authors: N. Skobelev, Yu. Penionzhkevich, S. Lukyanov, Yu. Sobolev, V. Burjan, J. Mrázek, E. Šimečková, N. Demekhina.

GRANTS

In 2019, 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 Belarussian Republican Foundation for Basic Research (BRFBR), the Ministry of Science and Higher Education of RF, and the Foundation of 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” (22 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”)” (7 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)” (9 projects); “Competition of the Best Projects of Interdisciplinary Fundamental Research” (2 projects); “Competition of Oriented Fundamental Research in Urgent Interdisciplinary Topics” (1 project); “Competition of the Best Projects of Organization of Scientific Events” (2 projects); “Competition for Financial Support for Preparation and Publication of Scientific Review Papers” (2 projects).

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 (1 project); together with the National Scientific Foundation of Bulgaria (2 projects); 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 (1 project); together with the German Scientific-Research Community (2 projects); together with the National Centre of Scientific Research of France (3 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” (6 projects), “Holding of Fundamental Scientific Research and Scientific Research by International Scientific Communities” (2 projects), “Holding of Initiative Research by Young Scientists” (1 project), “Holding of Research on the Basis of Existing Scientific Infrastructure of the World Level” (2 projects).

Five projects were financed in 2019 in the framework of the joint competition of BRFBR and JINR.

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”.

2019

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 2019 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 42 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 3229 specialists;

— for joint work and consultations, as well as for participation in meetings, conferences, and schools held at JINR, 1812 specialists were received;

— 43 international scientific conferences and schools, 25 workshops, and 20 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.

On 10–29 January, the representatives of JINR took part in the Physics School, which was held at iThemba LABS (Republic of South Africa). Annually in the framework of the school, students are chosen from universities in South Africa to participate in the International Student Practice of the JINR University Centre held at JINR. At the event, Professor A. Belushkin told the students about fundamental and applied research conducted at JINR's FLNP. Researcher of the Bogoliubov Laboratory of Theoretical Physics of JINR Dr. A. Gladyshev gave a lecture on particle physics and cosmology, and Director of the JINR University Centre Professor S. Pakuliak introduced the participants to the main fields of scientific research conducted at JINR, and spoke about the training programmes implemented on the basis of the Institute.

On 29 January, a festive ceremony of opening the International Year of the Periodic Table of Chemical Elements (IYPT2019) was held in the UNESCO headquarters in Paris (France). Minister of Science and Higher Education of Russia M. Kotyukov, President of the Russian Academy of Sciences A. Sergeev, President of the Academy of Sciences of France P. Corvol, and UNESCO Director-General A. Azoulay took part in the event.

JINR was represented by Director Academician V. Matveev, Vice-Director M. Itkis, FLNR Director S. Dmitriev, FLNR Scientific Leader Yu. Oganessian and FLNR Scientific Secretary A. Karpov. Reports were given by the world-known scientists: B. Feringa (laureate of the 2016 Nobel Prize in Chemistry), Sir M. Poliakoff (Vice-President of the Royal Society, author of the "The Periodic Table of Videos"), Professor Yu. Oganessian and other outstanding representatives of the international scientific community.

In total, the number of participants and guests of the event exceeded 1300 persons from 80 countries of the world — scientists, politicians, leaders of international, scientific and educational organizations, representatives of business companies and public societies.

As part of the opening of the International Year of the Periodic Table of Chemical Elements, an interactive exhibition devoted to chemistry and its modern achievements was organized, where guests could see the exposition from JINR. The programme of the event in Paris included reports of well-known scientists, Nobel laureates, presentations of young talented scientists, interactive scientific shows, musical performances, etc.

On 4–8 February, the international training programme for decision-makers in science and international scientific cooperation "JINR Expertise for Member States and Partner Countries" (JEMS) was held for the 10th time at JINR. Senior officials and specialists from relevant state institutions, educational and scientific organizations of the Czech Republic, Egypt, Poland, Romania, the RSA, Russia and Serbia came to JINR to participate in JEMS-10.

Traditionally, the agenda of the training programme included lectures and presentations on the principles of the organization, scientific research and fields of the JINR activities, the detailed acquaintance with the JINR research infrastructure and activities of all JINR laboratories, and a review lecture on the social infrastructure of the Institute. The programme was concluded by a round-table discussion chaired by JINR Vice-Director R. Lednický on the results of JEMS-10 and presenting the diplomas to the participants. Ambassador Extraordinary and Plenipotentiary of the Arab Republic of Egypt I. Nasr, who came to JINR on that day with a working visit, took part in the round-table discussion.

On 6 February, events of the International Year of the Periodic Table of Chemical Elements started in Russia. In Moscow, in the RAS Presidium the opening ceremony of the International Year of the Periodic Table of Chemical Elements was held, wchich was dedicated to the Day of Russian Science and the birth of D. I. Mendeleev. The general partner of the International Year of the Periodic Table of Chemical Elements is the Charity Foundation "Art, Science and Sport".

Chairman of the RF Government D. Medvedev opened the festive ceremony. RAS President A. Sergeev, Minister of Science and Higher Education of Russia M. Kotyukov, Minister of Education of Russia O. Vasilieva, and MSU Rector V. Sadovnichy took part in the ceremony. RAS President Academician A. Sergeev and Vice-President of the Royal Society Sir M. Poliakoff gave lectures.

Among the guests there was First Deputy Minister of Science and Higher Education of RF, JINR Director on science Academician G. Trubnikov. JINR was represented at the ceremony by JINR Director Academician V. Matveev, FLNR Director S. Dmitriev, FLNR Scientific Leader Academician Yu. Oganessian and FLNR Scientific Secretary A. Karpov.

A relocatable international exposition was opened in the framework of the event, which was dedicated to chemistry and its modern achievements. Earlier it was shown at the opening of the International Year in Paris in the UNESCO headquarters. The stand of JINR was devoted to the synthesis of superheavy elements and the new accelerator DC-280. During the jubilee year the chemical exhibition under the aegis of UNESCO will travel around the world.

On 8 February, Ambassador Extraordinary and Plenipotentiary of the Arab Republic of Egypt I. Nasr visited JINR. During the meeting at the JINR Directorate with JINR Director Academician V. Matveev, JINR Vice-Director R. Lednický, and Head of the JINR International Cooperation Department D. Kamanin, further measures were discussed as part of the roadmap for the development of cooperation of Egypt and JINR signed in December 2018 in Cairo as the result of the 8th session of the Joint Committee on ARE–JINR Cooperation. The discussion was held with the participation of Deputy Chairman of the Egyptian Atomic Energy Authority (EAEA) Kh. Sakr, Professor of the Nuclear Research Centre of the EAEA A. Hassan, Advisor to the Embassy Kh. Shaalan and Head of the national group of Egypt at JINR W. Badawy.

I. Nasr also attended the round-table ceremony of awarding certificates to participants of the 10th international training programme for decision-makers in science JEMS. In his speech at the event that concluded JEMS-10, the Ambassador noted that he saw good prospects for active development of cooperation both with African countries and with JINR in light of the creation of the first nuclear energy reactor in Egypt jointly with the Rosatom State Atomic Energy Corporation. He also met with representatives of local mass media and made comments on the results of his visit to JINR.

On 8 February, in the House of the Government of the Moscow Region, Governor of the Moscow Region A. Vorobyev, Rector of the Bauman Moscow State Technical University A. Aleksandrov, and Director of the Joint Institute for Nuclear Research V. Matveev signed an agreement on cooperation according to which the International School of Engineering would be opened in Dubna.

After signing of the document, V. Matveev noted that graduates of the International School of Engineering would be engaged in the implementation of the projects of the Joint Institute for Nuclear Research, in particular, the Factory of Superheavy Elements and the NICA collider, as well as in work of residents of the Special Economic Zone "Dubna".

On the occasion of the Day of Russian Science, Governor of the Moscow Region A. Vorobyev presented state and regional awards to the best scientists of the Moscow Region. Scientific Leader of the JINR Flerov Laboratory of Nuclear Reactions RAS Academician, Professor, Doctor of Physics and Mathematics Yu. Oganessian was awarded the Order "For Merit to the Fatherland", 2nd class.

Director of the JINR Laboratory of Radiation Biology RAS Corresponding Member, Professor, Doctor of Biology E. Krasavin and Director of the JINR Flerov Laboratory of Nuclear Reactions Professor, Doctor of Physics and Mathematics S. Dmitriev were awarded the Medal of the Order "For Merit to the Fatherland", 1st class.

On 12–13 February, the 29th regular meeting of the Joint Committee on Cooperation of the National Institute of Nuclear and Particle Physics of France (IN2P3) and JINR was held in Dubna. The French party at the meeting was represented by IN2P3 Director R. Pain, Scientific Directors P. Verdier, F. Farget, J. L. Biarrotte, V. Beckmann and Head of the IN2P3 International Cooperation Office Th. Palychata. The JINR delegation was headed by Director V. Matveev.

Latest information was exchanged on scientific priorities and the status of scientific projects implemented by the parties. The leaders of the JINR laboratories presented short reports on the progress in the implementation of the main projects of the Institute. Participants discussed the planned scientific exchange in the framework of 20 joint projects for 2019. The meeting of the Committee was concluded by signing of several agreements formalizing the conduct of joint work.

At the end of the meeting, the French delegation visited the Factory of Superheavy Elements of FLNR, where the separator for spectrometry of superheavy elements SHELS, which was assembled by the French high-tech company SigmaPhi, evoked special interest among the guests. At VBLHEP, the French delegation observed the constructed objects of the NICA collider and the factory of superconducting magnets.

On 14 February, a joint meeting of the Directorate and the Science and Technology Council (STC) of JINR was held in the International Conference Hall under the chairmanship of R. Jolos.

VBLHEP Director V. Kekelidze informed the audience on the status of the NICA project, speaking in detail about the main stages of ambitious efforts of the laboratory community and collaborators from scientific centres and enterprises from Russia and other countries. R. Jolos, I. Meshkov and V. Matveev adressed questions and comments to the speaker.

On the suggestion of the STC chairman, participants discussed most important scientific results of the laboratories that were to be presented in the review report of the JINR Director at the coming 125th session of the Scientific Council.

FLNP Director V. Shvetsov spoke about problems in the operation of the IBR-2 reactor, the basic facility, and measures to overcome them. He informed the participants about the completion of the five-year work to develop the new movable reflector PO-3 and about work to improve the user programme of the laboratory. He also indicated brightest scientific research of 2018 and spoke about the upgrading of the IREN facility and development of innovation activities. Comments were made by A. Malakhov and V. Matveev.

Important results obtained at LRB were reviewed by Director of the laboratory E. Krasavin. He noted, in particular, that in radiation therapy a new method is proposed and studied for increasing biological efficiency of the medical proton beam. First results were reported to RAS President A. Sergeev and General Director of FSBI "NMRC of Radiology" of the RF Ministry of Health Academician A. Kaprin. A new collaboration is established on application of this method in medical practice. V. Shvetsov, D. Naumov, R. Tsenov, I. Meshkov and A. Malakhov took part in the discussion of the report.

On 15 February, the gala-festival of Czech and Slovak culture was held at the JINR Cultural Centre "Mir". In the large concert hall of the Cultural Centre, JINR Vice-Director R. Lednický, the representatives of the Slovak Embassy in Moscow and the Czech Cultural Centre, and the organizer of the event from the Czech national group at JINR P. Dognal welcomed the audience. The concert part of the festival was opened by creative ensembles of Dubna: the Cultural Centre "Mir" academic choir "Belcanto" that performed a Russian folk song and a Slovak polka, and the children's dance band "Cheerful Academy" (orig. "Veselaya Academia") of the Centre of Children's Art.

In the exhibition hall, visitors were presented two art exhibitions: the watercolours "Three Days in Prague" and the illustrations for children's books "12 Worlds" offered by the Czech Cultural Centre in Moscow. An exhibition was organized of the book "The Good Soldier Švejk" by J. Hašek from private libraries. Books were also exhibited which were gifted to the JINR Universal Public Library by their authors.

Before the concert of the Slovak folk group, the audience could become familiar with the Slovak national musical instruments. The folklore performance of the Slovak ensemble was accompanied by colorful videos introducing architectural landmarks and unique natural beauties of Slovakia and the Czech Republic.

On 21 February, a delegation of the Republic of Zambia headed by Minister of Foreign Affairs of Zambia J. Malanji visited JINR. The delegation came to Dubna represented by Ambassador of Zambia to the Russian Federation Sh. Luwita and Chief Executive Officer of the Industrial Development Corporation of Zambia M. Kaluba, accompanied by representatives of the Ministry of Foreign Affairs of Zambia, the Office of the President of Zambia, the Embassy of Zambia in Russia and the Industrial Development Corporation of Zambia. Representatives of the RF Ministry of Foreign Affairs accompanied the delegation during the visit to Dubna.

The guests had an excursion to FLNP and FLNR. At the meeting with the JINR leaders, the sides discussed the organization of cooperation in issues connected with the construction of the first research reactor in Zambia and the Centre for Nuclear Science and Technology, as well as opportunities in training staff on JINR basis.

On 23 February, a delegation from the Republic of Uganda headed by Minister of Science, Technology and Innovation E. Tumwesigye visited JINR. Representatives of the Ministry, state bodies, industrial and scientific organizations of Uganda, as well as Counsellor Ambassador of the Embassy of Uganda in the Russian Federation R. Gideon Mvebase, came to Dubna as members of the delegation. The delegation arrived at Dubna accompanied by executive officers of the Ministry of Science and Higher Education of Russia and a working group of the Russian–Ugandan Intergovernmental Commission.

JINR Vice-Director M. Itkis welcomed the delegation from Uganda. The guests had an excursion to the

Frank Laboratory of Neutron Physics, where they were acquainted with opportunities of the research reactor IBR-2 and the practical application of neutron activation analysis in the projects of monitoring the environment at the REGATA facility. At the Flerov Laboratory of Nuclear Reactions, the guests visited the Factory of Superheavy Elements.

The working meeting of the delegation with JINR representatives was devoted to discussion of possible formats and mechanisms of participation of Uganda in JINR activities, including international educational programmes.

From 25 February to 5 March, a team of JINR staff members headed by JINR Vice-Director B. Sharkov worked in Havana (the Republic of Cuba). Their aim was to get acquainted with tasks and opportunities of the Centre for Advanced Research of Cuba and to discuss plans for cooperation and joint research.

The key target of the Centre created since 2006 is research and developments in the fields of nanoscience and nanotechnologies. Laboratories of the Centre have pure premises and are well equipped with the advanced analytical equipment, including facilities for scanning and fluorescent microscopy, liquid chromatography, mass spectrometry and many others.

As a result of conversations, directions of joint work were defined in the fields of production and study of new nanomaterials using ion-tracking technology, the use of track-etched membranes in biomedicine, pharmaceutical industry, agriculture and water cleaning; the study of the structure and properties of nanoparticles in biological objects; the use of nuclear methods, including synchrotron irradiation and neutron beams to determine properties of nanoparticles; in the fields of mathematical modelling of nanostructures and high-performance computing, and also plans for joint training of staff were worked out.

Working visits were held with the staff members of the National Centre of Biopharmaceuticals and the Cuban Neuroscience Centre, as well as with First Deputy Minister of Science, Technology and Environment of the Republic of Cuba F. Gonzalez and Ambassador of the Russian Federation to Cuba A. Guskov.

On 26 February, a meeting of the JINR Organizing Committee for independent awarding of academic degrees was held. Director of the Department of Attestation of Scientific and Pedagogical Staff of the RF Ministry of Science and Higer Education S. Pakhomov, Deputy Director of the Department E. Loginova and Chief Scientific Secretary of the Higher Attestation Commission (VAK) under the RF Ministry of Science and Higher Education I. Matskevich took part in the event.

General issues of the state attestation system of scientific and scientific-pedagogical staff of Russia were discussed; the experience of participating organizations of the pilot project for independent awarding of scientific degrees and the progress towards formation of a new system for dissertation defence in JINR were also considered. The Director of the Department gave a positive evaluation on the present state of drafts of JINR formal documents regulating the Institute's right to award scientific degrees independently.

During the visit to Dubna, representatives of the Department and the VAK visited the DC-280 accelerator at FLNR. At VBLHEP they had an excursion to the construction site of the NICA collider, the factory of superconducting magnets, the building of the Nuclotron and the site of assembling the booster's elements for the NICA complex.

On 6 March, the annual JINR Staff Conference on Implementation of the Collective Agreement between JINR Directorate and JINR Staff for 2017–2020 was held. JINR Director V. Matveev and Chairman of the Joint Trade Union Committee (JTUC) V. Nikolaev spoke at the event.

JINR Director V. Matveev informed the participants about the main results of JINR activities in 2018. The decisions to increase the budget were fulfilled; new normative documents are being prepared: new Provisions on Personnel, Provisions for Budget Adjustment, a document on purchase system. At the drafting stage is the strategy for development of the Institute up to 2030, meeting world tendencies of science development. The Public Council actively interacts with the local administration. V. Matveev paid special attention to activities in development of the social infrastructure of JINR: solution of housing issues of JINR staff members and problems in medical service.

The participants of the conference heard detailed information on implementation of the Collective Agreement between JINR Directorate and JINR Staff for 2017–2020 in 2018, presented by JTUC Chairman V. Nikolaev. The conference decided to consider the tasks adopted by the sides on the Collective Agreement between JINR Directorate and JINR Staff for 2017–2020 in 2018 accomplished.

According to suggestions made by delegates, JTUC must prepare and forward the following addresses: to the head of the city with a request to provide for implementation of the decisions of the JINR Public Council on upgrading of the embankment of the Volga River; to the Ministry of Health of the Moscow Region with a request to arrange establishment of conditions for provision of the quality and accessibility of health service in Medical Unit 9, according to functional normative documents (in accordance with the administration of JINR and Medical Unit 9).

On 14–15 March, a meeting of the Nuclear Physics Section of the Physical Sciences Department of the Russian Academy of Sciences was held in the International Conference Hall dedicated to scientific-technological and industrial cooperation in design and

development of a research infrastructure of the megascience class in the territory of the Russian Federation. The previous meetings of this Section on the topic were held in the Russian federal nuclear centres ARSRITP (Snezhinsk, October 2017) and ARSRIEP (Sarov, June 2018).

During the meeting, reports were heard and results were discussed on high energy physics and the NICA megaproject, issues of development of computer technology, neutrino physics, nuclear physics and neutron physics, charged particle accelerators, physics experiment technology, and applied research. The participants of the meeting had an excursion to VBLHEP, where they were shown the NICA accelerator complex under construction, and visited the Factory of Superheavy Elements at FLNR.

Reports were made by leading scientists and specialists from Russian scientific centres. The following reports were made about JINR projects: by I. Meshkov on the NICA project, V. Aksenov on "The Dubna Neutron Source of the Fourth Generation", Yu. Oganessian on the federal project "Synthesis and Properties of Superheavy Elements", and by L. Grigorenko on "Intensive Beams of Radioactive Ions for Research in Physics of Exotic Nuclei".

On 25 March, as part of the regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States, the ceremonial opening of the experimental hall of the Factory of Superheavy Elements and launch of its basic facility — the DC-280 cyclotron — were held at the Flerov Laboratory of Nuclear Reactions.

JINR Director V. Matveev addressed the participants of the CP session and guests, as well as representatives of the central and Dubna mass media who gathered in front of the building of the Factory of Superheavy Elements, where the DC-280 cyclotron is installed, with a brief speech: "As we know, today the Mendeleev Table already contains 118 elements. The scientists of our Institute discovered ten of them. Undoubtedly, it is great success of our multinational community and those scientists who were pioneers in this trend. They are Georgy Nikolaevich Flerov and Yuri Tsolakovich Oganessian. Their names are forever imprinted in the names of the new elements in the Mendeleev Table — flerovium and oganesson. Element 115 was named moscovium in gratitude to the Moscow Region, where such wonderful conditions for work were created. I kindly invite everybody to take part in this outstanding event — the launch of the unique accelerator complex DC-280".

A symbolic red ribbon of the Factory's experimental building was cut by JINR Director Academician V. Matveev, Plenipotentiary of the Government of Russia to JINR RF Minister of Science and Higher Education M. Kotyukov, Plenipotentiary of the Government of the Republic of Bulgaria to JINR Professor L. Kostov, who headed the CP in the years of the Factory's construction, Director of the UNESCO Division of Science Policy and Capacity Building P. E. Oti-Boateng, and President of the CERN Council U. Bassler.

After visiting the accelerator hall and seeing the new cyclotron, the participants were invited to the conference hall of FLNR where the scientific leader of the laboratory Academician Yu. Oganessian made a report on the history of the synthesis of superheavy elements and prospects that are opened with the launch of the SHE Factory.

The ceremonial launch of DC-280 was implemented in the mode of video communication from the cyclotron control room. V. Matveev commanded to launch the cyclotron. S. Dmitriev led the process of beam acceleration and tracking and, after the demonstration of the extracted beam, announced the fulfilled launch of the new JINR accelerator — the DC-280 cyclotron.

M. Kotyukov said in his congratulatory address: "I am very happy to be present at this outstanding event. It is the result of our mutual work. It is due to tremendous efforts of the Institute community that such serious results were obtained in short enough time. This result is an amalgam of science, engineer ideas and most advanced technology today. It is the result of great international scientific and technical cooperation. It is our mutual victory of scientists, engineers, experts and technologists. I am sure that the interest in events in Dubna will grow year by year. There is no doubt that this project will bring us many new and positive solutions and achievements. It is not the last but only the latest element of development of the Joint Institute for Nuclear Research and science in Russia. . ."

The guests from UNESCO and CERN P. E. Oti-Boateng and U. Bassler, as well as Head of Dubna M. Danilov, congratulated the audience on the outstanding event at the Joint Institute.

The last item in the CP session agenda was the ceremonial opening, in front of the main entrance to the administration building of FLNR, of the alley named after Academician Andrzej Hrynkiewicz, a famous Polish scientist whose life was closely connected with Dubna and his scientific career with the Laboratory of Nuclear Reactions. On this occasion a photo booklet "Andrzej Hrynkiewicz. 1925–2016" was issued with texts by M. Budzyński, M. Waligórski, W. Chmielowski, Yu. Oganessian, and M. Itkis, prepared by staff members of the Scientific Information Department and published by the JINR Publishing Department.

On 26 March, a ceremonial event on the occasion of the celebration of the 63rd anniversary of foundation of the Joint Institute for Nuclear Research was held at the Cultural Centre "Mir". Participants of the session of the Committee of Plenipotentiaries of the Governments of the JINR Member States, guests from embassies and leaders of scientific centres from Member States and

countries that cooperate with JINR, representatives of diplomatic missions, the city administration, leaders of Dubna enterprises, veterans, JINR staff members and citizens of Dubna gathered for the celebration.

JINR Director RAS Academician V. Matveev greeted the audience. He spoke about the latest achievements at the Institute that were highly estimated by CP: the inauguration of the building of the Factory of Superheavy Elements and the launch of the DC-280 cyclotron, the commission of the fourth cluster of the neutrino deep-water telescope in Lake Baikal, the start of the engineering school established in late 2018 in collaboration of the Dubna State University and the Bauman Moscow State Technical University, the signing of the decision to establish in Dubna a physics and mathematics lyceum named after V. Kadyshevsky by Governor of the Moscow Region A. Vorobyev.

The celebration continued with the traditional ceremony of awarding school teachers of Dubna who won the competition for JINR grants. This year, 18 teachers from the city schools took part in the competition. On the decision of the jury under the chairmanship of V. Matveev, 10 best of them were chosen: L. Balakshina (lyceum "Dubna", physics), L. Barminskaya (lyceum 6, informatics), N. Mikhaleva (school 11, mathematics), S. Moiseeva (school 10, mathematics), I. Smirnova (school 8, physics), E. Stepanova (school "Dialogue", supplementary education), N. Trusova (school 1, chemistry), M. Fedoseeva (school 3, informatics), M. Churinova (school 7, primary education), and O. Shakhalova (lyceum "Dubna", biology).

The event was crowned with the performance of the State Academic Big Symphonic Orchestra named after P. I. Tchaikovsky under the guidance of D. Lotoev.

On 2 April, on the eve of the opening of the first International Users Workshop on online experiments RAON (Rare isotope Accelerator complex for ON-line experiment, Daejeon, Korea) (https://indico.ibs.re.kr/event/285/overview), an outstanding event took place: a memorandum of understanding between JINR and the Korea University was signed.

The festive ceremony was the result of long-standing cooperation among staff members of the institutions of the two countries and the logical continuation of the course taken during the visit of the Korean delegations to JINR in August and December 2018. Staff members of FLNR E. Nikolsky, L. Grigorenko and A. Fomichev took part in the ceremony. They made reports about experiments with radioactive beams.

The Korean delegation was represented at the highest level: by Vice-President of the University Professor Cheung-O An and his colleagues. After the signing of the protocol, a fruitful discussion on plans for further joint work was held and the sides exchanged souvenirs.

On 3 April, a meeting of the Russian Federation–China working group on implementation of the NICA megascience project was held in Dubna. The meeting was co-chaired by Vice-Director of the Institute of Plasma Physics of the Chinese Academy of Sciences Dr. Yuntao Song and JINR Vice-Director and Leader of the NICA project Professor V. Kekelidze.

V. Kekelidze gave a short overview of the present state of the NICA project and the structure of the BM@N and MPD collaborations.

The working group reviewed a list of 8 joint projects for implementation in 2019–2021 and selected four projects of primary importance. Their financing is planned to be launched in 2019.

The draft of the Agreement between JINR and the Ministry of Science and Technology of China on participation of the Chinese party in implementation of the NICA project was prepared at the meeting. The possibility of signing the Agreement was discussed a day earlier, in Moscow, at the XI meeting of the working group for high technologies and innovations of the Russian–Chinese subcommission for scientific and technological cooperation with the participation of the representative delegation of the Ministry of Science and Technology of the People's Republic of China.

On 4 April, Minister of Education and Science of the Republic of Armenia A. Harutyunyan and Minister of Transport, Communication and Information Technologies of RA H. Arshakyan paid a reconnaissance visit to JINR. In the JINR Directorate, the high guests were welcomed by JINR Director Academician V. Matveev, JINR Vice-Director M. Itkis, Head of the JINR International Cooperation Department D. Kamanin and Senior Researcher of DLNP G. Torosyan.

Information about the JINR organizational principles, fields of its scientific activities at large as well as current projects implemented in the framework of the Armenia–JINR cooperation was presented to the guests. In particular, the guests heard about calibration with the use of crystals of the hodoscope electromagnetic calorimeter for the Mu2e experiment (Fermilab) at the beams of the LUE-75 accelerator in the Yerevan Physics Institute within the energy range of 15–75 MeV. Moreover, information was presented about joint work on development of the hardware and software complex for the set of several synchronized PLIs (the precision laser inclinometer, a unique device developed at JINR), its installation in Armenia and data processing for predicting earthquakes.

During the meeting, the parties noted that the current fruitful cooperation had wide prospects for further development, inter alia training of young Armenian scientists on the JINR basis, as well as the participation of Armenian students and teachers in JINR educational programmes. The need to consider new areas of interaction in the format of long-term plans was also noted.

The guests were acquainted with the Flerov Laboratory of Nuclear Reactions where, accompanied by FLNR Chief Engineer G. Gulbekyan, they visited the recently opened experimental building of the Factory of Superheavy Elements and JINR's new launched cyclotron DC-280, and also met with FLNR Scientific Leader Academician Yu. Oganessian and discussed promising directions of cooperation in line with the research programme of the laboratory.

On 5 April, in the JINR Scientists' Club, a regular meeting of the JINR Science and Technology Council was held chaired by R. Jolos. Academician V. Matveev opened the meeting with information on the results of the sessions of the JINR Finance Committee and the JINR CP. He noted, in particular, that at the moment along with the substantiation of the main provisions of the next seven-year plan, a great deal of work began to determine the long-term development strategy of JINR. A number of issues raised by the Director related to the implementation of the Seven-Year Programme of JINR — on human resourcing, the influx of young people, the development of social infrastructure, wage growth, caused a lively discussion.

JINR Vice-Director Professor V. Kekelidze reported on the CERN International Committee's work for update of the European strategy for particle physics. Professor Kekelidze and JINR Vice-Director Academician B. Sharkov are members of the CERN European Strategy Group (ESG), established to coordinate drafting of this document. In addition to the main research areas, the updated European strategy will also include such issues as the attractiveness of particle physics for young people given the long period for the project implementation, preserving the individuality of the scientist in large collaborations, etc. The final programme plan should be submitted to the CERN Council in March 2020. The speaker noted that the Russian contribution to the process of developing the European strategy is reflected in the document, which shows the role of JINR. In particular, information is discussed there about joint work on modernization of the CERN accelerating basis, integration of particle physics with astrophysics, development of research on the basis of the NICA complex and some other directions. R. Tsenov, R. Lednický, I. Meshkov, and Yu. Oganessian made comments and answered questions at the meeting.

HR&ID Office Director A. Ruzaev reported on the progress in the development of the Staff Regulation. He noted that, according to the decision of the CP, work on the document started at the end of 2016, and members of the working group under the CP Chairman, members of the JINR STC and leaders of national groups of the JINR Member States participated in it. In November, the document will be presented at the CP session.

The drafting process of the Regulation on scientific-research and the educational programmes of cooperation with institutes and universities of the JINR Member States was reported by JINR Chief Scientific Secretary A. Sorin.

R. Jolos, S. Nedelko, S. Dmitriev, I. Meshkov, and M. Itkis commented on the information provided.

On 16–17 April, the 3rd Collaboration Meeting of the MPD and BM@N Experiments at the NICA Facility was held in Dubna, where the issues of the international cooperation were discussed related to the process of creating experimental installations MPD and BM@N during the implementation of the NICA megascience project. The meeting participants were scientists and specialists from many countries. They visited the construction site, went through the tunnel for the magnetic structure to the pavilion where the MPD detector would be located — at the collision point of the NICA collider beams.

At the meeting of the MPD experiment, detailed accounts were presented on the present state of the subsystems construction, modeling and expected characteristics of the detector, and the physics programme of the experiment was discussed.

The multipurpose detector MPD is designed to study the properties of the hot and dense nuclear matter formed during collisions of high-energy heavy ions, in particular, to search for effects associated with the deconfinement. The MPD is meant to study the properties of the phase transitions and the mixed hadronic and quark–gluon phases.

In general, according to the participants of the meeting, the creation of the MPD detector is progressing, as expected. The modelling of the response of the detectors has shown that the installation is very well suited for the measurements that are essential for the physical programme of the MPD experiment. The production of light mesons and baryons with excellent particle identification will be studied in detail. The good possibility of the track installation system will allow a research of the birth of strange baryons. It is expected that with the help of the TPC and the TOF detectors in the experiment, the birth of a particularly large number of hypernuclei will be detected. The electromagnetic calorimeter will provide a detailed study of the characteristics of the production of the di-leptons, as well as heavy leptons and particles containing heavy quarks. The hadron forward calorimeter will allow one to study the general characteristics of the event, as well as to determine the plane of the event, which is important for conducting the collective flow research and measuring correlations. In conclusion, the meeting participants discussed the rich physical programme of the MPD experiment.

At the meeting on the BM@N (Baryonic Matter at the Nuclotron) experiment, the latest results of the analysis of the experimental data obtained using the relativistic beams of the carbon, argon and krypton ions were presented. About 150 million events have been recorded, the analysis of which will provide information about the products of the interaction of the "medium"

ion beams with various targets. The goal of the BM@N experiment is to study the interaction of the beams of the relativistic heavy ions with fixed targets. A lot of attention was paid to discussing the status of the work required to prepare the BM@N detector for the experimental programme with heavy ions. Considerable interest was shown in the report of the scientific partners of the BM@N experiment on the status of the SRC project. The studies on the search for the short-range correlations are performed using the BM@N detector subsystems.

The meeting participants noted clear progress, both in the analysis of the experimental data and in the preparation of the BM@N installation for future sessions.

On 18 April, the delegation of the Ministry of Science, Technology and Environment of the Republic of Cuba and the Embassy of Cuba in the Russian Federation, headed by First Deputy Minister of the Ministry of Science, Technology and Environment of Cuba F. Gonzalez and Councilor of the Embassy of Cuba in Russia V. Hitchman, visited JINR.

In the JINR Directorate, the delegation was welcomed by JINR Vice-Director Academician B. Sharkov, JINR Chief Scientific Secretary A. Sorin, Head of the JINR International Cooperation Department D. Kamanin and Head of Sector of the Flerov Laboratory of Nuclear Reactions A. Nechaev. The meeting was dedicated to the prospects for Cuba–JINR cooperation, in particular, the new projects in the fields of nuclear medicine and nuclear technologies, issues of training the staff and also JINR participation interest in development of the Centre for Advanced Research of Cuba being constructed, which the JINR working group visited in March 2019. The Cuban party expressed its interest in development of a long-term plan of Cuban participation in the JINR scientific activities in preparation for the strategy of JINR development until 2030 being worked out at present, as well as in extending the number of Cuban scientists at the Joint Institute.

At the conclusion of the visit, the Cuban delegation visited the Flerov Laboratory of Nuclear Reactions, where the guests were acquainted with the Nanocentre and the Factory of Superheavy Elements, and the Laboratory of Radiation Biology. A short meeting of the delegation with the JINR staff from Cuba was held.

On 18–19 April, a two-day visit of the interdepartmental delegation of the Socialist Republic of Vietnam to Dubna was held. The delegation, headed by Deputy Minister of Science and Technology Tran Van Tung, included Vice-President of the Đồng Nai province, President of the Vietnam Atomic Energy Institute (VINATOM) Tran Chi Thanh as well as representatives of administrative and party governing bodies and the Đồng Nai province, executives of the Ministry of Science and Technology and VINATOM. The visit was organized as part of continuing consultations on cooperation between JINR and the VINATOM leaders in view of the implementation of the Rosatom project for the construction of the research reactor in Vietnam.

The Vietnamese delegation visited the Veksler and Baldin Laboratory of High Energy Physics, the Flerov Laboratory of Nuclear Reactions, and the Factory of Superheavy Elements. At FLNR, the guests had a meeting with the JINR staff members from Vietnam. At the Frank Laboratory of Neutron Physics, after exploring research opportunities of the IBR-2 reactor and its spectrometer complex, a round table with representatives of the FLNP heads and leading scientists was organized for the guests.

The meeting of the delegation with representatives of the JINR Directorate headed by JINR Vice-Director M. Itkis was devoted to summarizing the visit. At the end of the meeting, a trilateral agreement was signed on cooperation in the fields of carrying out research and training of the scientific and engineering staff. The parties of the agreement were JINR, Plenipotentiary of the Government of Vietnam to JINR and VINATOM.

On 22 April, a meeting of the scientific delegation of Kazakhstan with young scientists and specialists working at JINR was held in the JINR Scientists' Club. The delegation was headed by Professor K. Kadyrzhanov, Director of the Institute of Nuclear Physics in Nur-Sultan M. Zdorovets and Head of the Laboratory of Applied and Theoretical Materials Science of the Institute of Nuclear Physics S. Kislitsyn. JINR Vice-Director M. Itkis and head of the national group of Kazakh staff members at JINR D. Aznabaev welcomed the Kazakhstani colleagues.

The meeting was dedicated to the results obtained in 2018 by Kazakhstani staff members of the scientific groups of the JINR laboratories in order to assess the viability of the research data for the development of science in the Republic of Kazakhstan. Today, JINR employs more than 100 young scientists and specialists from Kazakhstan who are involved in scientific research in various fields of nuclear and neutron physics, accelerator technology, radiation materials science, information and cloud technologies, actively participate in major international projects, etc.

On 14 May, the representatives of the Directorate of the Joint Institute for Nuclear Research headed by Academician V. Matveev and the leaders of departments of the Institute's management visited the Laboratory of Information Technologies to review the progress in work on the modernization of the supercomputer "Govorun".

The Director of the Laboratory of Information Technologies, V. Korenkov, informed the audience that the planned stage of the supercomputer modernization for the NICA experiment had been completed, which significantly improved the speed of processing and modeling data for theoretical calculations, as well as for modeling events on the MPD detector.

V. Korenkov spoke about the upgrading of the computer networks, development of a new high-speed basic network that connects all laboratories of the Institute and a unique super-speed channel (400 gigabit per second with a capacity to reach 800 gigabit per second) for the NICA project, and acquainted the guests with large-scale plans of the laboratory in development of the Multifunctional Information and Computing Complex of JINR. He also noted that one of the important elements in the modern data processing system is the system of long-term storage. For this purpose, tape robots are used. One of such robots is used at the laboratory for the Tier-1 complex; the purchase of the next tape robot is planned that will be used for the CMS experiment at the LHC of CERN and for experiments in the NICA megaproject.

The Directorate representatives visited the technical area of the laboratory where they were shown the integrated complex of the engineer infrastructure that includes Diesel motor generators, uninterruptable power systems, climate control systems, and cooling systems. V. Korenkov also spoke about solving the issues of staff training for modern technology: training courses, including those for JINR Member States in the framework of student schools and conferences.

On 17 May, Yunkyu Bang, President of the Asia Pacific Centre for Theoretical Physics (APCTP), visited the Joint Institute for Nuclear Research. The APCTP is an international non-governmental research organization that unites 17 countries of Asia and the Pacific. The country of its location is South Korea. Yunkyu Bang came to Dubna accompanied by coordinator of the APCTP–JINR cooperation Jihun Kim.

The programme of the visit started with an introductory lecture about JINR. The guests visited the Veksler and Baldin Laboratory of High Energy Physics where they were acquainted with the progress in implementation of the NICA megascience project. They also visited the Factory of Superheavy Elements at the Flerov Laboratory of Nuclear Reactions. At the meeting with leaders of the Bogoliubov Laboratory of Theoretical Physics, opportunities for the development of cooperation were discussed, in particular, the extension of participation of young Korean scientists in BLTP scientific schools.

In the Directorate, the guests were welcomed by JINR Director Academician V. Matveev. The parties noted the high level of the existing JINR–APCTP cooperation since 2007 as well as active development of contacts of the Institute with the Republic of Korea. One of the latest examples of it was an agreement signed in April 2019 with the Korea University in the fields of accelerating facilities and nuclear physics. The parties discussed opportunities for strengthening cooperation in the field of theoretical physics as well as in a wider range of fields. The meeting was concluded with signing a plan of cooperation in joint scientific research, academic exchange and training of young staff.

On 24 May, President of the Vietnam Academy of Science and Technology (VAST) Chau Van Minh visited JINR. The delegation was also represented by Head of the VAST Department of International Cooperation Ninh Khac Ban, Head of the VAST Department of Planning and Finance Le Truong Giang, Director of the VAST Space Technology Institute Bui Trong Tuyen, as well as Plenipotentiary of the Government of the Socialist Republic of Vietnam to JINR Le Hong Khiem.

During the meeting, issues of the cooperation development of scientific organizations of Vietnam and JINR were discussed, as well as issues of holding the meeting of the JINR Finance Committee and the session of the Committee of Plenipotentiaries of the Governments of the JINR Member States, and an international scientific conference as well, in Vietnam in November 2019. The importance was stressed of training highly qualified young staff on JINR basis on the occasion of implementation of a large project on the construction of a research reactor in Vietnam. Representatives of the national group of Vietnamese JINR staff members took part in the meeting.

The meeting concluded with signing of a framework agreement on cooperation between VAST and JINR in the fields of carrying out scientific research, training the scientific and engineering staff, and the exchange of scientific visits. In addition to the agreement, the parties signed a plan for the launch of joint VAST–JINR scientific and research projects.

The guests from Vietnam had tours around the Frank Laboratory of Neutron Physics, the Dzhelepov Laboratory of Nuclear Problems, and the Flerov Laboratory of Nuclear Reactions.

On 31 May, a delegation from the Hefei city of the People's Republic of China visited the Joint Institute. The delegation was represented by Chairman of the Board of the Hefei Industrial Investment Holding Fengshan Yong, Director of the Science and Technology Office of Hefei Qunying Huang, Deputy Director of the Institute of Plasma Physics (ASIPP) of the Chinese Academy of Sciences (CAS) in Hefei Yuntao Song, Director of the Hefei Science and Technology Office Fang Hong, Head of Department of Hefei Industrial Investment Holding Sichen Wang, and Administrative Director of the CAS Ion Medical Centre Lu Liu.

The Chinese delegation was welcomed by Assistant to JINR Director G. Shirkov, Head of the JINR International Cooperation Department D. Kamanin, and Director of the Laboratory of Radiation Biology RAS Corresponding Member E. Krasavin.

The guests expressed their vivid interest in the information presented at the meeting by E. Krasavin, who reported on LRB scientific research in the fields of biophysics and proton therapy. The sides discussed oppor-

tunities to develop cooperation in accelerator technology and radiation medicine. Furthermore, the Chinese party expressed its interest in extending scientific contacts in the framework of the NICA project. Exchange of scientific visits of young scientists between JINR and Hefei scientific centres was noted as a new promising trend in the development of interactions.

The guests visited the factory of superconducting magnets and the NICA collider complex being constructed at the Veksler and Baldin Laboratory of High Energy Physics. They also learned about opportunities and development prospects of the Medical and Technical Complex of the Dzhelepov Laboratory of Nuclear Problems.

On 2–4 June, President of the Bulgarian Academy of Sciences (BAS) J. Revalski, accompanied by BAS Chief Scientific Secretary E. Pasheva and BAS Scientific Secretary of the Division "Energy Resources and Energy Efficiency" S. Dimitrova, paid his first visit to JINR. During the visit the Bulgarian delegation was accompanied by BLTP Chief Researcher P. Fiziev.

JINR Director Academician V. Matveev welcomed the President of the Bulgarian Academy of Sciences in the JINR Directorate. Head of the JINR International Cooperation Department D. Kamanin and VBLHEP Deputy Director R. Tsenov also took part in the meeting.

The parties discussed opportunities for the cooperation development and noted a promising outlook of organization of joint projects on biophysics and computational mathematics. Furthermore, the parties noted the importance of attracting young people to science and the significance of establishing an academic exchange of young scientists. At the end of the meeting in the JINR Directorate, J. Revalski extended a formal invitation to V. Matveev to take part in festive events dedicated to the 150th anniversary of the foundation of the Bulgarian Academy of Sciences that would take place in October 2019.

The guests visited the Flerov Laboratory of Nuclear Reactions, the Veksler and Baldin Laboratory of High Energy Physics, and the Frank Laboratory of Neutron Physics, where they attended lectures by leading scientists. Moreover, meetings with leaders of the Laboratory of Information Technologies and the Laboratory of Radiation Biology were organized for the BAS representatives. During the visit to Dubna, the delegation had an informal meeting with Bulgarian staff members of the Joint Institute and a sightseeing tour around Dubna.

On 3–7 June, the 12th international training programme for decision-makers in science and international scientific cooperation JEMS — "JINR Expertise for Member States and Partner Countries" (JEMS-12) was held at JINR. It was attended by representatives of scientific organizations of Bulgaria, RSA, Russia, Slovakia, Vietnam, and for the first time Kazakhstan.

The programme included review excursions, lectures by leading scientists of JINR in all trends of scientific activities of the Institute, visits to key sites of the scientific infrastructure of JINR laboratories, meetings and discussions with leaders and leading specialists of the laboratories. A round-table discussion was held on the last day of the event where results of the training programme were considered.

On 5 June, a delegation of the China Institute of Atomic Energy (CIAE), headed by CIAE Director Wan Gang, visited the Joint Institute for Nuclear Research. The delegation was represented by Director of the Department of Nuclear Physics Chen Dongfeng, Director of the International Cooperation Office Zhang Jing and senior experts of the Department of Nuclear Physics Lin Chengjian, Li Xiaomei, and Han Wenze.

During the meeting in the JINR Directorate with the leaders of the Institute, the parties discussed possible ways to implement the memorandum on mutual understanding between JINR and CIAE signed in April 2018. The CIAE representatives expressed their interest in cooperation in the framework of the NICA megascience project and in trends of research at FLNP, FLNR and LRB.

The key issue of the visit was the memorial seminar jointly held on 5 June, dedicated to the memory of Academician Wang Ganchang — an outstanding Chinese research scientist, one of JINR founders and JINR Vice-Director (1958–1960). JINR Director Academician V. Matveev opened the seminar. CIAE Director Wan Gang and Chief Researcher of VBLHEP V. Nikitin made reports on the scientific career of Wang Ganchang. Representatives of CIAE made reports on scientific infrastructure and most important research at their Institute. Chief of a sector of FLNR A. Fomichev made suggestions on cooperation in radioactive nuclei physics.

The Chinese delegation visited the Frank Laboratory of Neutron Physics and the Veksler and Baldin Laboratory of High Energy Physics. It joined the work of the JEMS training programme for more details about the Institute and held additional working meetings with leaders of FLNP, VBLHEP and FLNR.

On 5–6 June, the 10th regular meeting of the international Machine Advisory Committee (MAC) on the NICA project was held at the Veksler and Baldin Laboratory of High Energy Physics. The work of the meeting was aimed at an expert assessment of the progress in the NICA megascience project, its current status, and receiving recommendations for its further implementation.

At the opening of the meeting, Head of the ESR Department of the GSI Accelerating Complex M. Steck, JINR Director Academician V. Matveev, JINR Vice-Director B. Sharkov, and JINR Vice-Director, Director of the Veksler and Baldin Laboratory of High Energy Physics V. Kekelidze delivered their welcoming speeches.

Beside the rich programme of reports on results of work on the NICA project, the participants of the MAC meeting had an excursion to the construction site of the NICA collider. The second day of the meeting was devoted to reports on the topics of polarized beams at NICA. The meeting concluded with a general discussion and adoption of the resolution.

On 18 June, representatives of the Ministry of Industry and Trade of the Czech Republic: Director of the Foreign Economic Policies Department M. Pospíšil, Head of the Section for Eastern Europe and Central Asia V. Lidl, and Territorial Expert V. Jelínková, came to JINR for an introductory visit. The delegation was also represented by Member of the Committee for Czech–JINR cooperation, Director of the "Vakuum Praha" company P. Hedbávný and Director of the "Asarko" company J. Granach.

During the meeting with JINR leaders, the Czech guests stressed their interest in the opportunities to develop cooperation with JINR, in particular, in innovation technology, artificial intellect and proton therapy. JINR Director V. Matveev noted the experience of the Institute in fruitful cooperation of JINR with Czech enterprises, including the firm "Asarko" for reconstruction of infrastructural buildings of JINR and production of high-technology equipment for basic facilities of JINR by the company "Vakuum Praha". The Czech representatives suggested that Days of the Vyšehrad Group — the union of four Central European states: Poland, the Czech Republic, Slovakia and Hungary — should be held in 2020 at JINR.

The Czech delegation visited the sites of scientific infrastructure of JINR. They were accompanied by Czech representatives of JINR — Head of the JINR Procurement and Logistics Service P. Dognal and ICD Chief Engineer Y. Makhonin. The guests visited the factory of superconducting magnets and saw the Nuclotron accelerator at the Veksler and Baldin Laboratory of High Energy Physics. They were also acquainted with the DC-280 cyclotron at the Factory of Superheavy Elements at FLNR.

From 18 to 20 June, leaders of the CMS collaboration (CERN) R. Carlin (spokesman) and A. Petrilli (PR manager) visited JINR on the invitation of JINR Director RAS Academician V. Matveev. They took part in the 51st meeting of the Programme Advisory Committee for Particle Physics. R. Carlin made a report dedicated to the creation of the CMS facility at the Large Hadron Collider at CERN.

On 19 June, a meeting of the guests with a group of CMS project participants from JINR was held at the Veksler and Baldin Laboratory of High Energy Physics, at which technical issues of JINR participation in the development of the CMS facility were discussed.

On 20 June, the guests visited the Laboratory of Information Technologies where they were acquainted with opportunities for processing and analysis of experimental data obtained at the CERN collider.

On 20 June, a joint meeting of the JINR Directorate and the JINR Science and Technology Council devoted to the establishment of the NICA accelerator complex was held in the International Conference Hall.

The meeting was opened by JINR Director Academician V. Matveev. He informed the audience about the completion of preparation of regulations related to the development of the system for certification of scientific personnel and the establishment of dissertation councils.

Among the major challenges the Institute faces at the moment, V. Matveev highlighted the necessity to increase the level of salaries for leading scientists and specialists.

V. Matveev spoke about the necessity of in-depth analysis of the role and place of JINR in international cooperation, in the development of a long-term strategy of JINR which would ensure an increasing role and importance of the Institute in the global system of international cooperation in the fields of fundamental and applied physics research.

R. Tsenov, S. Nedelko, I. Savin, V. Kekelidze, and M. Itkis took part in the discussion.

Scientific Director of the NICA project RAS Corresponding Member I. Meshkov presented the report "NICA Accelerator Complex — Three Tasks and Three Stages" with a brief historical overview of the project and spoke about a number of problems that prevent timely implementation of the project, such as insufficient number of scientific and technical staff, discrepancy between the regulations of the Institute's services and the dynamics of the project implementation, a one-year lag in construction of the 17th building, delays in the reconstruction and repair of the infrastructure, the large workload of the preparation of project documents for obtaining permits for commissioning of facilities. The speaker outlined proposals to overcome the delay in the implementation of the NICA project. In addition, I. Meshkov gave a brief review on the 10th MAC-NICA Meeting, which took place on 5–6 June. R. Jolos, V. Matveev, R. Tsenov, V. Kekelidze, A. Butenko, and A. Kovalenko took part in the discussion of the report.

The report of Head of the VBLHEP Accelerator Department A. Butenko was devoted to the assembling of the Booster and channels, as well as to the prospects of the BM@N experiment. V. Matveev, R. Lednický, S. Dmitriev, V. Kekelidze, and V. Karpinsky delivered their comments.

Chief Engineer of the Nuclotron E. Syresin presented the report "The NICA Collider and the Channel Nuclotron–Collider: The Status of Work". The speaker spoke about the size and parameters of the collider, the amount and timing of the upcoming work, the development of the power supply system, the scholastic cooling system and the system of beam extraction.

Commenting on the presentations, V. Matveev noted on the whole the necessity for the JINR Directorate together with the project leaders to analyze reasons for the delays and inefficiency in the work and to take measures to eliminate them timely.

On 21–22 June, the 95th meeting of the Nuclear Physics European Collaboration Committee (NuPECC) was held in the International Conference Hall in Dubna for the first time. It was aimed at implementation of the European long-standing plan in nuclear physics and coordination of activities of nuclear physics centres in Europe.

NuPECC includes representatives of leading nuclear physics laboratories of the majority of European countries, associated members from South Africa and Japan, and observers from South America, Canada, the USA and Asia. JINR has been full member of NuPECC since 2014. The Committee meets three times a year. Current status of various projects in nuclear physics is discussed at the meetings of the Committee, making it possible for the members to follow their development several times a year. Reports on leading scientific projects, such as FAIR, GANIL-SPRIRAL 2 and projects of other countries in nuclear physics were presented at the meeting in Dubna.

JINR Vice-Director Academician B. Sharkov represents the Institute at NuPECC. JINR is well integrated in the European scientific community and has strong ties in nuclear physics with many scientific projects in Europe. Two big projects of JINR — NICA and the Factory of Superheavy Elements — are included in the long-term plan of NuPECC (NuPECC Long Range Plan 2017) that determines the strategy of development of nuclear physics in Europe in the nearest decade.

The joint meeting of the NuPECC representatives and JINR leaders opened the work of the Committee in Dubna. JINR Director Academician V. Matveev greeted the participants; JINR Vice-Director B. Sharkov gave a review presentation on the Joint Institute. FLNR Scientific Leader Academician Yu. Oganessian made a report about scientific activities at the laboratory in the synthesis of superheavy elements. MPD experiment spokesman A. Kisiel reported on the current status of the NICA collider construction. FNLP Director V. Shvetsov spoke about the IBR-2 research reactor and prospects of research at neutron beams. Head of FLNR sector A. Fomichev informed the participants about the tasks of the JINR radioactive nuclei beams research programme. FLNR Chief Researcher RAS Corresponding Member L. Grigorenko discussed future studies in the field of light exotic nuclei at the laboratory.

On the first day of the 95th meeting of NuPECC, the participants visited the Factory of Superheavy Elements, the DC-280 cyclotron and the fragment separator ACCULINNA-2. The next day the guests were shown the NICA collider complex under construction at the Veksler and Baldin Laboratory of High Energy Physics.

On 27 June, the official launch ceremony of the implementation of the Russian–German cooperation Roadmap in education, science, research and innovations signed on 10 December 2018 in Moscow and regulating the scientific and technological cooperation between the two countries for the next decade was held in Berlin. The representatives of the scientific organizations, universities, assets of Russia and Germany took part in the ceremony. The Joint Institute for Nuclear Research was represented by JINR Director Academician V. Matveev, JINR Vice-Director, VBLHEP Director V. Kekelidze and JINR Chief Scientific Secretary A. Sorin.

At the opening of the ceremony, the audience was welcomed by First Deputy Minister of Science and Higher Education of the Russian Federation (Minobrnauki) G. Trubnikov and State Secretary of the Federal Ministry of Education and Research of Germany (BMBF) G. Schütte. During the ceremony, the young scientists of the two countries represented the reports performed in the following areas of the Roadmap: "The Large Research Infrastructure", "The Priorities", "The Young Abilities", and "Innovations, Science and Society".

During the event, an exhibition was organized where visitors could become acquainted with the successful examples of scientific and technical cooperation among Russian, German and international organizations. The significant part of the exhibition was devoted to the Joint Institute for Nuclear Research, whose activities were covered by five information stands, as well as the relevant booklets.

The next day, on 28 June, a regular meeting of the mixed Russian–German commission on scientific and technical cooperation was held in Berlin. The commission was established 10 years ago under the Agreement signed on scientific and technical cooperation of the two countries. Co-chairmen of the meeting, which gathered more than 70 experts from Russia and Germany, were G. Trubnikov and G. Schütte. During the meeting, the parties discussed the progress in and plans for further implementation of the Roadmap for the Russian–German cooperation in education, science, research and innovations. A specially established working group of Minobrnauki and BMBF will constantly coordinate the progress in the implementation of the Roadmap.

Following the results of the meeting, G. Trubnikov and G. Schütte signed the "Berlin Ministerial Declaration of Intent". It is the document which fixes the mutual interest of both parties to develop cooperation in the framework of the PIC and NICA projects, in particular, in the creation of the international organization for the use of neutrons in research.

On 6–14 July, JINR took part in one of the largest festivals of science, technology and arts "Geek Picnic"

that annually gathers about 100,000 people at its two sites in St. Petersburg and Moscow. Prominent scientists and specialists not only from Russia but from all over the world delivered about a hundred lectures in the framework of the festival, which were devoted to the latest scientific research and discoveries in science.

JINR scientists were among the lecturers: Head of Sector of the Frank Laboratory of Neutron Physics M. Frontasyeva, Coordinator of the UN Programme for Air in Europe, gave the lecture "Assessment of air pollution of ecosystems using the method of the neutron activation analysis of the moss as a biomonitor"; Director of the Bogoliubov Laboratory of Theoretical Physics RAS Corresponding Member D. Kazakov delivered the lecture "Dark matter in space"; Professor A. Arbuzov in his lecture "Secrets of cosmology" told the audience about the present status of fundamental physics of the micro- and macroworld; VBLHEP researcher D. Dryablov in his lecture "Big Bang theory. Evolution of the Universe" presented the modern understanding of the origin and evolution of the Universe and told participants about the NICA accelerator complex being constructed now, thanks to which scientists will be able to learn about the first moments of the Universe evolution that have not been studied yet; researcher of the Laboratory of Radiation Biology Yu. Severiukhin delivered the lecture "Impact of radiation on the organism in space and on the Earth".

On 12 July, representatives of the Ministry of Science and Higher Education of the Russian Federation (Minobrnauki), the Bauman Moscow State Technical University (BMSTU), and the Moscow Institute of Physics and Technology (MIPT) visited JINR with the aim to discuss issues of training highly qualified scientific and engineer staff to implement unique projects of JINR.

The delegation was headed by First Deputy Minister of Science and Higher Education G. Trubnikov, Director of the Department of Innovation and Advanced Research of Minobrnauki V. Medvedev, BMSTU Rector A. Aleksandrov, and MIPT Rector N. Kudryavtsev. The delegation was also represented by Vice-Rector for Research and Development S. Garichev and Vice-Rector for Science and Development Programmes V. Bagan (representing MIPT), as well as Vice-Rector for Economy and Innovations E. Starozhuk, Dean of the Faculty of Power Plant Engineering A. Zherdev, Assistant to Rector M. Safronov (representing BMSTU), and Assistant to First Deputy Minister of Science and Higher Education A. Dryakhlov. The sides discussed specific measures in training staff and attraction of graduates of leading specialized universities to work at JINR.

During the visit, the guests were acquainted with objects of the JINR scientific infrastructure accompanied by JINR Director Academician V. Matveev and JINR Chief Scientific Secretary A. Sorin, and had meetings with heads of the JINR laboratories. The delegation visited the Veksler and Baldin Laboratory of High Energy Physics, where they saw the NICA accelerator complex being constructed and the factory of superconducting magnets. The guests had a meeting with JINR Vice-Director, VBLHEP Director V. Kekelidze and VBLHEP Scientific Secretary D. Peshekhonov. FLNR Director S. Dmitriev and FLNR Scientific Secretary A. Karpov welcomed the delegation at the Flerov Laboratory of Nuclear Reactions. The delegation visited the Factory of Superheavy Elements and had a meeting with FLNR Scientific Leader Academician Yu. Oganessian.

From 15 to 18 July, a Polish delegation stayed in Dubna. The delegation was represented by Chief Specialist of the Ministry of Science and Higher Education of Poland A. Bereza, Head of Department in this Ministry M. Piątek, Head of Department in the Ministry of Foreign Affairs of Poland M. Grodzki, Director of this Ministry's Department J. Hofmokl, Plenipotentiary of the Government of the Republic of Poland to JINR Professor M. Waligórski and Chairman of the Commission on cooperation with JINR under the Plenipotentiary Professor M. Budzyński. Ambassador of the Republic of Poland to Russia W. Marciniak took part in meetings held in Dubna.

On the arrival, members of the delegation met their compatriots working at JINR. On 16 July, in the JINR Directorate, the delegation had a meeting with JINR Director V. Matveev, JINR Chief Scientific Secretary A. Sorin, VBLHEP Director and JINR Vice-Director V. Kekelidze, FLNR Deputy Director S. Sidorchuk, and Assistant to Head of the Science Organization & International Cooperation Office W. Chmielowski. The participants of the meeting paid much attention to the participation of Polish scientists and specialists in the JINR flagship projects, namely, development of the NICA complex and the Factory of Superheavy Elements, as well as to the progress towards the creation of the SOLARIS laboratory at the Krakow Institute of Nuclear Physics. The delegation had an excursion to FLNR and VBLHEP.

On 17 and 18 July, the guests went on an excursion to Tver and the memorial complex "Mednoe", and to Serguiev Posad where they were acquainted with treasures of the Trinity Lavra.

A meeting of the discoverers of new chemical elements was held at the 6th International Conference on the Chemistry and Physics of Transactinide Elements (TAN) taking place in Wilhelmshaven (Germany) **from 25 to 30 August** in the framework of the International Year of the Periodic Table of Chemical Elements 2019. Professors P. Armbruster and G. Münzenberg from the Helmholtz Centre for Heavy Ion Research (GSI) made fundamental contributions to research on the synthesis of elements 107–112 (bohrium, hassium, meitnerium, darmstadtium, roentgenium and copernicium). Dr. K. Morimoto of the RIKEN Nishina Centre for Accelerator-Based Science (Japan) was a member of the

element 113 discovery team. Professor Yu. Oganessian (JINR) was head of the discovery team of elements 114 to 118 (flerovium, moscovium, livermorium, tennessine and oganesson) at the Flerov Laboratory of Nuclear Reactions (FLNR) of JINR. The current heads of GSI, FLNR and the RIKEN Nishina Centre, where the respective elements were discovered, also participated in the conference.

The GSI and the Johannes Gutenberg University Mainz were the organizers of this year's TAN conference. A total of 120 researchers from 19 countries and 4 continents took part in the TAN conference. JINR was represented at the conference by Vice-Director M. Itkis, FLNR Director S. Dmitriev, FLNR Deputy Director A. Popeko and FLNR staff member P. Steinegger.

On 29 August, a reference visit of a delegation from the Federal Republic of Germany to the Joint Institute for Nuclear Research was held. It included representatives of the Federal Ministry of Education and Research (BMBF), namely, S. Carl, Desk Officer for EU Education Programmes and International Cooperation in Education, and A. Schwartz, Desk Officer for Cooperation with Eastern Partnership Countries, Russia, and Central Asia, as well as representatives of the Federal Institute for Vocational Education and Training, the German Aerospace Centre, the Goethe Institute in Moscow, and research centres in Jülich and Darmstadt. The delegation was accompanied by J. Bohdanowicz, Head of the Division of Labour, Social Affairs and Health of the German Embassy in Moscow, and Professor E. Esenina, Leading Researcher of the Federal Institute of Education Development (Moscow). The visit was organized as part of implementation of the Roadmap for Russian–German cooperation in education, science, research and innovations, signed in December 2018.

The delegation was acquainted with the Veksler and Baldin Laboratory of High Energy Physics and the Frank Laboratory of Neutron Physics where the guests visited the objects of the scientific infrastructure, learned about major fields of research, and met leaders of the laboratories. The visit was concluded by a thematic discussion at a meeting of the delegation with representatives of the JINR leadership. JINR was represented by Vice-Directors R. Lednický and V. Kekelidze, Chief Engineer B. Gikal, Assistant Director for Human Resources A. Ruzaev, Head of the International Cooperation Department D. Kamanin and his Deputy A. Kotova, FLNP Director V. Shvetsov, Deputy Director of the University Centre A. Zhemchugov, and Head of VBLHEP Department S. Kostromin. The sides discussed in particular issues of professional training and skills development of engineers and technicians on the basis of the Institute.

Since 1 September, dissertation councils have been launched at JINR, operating due to the right to award academic degrees independently. According to the federal laws of JINR's country residence (the Russian Federation), JINR exercises the right:

— to establish JINR-based dissertation councils; to appoint and change their membership; to determine their authority; to select scientific specialities of dissertations, these councils are granted the right to accept for defence; to control, suspend, resume and terminate the activities of these councils;

— to set the procedure for degree awarding, including the requirements for dissertations, the order of presentation, defence of dissertations to confer scientific degrees, the order of withholding, restoration of academic degrees, the appeal proceedings;

— to approve regulations for the Council for the defence of dissertations for attaining the degrees of candidate of sciences, doctor of sciences, the formats of academic degrees diplomas, technical requirements for such documents, the procedure for their processing and issuance.

JINR provides six dissertation councils. Five of them operate permanently: the Dissertation Council on Particle Physics (under VBLHEP), the Dissertation Council on Heavy Ion Physics (under FLNR), the Dissertation Council on Nuclear Physics (under DLNP), the Dissertation Council on Condensed Matter Physics (under FLNP), and the Dissertation Council on Information Technologies and Computational Physics (under LIT). The Dissertation Council on Theoretical Physics (under BLTP) is formed on a one-time basis for each thesis submitted to the defence.

JINR provides an opportunity to make a preliminary submission of the documents (in electronic form) to the dissertation councils. For this aim, JINR established the Information System for Scientific Certification. More details about the procedure for obtaining scientific degrees at JINR are available on the website https://dissertations.jinr.ru/.

On 9 September, in St. Petersburg, the festive opening ceremony of the XXI Mendeleev Congress on General and Applied Chemistry was held attended by RF Prime Minister D. Medvedev, Deputy Prime Minister of Russia T. Golikova, Minister of Science and Higher Education M. Kotyukov, and RAS President A. Sergeev. President of the Russian Federation V. Putin sent his greetings to the participants of the event. About 3000 people, including 300 foreign scientists from 52 countries and Nobel laureates, took part in the event. More than half of the participants were young scientists.

Every 4 or 5 years, the Mendeleev Congress welcomes scientists from all over the world to the scientific and cultural centres of Russia. These are important scientific forums where achievements of the world and Russian chemical science are traditionally demonstrated.

According to the opinion of the participants of the congress, its topics are far beyond chemical science, and

discussions of issues will be interesting to researchers who specialize in many other topics.

On the first day of the congress, Nobel Prize holders J.-P. Sauvage and W. Moerner, as well as the outstanding Russian scientist Academician Yu. Oganessian and the British chemist, science popularizer M. Poliakoff, delivered their reports.

On 11 September, a working meeting of the delegation of the Republic of Serbia with JINR leaders was held. The Serbian delegation was represented by Rector of the University of Novi Sad Professor D. Jakšić, Vice-Rector of the University of Novi Sad Professor S. Podunavac-Kuzmanovic, and Deputy Director of the Vinča Institute of Nuclear Sciences Dr. L. Hadzievski, all of whom took part in the 13th international training programme for decision-makers in science and international scientific cooperation JEMS — "JINR Expertise for Member States and Partner Countries" (JEMS-13) opened the day before. Moreover, the delegation was represented by Coordinator for Serbia–JINR cooperation, Director of Physics Department of the Vinča Institute of Nuclear Sciences Professor S. Petrović.

The Joint Institute was represented by JINR Vice-Director R. Lednický, Head of the International Cooperation Department D. Kamanin, Director of the JINR University Centre S. Pakuliak, and Secretary for the JINR–Serbia Cooperation Yu. Polyakova.

At the meeting, the parties discussed urgent issues of cooperation between Serbia and JINR. The Serbian partners expressed their special interest in training highly qualified Serbian specialists on the JINR basis. The parties highlighted the importance of informing the Serbian society, both the youth and senior officers, about JINR opportunities. Concluding the visit, proposals were formed for discussion at the meeting of the regular Joint Coordination Committee on JINR–Serbia Cooperation. At the end of the meeting, the parties initiated the drafting of an agreement on cooperation between the University of Novi Sad and JINR.

On 20 September, President of the Academy of Sciences of Uzbekistan B. Yuldashev, who came into office of the Plenipotentiary of the Government of the Republic of Uzbekistan to JINR, met with the JINR leadership represented by JINR Director Academician V. Matveev and Vice-Director M. Itkis. Head of the national staff group of the Republic of Uzbekistan at JINR, Principal Researcher of DLNP A. Inoyatov also participated in the meeting. The process of the restoration of the full membership of the Republic of Uzbekistan in JINR was discussed.

On 20 September, a delegation from the Republic of Cuba visited JINR. The delegation was represented by staff member of the Centre of Advanced Research of Cuba O. Perez and Councillor of the Nuclear Energy and Advanced Technology Agency H. Dona. Head of the national group of Cuban staff members at JINR A. Fabelo accompanied the delegation.

The guests visited the Nanocentre and the Factory of Superheavy Elements at the Flerov Laboratory of Nuclear Reactions. The delegation visited the production and research site of the Medipics and MicroMegas detectors at the Dzhelepov Laboratory of Nuclear Problems as well.

A meeting with JINR Vice-Director B. Sharkov and Deputy Director of the JINR University Centre A. Zhemchugov took place. The meeting was also attended by Director of the Centre for Applied Technologies and Nuclear Development I. P. Diaz. During the discussion of areas of cooperation, special attention was paid to the issues of training highly qualified staff on the JINR basis for the Republic of Cuba and other countries of Latin America.

On 11 October, a regular meeting of the Science and Technology Council of JINR was held. JINR Director Academician V. Matveev told members of the Council about the implementation of the JINR budget plan in 2020, outlined the milestones of the 126th session of the Scientific Council and congratulated A. Bugay on having been elected for the position of Director of the Laboratory of Radiation Biology.

The report on preparing the strategy of the JINR development was made by JINR Vice-Director B. Sharkov. The speaker prepared his speech based on the reports by representatives of the JINR laboratories made at the 126th session of the Scientific Council devoted to new scientific research trends in 2023–2030, expected physics and technology results, development of the necessary research infrastructure and staff needs, composition of topic subgroups and organization of their work (meetings, workshops, video conferences, etc.).

The report was discussed by V. Matveev, R. Jolos, S. Nedelko, N. Russakovich, I. Savin, D. Peshekhonov, A. Frank, D. Kamanin, V. Shvetsov, Yu. Oganessian, M. Itkis, V. Aksenov, L. Grigorenko, and I. Meshkov.

On 11–13 October, the Joint Institute for Nuclear Research participated in the science festival NAUKA 0+ for the fourth time, presenting Institute's exhibition stands in the MSU Fundamental Library and at the Expocentre at Krasnaya Presnya.

At the expositions in the MSU Fundamental Library, visitors were able to see the layouts of the current operating JINR facilities: new cyclotron DC-280 which is the main research facility of the Factory of Superheavy Elements; IBR-2 reactor; Medical and Technical Complex of the Dzhelepov Laboratory of Nuclear Problems; the Baikal deep underwater neutrino telescope. The Institute also presented interactive stands featuring the main directions of research and JINR flagship projects.

The following lectures were delivered in the Shuvalovsky pavilion of MSU: by V. Shvetsov about the search for water on Mars with a neutron detector developed with JINR participation; by K. Vergel about how to define ecological situation in the Moscow Region

with moss; by S. Merts about colliders and the NICA accelerator complex.

The programme for school students, carried out by JINR staff at the Expocentre, included master classes on robotic engineering, chemistry experiments, contests and quizzes. JINR representatives also provided an interactive platform with learning programmes and games.

On 12 October, a Memorandum of Understanding between JINR and a community of scientific and research institutes of Mexico was signed in Mexico City at the Russian Embassy in Mexico. The document lays the basis for the establishment and development of the scientific cooperation between JINR and Mexican scientific centres for joint research in the field of fundamental physics, and regulates participation in the implementation of the NICA megascience project.

Ambassador of the Russian Federation in Mexico V. Koronelli, JINR Vice-Director, Director of VBLHEP V. Kekelidze, JINR Chief Scientific Secretary A. Sorin and Head of the MPD Collaboration A. Kisiel took part in the festive signing ceremony. Rectors of universities, heads of scientific centres and leading scientists took part in the ceremony on behalf of the Mexican part.

Leader of the community of Mexican scientists participating in NICA (MexNICA Collaboration) J. Ayala (the National Autonomous University of Mexico) noted in his solemn speech that this document provides the official foundation for scientists from Mexico to collaborate with scientists from all over the world in the framework of the implementation of the NICA project for addressing the fundamental questions in physics.

During the visit to Mexico, the JINR delegation did not only sign the Memorandum but also presented 15 reports on JINR activities and the NICA project at Mexican universities; numerous meetings dedicated to discussing various aspects of cooperation were organized with heads of these universities, their students and staff members, as well as with heads of funds backing them.

On 14–15 October, the 4th Collaboration Meeting of the BM@N Experiment was held at the Veksler and Baldin Laboratory of High Energy Physics. The event was attended by 120 scientific staff members and engineers from Bulgaria, the Czech Republic, Georgia, Germany, Israel, Poland, Russian scientific centres, namely, ITEP, INP, NRC "Kurchatov Institute", MEPhI, SINP MSU, LPI, as well as representatives of industrial companies.

The BM@N (Baryonic Matter at the Nuclotron) project is the first experiment at the NICA accelerator complex being constructed. Nowadays, 234 scientists from 11 countries participate in the Collaboration. Three runs of irradiation of the facility with carbon, argon and krypton ion beams have been conducted; the data processing and modernization of detectors are underway. Now, much attention is paid to work necessary for preparing the BM@N facility to the experimental programme with heavy ions.

At the plenary session, reports on the project were made. Head of the Collaboration, Head of the Sector of Detectors and Data Analysis M. Kapishin spoke about the present status of the BM@N project. Technical Coordinator A. Maksimchuk made a report on the modernization of the experimental facility. Some reports considered particular systems and the analysis of experimental data. Deputy Head of the Accelerator Department A. Sidorin discussed the progress in work on the creation of the Booster and the modernization of the Nuclotron. The report by F. Guber (INR RAS) considered FHCAL, a new zero-degree calorimeter. D. Kahlbow spoke about the current status of data analysis in the SRC project on the search for short-range correlation.

The Collaboration Meeting was divided into three sections dedicated to detectors, data processing and software. In total, 40 reports were presented. Much attention was paid to international cooperation.

On 16–18 October, a delegation from the Republic of Serbia visited JINR to take part in the meeting of the Joint Coordination Committee (JCC) on JINR–Serbia Cooperation. The Serbian party at the event was represented by Secretary of State of the Ministry of Education, Science and Technological Development of the Republic of Serbia V. Popović, Assistant Minister V. Nedović, Chief Researcher of the Vinča Institute of Nuclear Sciences and a member of the JINR Scientific Council N. Nešković, as well as Coordinator of Serbia–JINR cooperation S. Petrović and scientific staff members of the Institute of Physics Belgrade D. Maletić and M. Aničić Urošević.

JINR was represented at the meeting by JINR Vice-Director R. Lednický, UC Director S. Pakuliak, Head of the International Cooperation Department D. Kamanin, Deputy Director of FLNP on science O. Culicov, and Secretary of the JINR–Serbia committee Yu. Polyakova.

During the visit, excursions were organized to the Institute laboratories. In the Directorate of JINR, proposals on the development of cooperation were finally discussed.

On 22–25 October, the 3rd conference "NICA Days 2019" dedicated to the NICA megascience project was held. It was organized by JINR jointly with the Warsaw University of Technology under the supervision of the Ministry of Science and Higher Education of Poland. The conference brought together experts, scientists, engineers and students in heavy ion physics and creation of design and construction of measuring equipment for NICA experiments. In the framework of the conference, the 4th Collaboration Meeting of the MPD Experiment and the 5th conference "Slow Control Warsaw" were held.

On 28–30 October, a regular meeting of the committee on the cooperation of JINR with the Republic of Armenia was held in Yerevan. JINR Vice-Director M. Itkis headed the JINR delegation. The committee

discussed a wide range of issues relating to cooperation development, including joint training of young scientific staff members and, in particular, the support of joint work on the Precision Laser Inclinometer (PLI).

On 28 October, the JINR delegation visited the underground laboratory of the Ministry of Emergency Situations of the Republic of Armenia (MES RA) in Garni where one PLI which was developed and created at JINR successfully operates in the tunnel of the Garni Geophysical Observatory. The meeting with Acting Director of the Regional Survey for Seismic Protection of MES RA S. Margaryan was held.

On 29 October, a seminar dedicated to plans for the creation of the PLI network in Armenia was discussed in the Presidium of the National Academy of Sciences of the Republic of Armenia chaired by Academicians-Secretary of the Division of Chemistry and Earth Sciences of NAS RA L. Tavadyan and the Division of Mathematical and Technical Sciences of NAS RA L. Agalovyan. At the end of the seminar, President of NAS RA R. Martirosyan met with its participants.

At the Yerevan Physics Institute (YerPhI), the JINR delegation was welcomed by Deputy Director of the Institute G. Karyan. At the workshop, the parties discussed the development of international contacts and the YerPhI scientific infrastructure, as well as the resumption of broad cooperation with JINR. The delegation got acquainted with the modernized equipment of the electronic linear accelerator (LUE-75).

The milestones of the committee were summed up at the meeting with Plenipotentiary of the Government of the Republic of Armenia to JINR, Chairman of the State Committee of Science S. Harutyunyan who, in particular, shared plans to enhance cooperation with JINR.

From 29 October to 6 November, the joint CERN–Japan–Russia International Accelerator School "Ion Collider Physics" worked in the SEZ "Dubna". The International Organizing Committee of the school was chaired by RAS Corresponding Member I. Meshkov (JINR). Co-chairmen were RAS Academician B. Sharkov (JINR) and Dr. E. Levichev (BINP SB RAS).

The audience of the school consisted of students who master physics and technology of accelerators, young specialists of accelerator centres and companies that produce accelerator equipment. Lectures were given by leading experts of CERN, Budker INP, GSI, MEPhI and other centres in the field of physics and technology of ion colliders.

The listeners of the school were given the opportunity to try their hand at solving specific problems related to beam dynamics, ion sources, RF systems, vacuum technologies, etc. Special place in the programme of the school was occupied by accelerator projects and new developments of such centres as CERN, JINR, GSI (Germany), KEK (Japan), BINP SB RAS and NRNU MEPhI.

On 9 November, Academician and Honorary Secretary of the French Academy of Sciences Catherine Bréchignac visited JINR. In her trip to Dubna, Mme Bréchignac was accompanied by Dr. Gael Moullec, Advisor on cooperation with Russia and the Eurasian region to the Academy of Sciences of France.

JINR Director V. Matveev and JINR Vice-Director M. Itkis welcomed the French delegation and briefly introduced to the guests today's JINR, its new projects and scientific results, as well as progress in cooperation between JINR and French scientific organizations.

FLNR Director S. Dmitriev and FLNR Scientific Leader Yu. Oganessian guided a tour around the Factory of Superheavy Elements. They spoke about opportunities of the DC-280 cyclotron.

FLNP Director V. Shvetsov and his colleagues showed the guests the research potential of IBR-2. I. Saprykina, a researcher from the RAS Institute of Archaeology, proved the relevance of the neutron physics methods in the study of historical and cultural heritage.

On 12 November, a meeting with a delegation from the Federal Ministry of Education and Research (BMBF) of the FRG took place in the Ministry of Science and Higher Education of the Russian Federation. JINR Director Academician V. Matveev and Deputy Head of the International Cooperation Department A. Kotova represented the Joint Institute for Nuclear Research at the meeting.

During the discussion, the participants stressed the need in the further development of the cooperation between Russia and Germany and, in particular, with the Joint Institute for Nuclear Research. The German party highlighted its interest in participation in the mega-science projects NICA and PIC implemented in the Russian territory, as well as paid attention to scientific and educational activities in the field of training of the scientific staff. At the end of the discussion, V. Matveev and Director of the Large Facilities and Basic Research Department of BMBF V. Dietz signed a joint declaration of intent.

On 13 November, the guests from BMBF visited JINR to discuss the issues of implementation of the document signed in Moscow and the status and prospects of JINR–Germany cooperation. Deputy Head of the International Cooperation Department A. Kotova, Senior Researcher of BLTP W. Kleinig and Advisor to JINR Director U. Meyer took part in the discussion. The guests visited the Veksler and Baldin Laboratory of High Energy Physics, the Frank Laboratory of Neutron Physics and the Flerov Laboratory of Nuclear Reactions, where they were shown the objects of research infrastructure of JINR. In conclusion of the visit, the sides discussed details of the plan of implementation of the declaration of intent for the year 2020.

On 14 November, a presentation and a demonstration of the modernized "Govorun" supercomputer took place at the Laboratory of Information Technologies of

JINR. The updated supercomputer has a joint theoretical peak performance of 860 TFlops of double precision, which allowed it to take the 10th place in the Top-50 list of the most powerful supercomputers in Russia and the CIS.

LIT staff members and employees of other JINR laboratories, as well as Russian computing centres such as ISC RAS, ICM&MG SB RAS, SPbPU, ICG SB RAS, ICT SB RAS, specialists of the "Intel" and "RSC Technologies" companies, participated in the presentation. In the first part of the presentation, which was held in the computer room of the Multifunctional Information and Computing Complex, LIT Director V. Korenkov addressed the participants of the event. He noted that over the past year and a half, the JINR supercomputer named after N. Govorun in its first modification had made it possible to carry out a number of complex resource-intensive calculations in the field of lattice quantum chromodynamics, to calculate radiation safety of the JINR experimental facilities and to significantly accelerate research in the field of radiation biology and other scientific and applied problems being solved at JINR.

JINR Vice-Director R. Lednický congratulated LIT team on the launch of the second modification of the supercomputer: "Nowadays the progress of science is unthinkable without great computing power. The analysis of data obtained at the collider will be impossible without a supercomputer." O. Rogachevsky, the coordinator of the MPD project (VBLHEP), observed that the computing resources of the supercomputer were already actively used by the MPD collaboration of the NICA megascience project to generate and reconstruct events, and the given modernization would qualitatively increase the speed of modeling the dynamics of collisions of relativistic heavy ions and accelerate the process of generating and reconstructing events for the NICA experiments. In his speech, Rector of Dubna University D. Fursaev congratulated the Laboratory staff on this huge success and paid attention to the importance of students' training of high-performance computing technologies on the latest computing architectures. Yu. Migal (RSC, Moscow) introduced the technical characteristics of the updated supercomputer to the audience, and N. Mester (Intel) talked about novel hyperconverged approaches implemented in the second modification of the supercomputer allowing one to significantly speed up work with large amounts of data, which is particularly relevant for the NICA megascience project.

After the presentation, a seminar on novel software and hardware solutions of the "Govorun" supercomputer and on the results of its operation was held. V. Kekelidze, who noted the importance of the "Govorun" supercomputer for all tasks to be solved at JINR, especially for the NICA megascience project, opened the seminar. V. Korenkov enlarged upon the development trends of the Multifunctional Information and Computing Complex as the basic facility of JINR. In his report, D. Podgainy spoke about the experience of operating the supercomputer; in particular, he noted that the results of scientific research using the computing resources of the supercomputer had been published in more than 50 leading world scientific journals. N. Mester (Intel) introduced the current trends in the development of the latest computing architectures from Intel. Representatives of the "RSC Technologies" company A. Shmelev and P. Lavrenko presented an overview of solutions for HPC platforms on contact liquid cooling, as well as novel approaches to working with large amounts of data implemented on the "Govorun" supercomputer.

On 5 December, a JINR delegation took part in the official closing ceremony of the International Year of the Periodic Table of Chemical Elements (IYPT) in Tokyo (Japan). The ceremony was attended by First Deputy Minister of Science and Higher Education of Russia G. Trubnikov, Past President of the International Union of Pure and Applied Chemistry, Co-chairman of the IYPT International Committee N. Tarasova, Chairman of the Executive Committee of the International Year of the Periodic Table in Japan K. Tamao and others.

A considerable part of the IYPT closing ceremony was dedicated to the Periodic Table. Representatives of the International Union of Pure and Applied Chemistry and the International Union of Pure and Applied Physics, world-famous scientists made the reports. A public speaking was organized by RAS President A. Sergeev, laureates of the 2008 Nobel Prize in Physics M. Kobayashi and the 2019 Nobel Prize in Chemistry A. Yoshino. Sir Martyn Poliakoff, the Vice-President of the Royal Society, addressed the audience with a video message.

In the framework of the ceremony, the session "Creation of superheavy elements" was held at which leading scientists, who made a considerable contribution to the synthesis and discovery of superheavy elements, appeared on stage to celebrate the completion of the 7th row of the Mendeleev Periodic Table. Representatives of GANIL, GSI, LBL, LLNL, ORNL, RIKEN, and JINR lined up to form a symbolic 7th row of the Periodic Table. JINR Director Academician V. Matveev presented element 105 (dubnium); JINR Vice-Director M. Itkis, rutherfordium (104); FLNR Director S. Dmitriev, flerovium (114); Head of the FLNR Sector V. Utyonkov, moscovium (115); and FLNR Scientific Secretary A. Karpov, oganesson (118). The session was concluded with a speech by Yu. Oganessian who expressed gratitude on behalf of all discoverers and noted a significant contribution of numerous scientific institutes, international organizations and states to the synthesis and acknowledgement of discoveries of new superheavy elements.

A bright milestone of the International Year of the Periodic Table celebration all over the world was the

unique interactive exhibition presented in the framework of the closing ceremony.

On 11 December, in Moscow, at the joint meeting of the Presidium of the Science and Technology Council of the Rosatom State Corporation and leaders of the Joint Institute for Nuclear Research, chaired by Academician G. Rykovanov, an agreement on partnership interaction was signed in some issues of leading scientific projects, including the development of the NICA collider complex, the Factory of Superheavy Elements, the use of the IBR-2 pulsed reactor and the development of a new pulsed reactor facility in Dubna. Director General of Rosatom A. Likhachev and JINR Director RAS Academician V. Matveev signed the document.

First Deputy Minister of Science and Higher Education of the Russian Federation Academician G. Trubnikov welcomed participants of the meeting. The programme of the meeting included reports on major fields of cooperation made by leading scientists of JINR, leaders of JINR large-scale projects, as well as their colleagues from Rosatom cooperating organizations. JINR Vice-Director, VBLHEP Director RAS Corresponding Member V. Kekelidze made a report on the NICA megascience project. Academician Yu. Oganessian dedicated his report to new opportunities in the synthesis of superheavy elements. A report "Opportunities of the Rosatom State Corporation in providing isotopes to the Superheavy Element Factory accelerating complex" was delivered by Director of JSC "SSC RIAR" A. Tuzov. The IBR-3 fast pulsed reactor was a topic of the report by FLNP Scientific Leader RAS Corresponding Member V. Aksenov. JINR Assistant Director RAS Corresponding Member G. Shirkov made an overview of the theme "Accelerators for nuclear medicine".

On 13 December, a regular meeting of the JINR Science and Technology Council took place in the International Conference Hall chaired by Professor R. Jolos. Summing up the results of the year, JINR Director Academician V. Matveev noted the brightest events, scientific results and achievements of the international community of the Institute and talked about primary tasks to modernize the administration system of the Institute and its financial activities, which were discussed at the 126th session of the Scientific Council and the guest session of CP in Vietnam.

D. Kazakov, S. Nedelko, A. Frank, M. Itkis, I. Meshkov, S. Dmitriev, Yu. Potrebenikov, D. Naumov, R. Jolos, and D. Peshekhonov asked questions and made comments.

JINR Assistant Director RAS Corresponding Member G. Shirkov made a report on the creation of the joint JINR–FMBA Medical and Biological Centre for Proton Therapy in cooperation with IBA, the world leader in manufacturing facilities for proton therapy. The speaker spoke about the history of the issue that dates back to 1967 when the first runs for the clinical application of proton beams produced by the JINR Phasotron were carried out on the initiative and with the support of Director of the Laboratory of Nuclear Problems V. Dzhelepov. He also gave examples of successful cooperation of JINR with IBA in development of accelerators and physics facilities for fundamental and applied research.

V. Shvetsov, V. Bednyakov, O. Culicov, M. Gnatich, Yu. Usov, D. Naumov, E. Krasavin, E. Syresin, M. Itkis, B. Gikal, I. Meshkov, A. Baldin, and R. Jolos took part in the discussion of the report.

CONFERENCES AND MEETINGS HELD BY JINR

Nine conferences were the largest among the scientific conferences and workshops held at JINR in 2019.

On 15–19 April, ***XXIII International Scientific Conference of Young Scientists and Specialists of JINR (AYSS-2019)*** was held at the Laboratory of Information Technologies. More than 200 attendants took part in it: 140 participants from JINR and 68 persons from 33 universities and scientific centres of Armenia, Belarus, Chile, the Czech Republic, Germany, India, Iran, Kazakhstan, Poland, Russia, Romania, Serbia and Slovakia.

The programme of the conference included 9 lectures on urgent problems in modern science. They were given by FLNP Senior Researcher I. Zinicovscaia, BLTP Director D. Kazakov, FLNR Scientific Secretary A. Karpov, Head of the MPD collaboration A. Kisiel, FLNR Senior Researcher V. Hudoba, FLNP Director V. Shvetsov, Academician V. Rubakov (INR RAS), Senior Researcher of Samara University R. Eremin, and representative of FAIR (Germany) E. Lavrik.

Under the support of LIT, the leading specialist in the analysis of data of the SAP SE company (Germany) A. Streltsov gave a training course "Deep and Machine Learning Methods for Document Clustering and Classification" that was attended by over 80 young scientists and specialists. The lectures are available on the website stream.jinr.ru.

The participants of the conference presented 126 oral reports in eight sections. A poster session was held at the JINR Scientists' Club. From 40 poster reports, members of the programme and organizing committees singled out reports by E. Adamska (Warsaw University) and A. Nazarova (FLNP, JINR).

Excursions were organized for the conference participants to the JINR basic facilities: the NICA accelerator complex under construction at VBLHEP, the new

accelerator DC-280 at FLNR, and the IBR-2 reactor at FLNP.

The international workshop ***"SPD at NICA"*** was held at the Veksler and Baldin Laboratory of High Energy Physics on 4–8 June. The event continued the series of meetings on problems of polarized phenomena in particle physics, nuclear physics and astrophysics connected to particle spin and the nucleon spin structure.

This year the workshop was dedicated to the topic of the SPD (Spin Physics Detector) project at the NICA collider. One of the main aims of the workshop was to establish an international collaboration for design and construction of the SPD detector and for preparation and conduct of physics experiments at the SPD facility.

More than 120 participants from leading accelerator centres of Armenia, Belarus, Bulgaria, China, Cuba, the Czech Republic, France, Germany, Italy, Poland, Slovakia, Ukraine, Switzerland and Russian scientific research centres took part in the workshop.

About 50 scientific reports were delivered, discussions were held at a round table meeting. The participants had excursions to the NICA accelerator complex under construction and the factory of superconducting magnets.

On 10–14 June, Dubna hosted the annual ***International Seminar on Interaction of Neutrons with Nuclei (ISINN-27)*** that "returned to its homeland" after last year's "visit" to Xi'an, the ancient capital of China. It was organized by the Frank Laboratory of Neutron Physics of JINR together with the colleagues from Chinese institutes and universities. The scientific programme of the seminar traditionally covered a wide range of topics in neutron physics varying from fundamental properties of the neutron and fundamental interactions in reactions with neutrons, nuclear fission, ultracold neutrons (UCN) to analytical methods in materials science and life sciences. The seminar brought together over 100 participants from physics research centres of Azerbaijan, Bulgaria, China, the Czech Republic, Egypt, France, Germany, Moldova, Romania, Serbia, South Africa and Vietnam, as well as from the Institute of Physics and Power Engineering (IPPE) and the Medical Radiological Research Centre (MRRC) (Obninsk), the National Research Centre "Kurchatov Institute" (NRC KI) and the Institute for Theoretical and Experimental Physics (ITEP) of NRC KI (Moscow), the Petersburg Nuclear Physics Institute of NRC KI (Gatchina), Institute for Nuclear Research of RAS (Troitsk), the Landau Institute for Theoretical Physics of RAS (Chernogolovka), INP MSU (Moscow), and VNIIA (Moscow). The staff of JINR FLNP also attended the seminar. A total of 49 oral and 41 poster reports were presented (for more details, see the seminar webpage http://isinn.jinr.ru/past-isinns/isinn-27/program.html).

According to the long-standing tradition, the first plenary session of the seminar was opened by P. Geltenbort (ILL, France) with a review report on the current status of the investigation of the beta decay of the free neutron, which is important for refining the Standard Model. Today, a paradoxical situation has emerged: two methods of measurement (beam measurement technique and method based on the storage of UCN in a "bottle") produce the results that differ by four standard errors, while the measurement errors have been brought to the level of 0.05%. In this regard, many laboratories in Europe and the United States are developing and constructing new high-precision and expensive facilities to resolve the existing contradiction. The speaker noted the original proposal made by researchers from JINR FLNP on the measurement of the neutron lifetime at the IBR-2 reactor. This method is fundamentally different from the two already existing and therefore can help to solve the problem.

The first day of the meeting ended with a session devoted to applied aspects of neutron physics. The first and very promising results of the application of tagged neutrons for online analysis of the composition of apatite ores were reviewed in the report delivered by Yu. Rogov (Diamant LLC, Dubna). N. Simbirtseva (FLNP, JINR) spoke about the investigation of the elemental composition of the Old Russian medallion (12th–13th centuries) using neutron resonance capture analysis at the IREN facility (JINR).

The second day of the seminar was opened with a session dedicated to new promising sources of neutrons and neutrinos. Two reports presented by Jingyu Tang from the Institute of High Energy Physics of CAS (Beijing) provided an overview of the programme and the first results of experimental studies at the newly commissioned Chinese Spallation Neutron Source (CSNS) and CSNS Back-n White Neutron facility. This facility even now makes it possible to obtain the most intense resonance neutron fluxes in the world, and in the next three years it is planned to increase its beam power even more (by a factor of five). The speaker emphasized the interest of his Institute in maximally expanding the international cooperation in the use of this unique neutron source and invited colleagues from JINR and its Member States to take an active part in the development of new experimental instruments on CSNS beamlines.

V. Shvetsov (FLNP, JINR) spoke about the plans to construct a new neutron source at JINR, which should replace the IBR-2 reactor after its service life expires. The parameters of this source should be higher than those of the European Spallation Source (ESS) in Sweden, since it is expected to start operating after 2030. At present, two alternative concepts of this source are being considered and intensively studied in close cooperation with the JINR's long-standing partner NIKIET, the chief designer of the IBR-2 reactor.

V. Lyashuk (INR, RAS) reported on the scheme and possible parameters of an intense antineutrino source

based on a nuclear reactor designed to detect sterile neutrinos.

The research field "Nuclear Analytical Methods in the Life Sciences and Materials Science", popular among the JINR Member States, was the subject of the evening session of the second day of the seminar. In the review report by O. Duliu (FLNP, JINR), the conclusive results of years-long studies of sediments in the western part of the Black Sea were discussed, which provide important information on the pollutant transport by rivers. V. Zaichick (MRRC, Obninsk) presented very important results about a new method for the early diagnosis of human prostate diseases, which inspired an active discussion.

W. Badawy (FLNP, JINR) reported on the joint investigations in the framework of the long-term cooperation programme between JINR and the Arab Republic of Egypt (ARE) on the biomonitoring of heavy metal contamination of the Nile River basin and the Greater Cairo region. The coordinator of the JINR–ARE cooperation programme, Dr. H. El Samman, who attended the session, expressed satisfaction with the results of the joint work.

The poster session featured studies of young scientists from Azerbaijan, Bulgaria, China, Egypt, JINR, Russia, and Vietnam on the biomonitoring of territories with a strong anthropogenic load, methods of experiments with neutrons, as well as on the fundamental problems in nuclear physics.

The final session of the seminar was focused on the discussion of the so-called collinear cluster tri-partition discovered at FLNR, JINR. As D. Kamanin (FLNR, JINR) noted in his report, this phenomenon has been discussed at the ISINN conferences for more than 10 years, and each time it sparked a lively discussion. This time, he reported on the first observation of the true quaternary fission in the $^{235}\mathrm{U}(n_{\mathrm{th}}, f)$ reaction. The report of Yu. Pyatkov (MEPhI; FLNR, JINR) contained the results of the first full measurement of characteristics of the products of the collinear cluster tri-partition. In addition, he reported on the first successful experiment in which a heavy fission fragment was transported through a special channel over a distance of 4 m. The report of Yu. Tchuvilsky (INP, MSU) poured "cold water" on the interpretation of the phenomenon under study. The speaker presented theoretical limitations on the observed process, which follow from the general principles of quantum mechanics. Yet again, the ball is in the court of experimenters.

The success of the ISINN-27 has confirmed the usefulness and attractiveness of the format of annual meetings on a wide range of issues in neutron physics that had been chosen for this conference a little more than a quarter of a century ago. The feasibility and effectiveness of neutron methods for solving fundamental and applied problems of science have been proved as well. The growing number of young participants attending the seminar shows that it has a future.

From 1 to 5 July, under the aegis of JINR and RAS the traditional ***LXIX International Conference on Nuclear Spectroscopy and Nuclear Structure*** "Fundamental Problems of Nuclear Physics, Nuclei at Borders of Nucleon Stability, High Technologies" ("Nucleus-2019") was held in Dubna. Co-organizers of the conference were also St. Petersburg and Moscow Universities. The Chairman of the Organizing Committee was JINR Director Academician V. Matveev, Deputy Chairmen were Professors V. Brudanin and Yu. Penionzhkevich.

It is a regular annual conference that gathers nuclear physicists from the majority of scientific centres of the USSR (before 2000) and the Russian Federation. The conference is significant for postgraduates, teachers and staff members of universities where there are chairs of nuclear physics. Practically all participants can make oral and poster reports which is important for young scientists. Over 300 scientists took part in the conference: 120 from JINR, about 100 from institutes and universities of Russia and about 80 persons from other countries, including the USA, France, India, South Africa, China, Japan and others.

This year is a special one for physicists, it is announced by UNESCO as the jubilee year — 150 years since the discovery of the Periodic System of Elements by D. Mendeleev. JINR has made a great contribution to the discovery of new elements. That is why the first day of the conference was devoted to this event, and the first plenary meeting of the conference focused on the synthesis of new superheavy elements. Scientific Leader of JINR's FLNR Academician Yu. Oganessian made a report on this topic, JINR Vice-Director Professor M. Itkis gave an overview of the prospects of JINR development, V. Kekelidze spoke about the NICA megaproject, and A. Karpov reported on the studies at FLNR. Participants of the conference discussed other urgent problems in nuclear physics — the synthesis and properties of new exotic nuclei, nuclear reactions with stable and radioactive beams. They also considered theoretical approaches to various aspects of nuclear physics and application of nuclear physics methods in related fields of science and technology (nuclear medicine, nanotechnology, radiation technology, radiation stability of products of microelectronics and systems of spaceships).

Plenary meetings with invited and review talks and parallel section meetings with interesting information were held at the conference. Poster reports were presented as well. The Proceedings of the conference will be published in the journals "Izvestiya RAN. Seriya fizicheskaya", "Nuclear Physics" and "Nuclear Physics and Engineering".

From 3 to 8 September, the 13th international scientific workshop ***"Problems of Colliders and Charged Particle Accelerators. Applied Research on Accelerators"*** organized in memory of Professor V. Sarantsev

was held in the resort hotel "Dubna" of the Joint Institute for Nuclear Research in Alushta (Crimea). Organizers of the event were the Joint Institute for Nuclear Research, the Institute of Nuclear Physics of SB RAS, and the Scientific Council on Charged Particle Accelerators of the Russian Academy of Sciences.

The workshop is aimed at encouraging the information exchange and discussion of issues in the fields of accelerator science and technologies, physics of beams of charged particles, the development of new projects of lepton and hadron colliders, modernization of operating facilities, the use of accelerators for scientific and applied aims, attracting young scientists to solve the problems of acceleration technologies. The workshop has been held in Alushta since 2005.

Reporters represented the largest accelerator centres of Russia, such as INP SB RAS (Novosibirsk), JINR (Dubna), ITEP (Moscow), IPCE RAS (Moscow), INR RAS (Moscow), MSU (Moscow), NRC "Kurchatov Institute" (Moscow), MEPhI (Moscow), high-tech organizations Millab and Research and Production Enterprise "Toriy" (Moscow), NSU (Novosibirsk), LPI PTC (Protvino), St. Petersburg State University, SRIEPA (St. Petersburg), INR (Troitsk), as well as IFIN-HH, NRC NP (Bucharest).

The topics of the seminar included important issues of accelerator physics such as projects of ultra-high energy colliders, modern ion accelerators and colliders, circular electron–positron colliders, generation of coherent radiation of free-electron lasers, dynamics of beams of charged particles, new methods of acceleration, and accelerators for applied purposes.

From 4 to 17 September, the annual ***27th European School on High Energy Physics (ESHEP-2019)*** was held in Saint-Petersburg. This series of schools, famous as CERN–JINR schools, traditionally attract much attention of the youth thanks to a sophisticated scientific programme, well-developed format, and a careful choice of lecturers and leaders of discussions.

These schools are held successively in the Member States of two international organizations, namely, the European Organization for Nuclear Research and the Joint Institute for Nuclear Research. In 2019, the Russian Federation was chosen to hold the event. The Ministry of Science and Higher Education of the Russian Federation, the Russian Academy of Sciences, and the National Research Centre "Kurchatov Institute" also took part in the organization of the School-2019.

About 100 listeners from more than 30 countries participated in the 27th school. Most of them were post-graduate students who finish their dissertations, possess a high scientific potential, and take part in recent research. Leading scientists delivered their lectures in the main topics of modern high energy physics.

CERN Director-General Professor F. Gianotti and JINR Director RAS Academician V. Matveev presented traditional lectures on scientific programmes and prospects for research in the fields of high energy and particle physics.

On 6 September, a discussion of the role of fundamental science in the development of the modern society with the participation of the public, listeners of the school, CERN and JINR leadership, representatives of science and organizations financing science was held in the Big Hall of the St. Petersburg RAS Scientific Centre.

CERN Director-General F. Gianotti made a public lecture followed by a discussion with the participation of guests: JINR Director RAS Academician V. Matveev, Deputy Academician-Secretary and Head of the RAS Department of Physical Sciences Academician V. Rubakov, First Deputy Minister of Science and Higher Education RAS Academician G. Trubnikov, President of the NRC "Kurchatov Institute" RAS Corresponding Member M. Kovalchuk, SPbSTU Rector RAS Academician A. Rudskoy, and SPSU Rector Professor N. Kropachev.

Thus, the whole series of European Schools of High Energy Physics organized by CERN and JINR continues to fulfil its scientific and cultural mission at a high level, constantly enhancing the programme and formats of interaction with the audience and the public.

From 9 to 10 September, in Moscow at the Steklov Mathematical Institute of RAS (MIRAN), and from 11 to 13 September, in Dubna at the Joint Institute for Nuclear Research (JINR), the International Bogoliubov Conference ***"Problems of Theoretical and Mathematical Physics"*** was held, which was dedicated to the 110th anniversary of the birth of the outstanding scientist — mathematician and physicist, Academician of the Russian Academy of Sciences and AS of the Ukrainian SSR, director of JINR (1965–1989), founder and first director of JINR's LTP (1956–1965) Nikolai Nikolayevich Bogoliubov (21.08.1909–13.02.1992).

The Bogoliubov conference was organized by the Russian Academy of Sciences, the Joint Institute for Nuclear Research and the Steklov Mathematical Institute of RAS. The Bogoliubov Conference–2019 was possible thanks to the financial support of JINR and the Russian Foundation for Basic Research.

The main topics of the 2019 Bogoliubov Conference were mathematics and nonlinear mechanics, quantum field theory, elementary particle theory, statistical mechanics and kinetics, quantum condensed matter theory, nuclear physics — the areas to which N. N. Bogoliubov made a fundamental contribution.

The conference was attended by more than 230 scientists from Belarus, Bulgaria, Chile, China, Cuba, the Czech Republic, Egypt, France, Georgia, Germany, Great Britain, Greece, Italy, the Republic of Korea, Moldova, Mongolia, Poland, Portugal, Russia, Serbia, Slovakia, Spain, Sweden, Ukraine, the USA, and Uzbekistan. Among them are leading physi-

cists and mathematicians who are both students of N. N. Bogoliubov and representatives of many schools created by the great scientist. Participants of the conference included not only well-known foreign scientists but also Russian physicists and mathematicians representing leading domestic scientific centres, including the Steklov MI RAS, Lebedev PI RAS, INR RAS, ITEP, St. Petersburg Institute of Nuclear Physics of RAS, INP SB RAS, IHEP, JINR, Lomonosov Moscow State University, Novosibirsk, Samara, Saratov State Universities, etc. Among the participants there were many actively working young scientists from Dubna and Moscow, as well as from many Russian and international centres.

The programme of the Bogoliubov Conference–2019 included 30 plenary and 104 section reports.

On 9 September, Vice-President of the Russian Academy of Sciences Academician V. Kozlov and JINR Director Academician V. Matveev opened the conference in the conference hall of the Steklov Mathematical Institute of RAS. Then plenary reports were presented. Academician V. Kozlov (Moscow) devoted his report to the polynomial conservation laws of quantum systems; Corresponding Member I. Volovich (Moscow) discussed the ideas of N. N. Bogoliubov in nonequilibrium statistical mechanics and advances in the problem of irreversibility; P. Exner (Czech Republic) studied the properties of singular Dirac operators with delta-shell interactions; V. Zagrebnov (France) discussed the Trotter–Kato product formulae for Gibbs semigroups; V. Kazakov (France) considered the properties of conformal fishnet theory at any dimensions; A. Gorsky (Moscow) studied the resummation of instantons in the partition function of supersymmetric Yang–Mills theories; C. Zarembo (Sweden) presented exact results in holographic duality; Academician V. Neznamov (Sarov) introduced the quantum mechanics of stationary states of particles in external singular fields of black holes with event horizons of zero thickness.

On the second day of the conference, plenary reports were made by: Academician D. Treschev (Moscow), on the entropy of unitary operators; L. Accardi (Italy), on extensions of quantum mechanics and quantum field theory canonically emerging from the theory of orthogonal polynomials; G. Savvidy (Greece), on the maximally chaotic dynamical Anosov–Kolmogorov systems; E. Zelenov (Moscow), on entropy gain in p-adic quantum channels.

From 11 to 13 September, the Bogoliubov conference continued its work in Dubna, at the JINR Laboratory of Theoretical Physics, named after N. N. Bogoliubov. The conference in Dubna began with a report of JINR Director Academician V. Matveev about the scientific school of N. N. Bogoliubov in Dubna. In the next review report, Academician R. Ilkaev (Sarov) spoke about Bogoliubov's work in the RFNC-ARSRIEPh in the 50s of the 20th century. In plenary reports of this working day of the conference, Director of the JINR Bogoliubov Laboratory of Theoretical Physics Corresponding Member D. Kazakov discussed the Bogoliubov R-operation in non-renormalizable theories; I. Aref'eva (Moscow) presented research on holography for nonperturbative study of quantum field theories, in particular, QCD; C. Bai (China) examined deformations and their controlling cohomologies of O-operators and their application for describing deformations of skew-symmetric r-matrices; V. Dobrev (Bulgaria) presented the construction of a multiparameter quantum Minkowski spacetime and quantum Maxwell hierarchy.

On the second day of the Dubna part of the Bogoliubov conference, plenary reports were made by: Academician V. Rubakov (Moscow), towards bouncing and Genesis cosmologies; G. Korchemsky (France), about energy correlations at "conformal collider"; Corresponding Member K. Chetyrkin (Germany), on the latest studies on the multiloop renormalization group in QCD; V. Fadin (Novosibirsk), on the status of the Bogoliubov–Fadin–Kuraev–Lipatov equation and problems in its application; S. Derkachev (St. Petersburg), on the separation of variables and Basso–Dixon correlators in two-dimensional conformal field fishnet theory; V. Spiridonov (Dubna), on superconformal indices, Seiberg duality and the use of special functions in superconformal theories.

In plenary lectures on the last day of the Bogoliubov conference, S. Flah (Republic of Korea) examined the dynamics of ergodization in weakly nonintegrable many-body systems using dynamic glass as an example; N. Plakida (Dubna) discussed superconductivity in electron systems with strong correlations; V. Zakharov (Moscow) demonstrated the manifestations of quantum anomalies in quantum statistical mechanics; Corresponding Member D. Gorbunov (Moscow) spoke about the current status of inflationary theory; E. Boos (Moscow) discussed the approach of an effective theory to beyond the Standard Model; R. Faustov (Moscow) considered the properties of heavy baryons in the relativistic quark model.

Sectional sessions were held in separate scientific areas, closely related to the scientific activity of N. N. Bogoliubov.

The reports of the section "Mathematics and nonlinear mechanics", presented mainly in Moscow, discussed the Bogoliubov microscopic solutions of the Boltzmann–Enskog kinetic equation, the correlation functions of integrable models, the connection of super-Yangians and quantum loop superalgebras, macroscopic long-range dynamics of fermions and quantum spins on a lattice, aspects of current algebra representations and factorized structure of quantum integrable many-particle models, modern problems in gravity, out-of-equilibrium two-dimensional Yukawa theory in a strong scalar wave background, nonlinear interaction of strong gravitational and electromagnetic waves of the expand-

ing universe, the properties of rotating black holes, the properties of the Lie–Poisson structures, cosmological model with the Gauss–Bonnet term and non-minimally coupled scalar fields, and others.

The section "Quantum field theory and elementary particle theory" addressed in detail the issues of diffraction scattering in QCD, the search for light dark matter on accelerators, the Higgs composite model and the generation of baryon asymmetry, light scalars in NMSSM, dijet correlation in multijet processes in the Regge limit of QCD, Bogoliubov compensation approach and effective interactions in the Standard Model, NSVZ scheme in non-Abelian supersymmetric gauge theories, nonleptonic decays of doubly charmed baryons, Landau–Khalatnikov–Fradkin transformations and the mystery of even zeta-values in Euclidean mass correlators, conformal symmetry breaking in massless analytic PT expressions for the Adler D-function and the Bjorken polarized sum rule, cut-off technique for four-loop massless propagators, elliptic principal integrals in nonrelativistic QCD, collinear OPE in $N = 4$ supersymmetric Yang–Mills theory, etc.

The main topics addressed in the section "Statistical mechanics, kinetics and quantum theory of condensed matter" were topology- and geometry-driven quantum phenomena in nanoarchitectures of semiconductors and superconductors, the Hartree–Fock–Bogoliubov method in the theory of Bose-condensed systems, resonance features of superconductor–ferromagnet Josephson junctions, classical and quantum crystal rainbow processes, time evolution of open nonequilibrium systems and irreversibility, anomalous scaling in the turbulence phenomena, quantum correlation in a quasihomogeneous macromolecular chains with single-vibronic excitation.

The section "Nuclear physics" discussed the Bohr–Sommerfeld quantization rule in the case of decreasing power potential, resonances in the Friedrichs–Faddeev model, proton charge radius and Rydberg constant from HD+ spectroscopy, confinement-induced resonances caused in two-centre problem, the Van der Waals three-body systems, etc.

The Bogoliubov Conference–2019 showed the preservation of the scientific traditions laid down by N. N. Bogoliubov in the world scientific community.

On 23 September, ***the 23rd International School on Nuclear Physics, Neutron Physics and Applications*** started in Varna (Bulgaria). The school is organized by the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences and the Joint Institute for Nuclear Research biannually.

The main goal of the school is to stimulate the activity of the nuclear physics community in the south-eastern part of Europe. For prominent physicists and their young colleagues from all over the world, it is a popular attractive place to discuss the most interesting experimental and theoretical topics in the field. This year, more than 100 scientists from different countries came to Bulgaria to participate in the school.

The programme of the meeting covered the following topics: nuclear excitations at various energies, nuclei with big angular momenta and at high temperature, nucleus structure and nuclear reactions far from stability, symmetries and collective phenomena, methods for particle lifetime measurements, astrophysical aspects of nuclear structure, neutron nuclear physics, nuclear data, advanced methods in nuclear waste treatment and nuclear methods for applications.

The programme of the meeting included invited reports, oral and poster reports. During the informal conversation, participants discussed future prospects of joint research in different scientific centres.

On 30 September – 4 October, ***the 27 International Symposium on Nuclear Electronics and Computing (NEC'2019)*** was held in Budva, the Republic of Montenegro. The forum has rich traditions and has been held by JINR since 1963, and JINR and CERN are its organizers for the tenth time. The symposium co-chairmen were V. Korenkov, director of JINR LIT, and I. Bird, WLCG project leader of CERN. Over 190 leading specialists (representatives of 30 scientific organizations) in the field of modern computer and network technologies, distributed computing and nuclear electronics from 13 countries (Belarus, Bulgaria, China, the Czech Republic, France, Germany, Italy, Russia, Slovakia, South Africa, Switzerland, the United Kingdom, and the USA) took part in the symposium.

The scientific programme of the symposium covered a wide range of issues and comprised the following sections: detector and nuclear electronics, trigger systems and data acquisition systems, machine learning algorithms and Big Data analytics, grid technologies and cloud computing, computing for experiments at large-scale accelerator facilities (LHC, FAIR, NICA, SKA, PIC, XFEL, ELI, etc.), research data infrastructures, computing on hybrid systems, as well as the traditional section of the symposium — information technologies in education. The symposium was sponsored by IBS Platformix, Supermicro Computer, NIAGARA, Jet Infosystems, Intel, RSC Group, Cisco, Dell EMC, and ITCost.

At plenary sessions, reports were presented, in particular, by V. Korenkov on the development strategy of information technologies of LIT, by D. Barberis (CERN) on the development of tools for monitoring distributed computing systems in the ATLAS experiment, by A. Valassi (CERN) on the analysis and accounting of computing resources in the WLCG (Worldwide LHC Computing Grid) project, and by I. de Bruyn (University of Wisconsin, Madison) on updating electronics for the CMS muon system at the LHC with high luminosity. S. Sidorchuk (JINR) spoke in his report about experimental projects dedicated to the study of exotic nuclei in Dubna. The report of A. Kiryanov (PNPI, Gatchina)

was devoted to the organization of the Russian federative distributed data storage, i.e., the National Data Lake.

Leading experts W. Vandelli (CERN), O. Rogachevskiy (JINR), A. Maksymchuk (JINR), R. Hadjiska (Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences), and H. Sert (RWTH Aachen University) delivered plenary reports on the issues of data acquisition, computing and the organization of data storage for large-scale experimental facilities such as the LHC and NICA.

Reports that evoked great interest among the symposium participants and were devoted to topical issues of the development of the detector's equipment, data acquisition and automation systems, computing for large-scale experimental facilities, research data infrastructures, the use of state-of-the-art IT technologies such as grid, cloud computing, hybrid computing, machine learning to solve modern scientific problems, were presented at sectional sessions.

Two round tables were organized in the framework of the scientific programme of the forum. Topics of discussions covered practical aspects of applying Cisco technologies for the server part, data storage, networking, including for private and hybrid clouds. Issues of the processor microarchitecture, trends in the development of the supercomputer architecture, data processing and storage were discussed at the round table organized by the NIAGARA company.

The international student school on modern information technologies "Big Data Mining and Distributed Systems" was held as part of the symposium for the fifth time. The major topics of the school scientific programme were Big Data analytics, machine learning and distributed systems. The best reports of students were selected within the school-conference, and the winners made their presentations at the final plenary session of the symposium. All the participants of the student school were awarded certificates, and the best students were awarded diplomas.

The results of the symposium were summed up at the closing ceremony. In total, within the scientific programme of the event, 32 meetings were held, 140 reports were presented, including 31 plenary and 109 sectional ones. The closing remarks were made by representatives of the Local Organizing Committee. All the speakers noted a high level and a depth of the content of the reports and the activity of the participants.

PARTICIPATION OF JINR IN INTERNATIONAL CONFERENCES

In 2019, scientists and specialists of the Joint Institute for Nuclear Research took part in 485 international conferences and meetings.

The largest delegations representing JINR attended the following events: Physics Summer School at iThemba LABS (Cape Town, RSA); 13th International JUNO Collaboration Meeting (Shanghai, China); GSI/FAIR Workshop on Stochastic Cooling (Darmstadt, Germany); conference "Complete Designs of Microchips by Means of Mentor Graphics CAD" (Zelenograd, Russia); Festive Opening Ceremony of the International Year of the Periodic Table of Chemical Elements (Paris, France); EOS Workshop (Geneva, Switzerland); B&R Annual Conference "Innovation Days" (Moscow, Russia); COMPASS DAQFEET 2019 Workshop (Garching, Germany); 10th Asian Forum for Future Accelerators and Detectors (AFAD-2019) (Dehli, India); 32nd Task Force Meeting of the UNECE ICP Vegetation (Targoviste, Romania); 27th COMET Collaboration Meeting (CM27) (Tokai, Japan); Moscow International School of Physics (Voronovo, Russia); NOνA Collaboration Meeting (Austin, USA); NUSTAR Annual Meeting (Darmstadt, Germany); 34th International Conference on Interaction of Intense Energy Fluxes with Matter (Elbrus 2019) (Terskol, Russia); 53rd PNPI Winter School (Roshchino, Russia); 23rd International Symposium "Nanophysics and Nanoelectronics" (Nizhniy Novgorod, Russia); 36th HADES Collaboration Meeting (Darmstadt, Germany); 4th xFitter Workshop (Minsk, Belarus); international workshop "Subcritical Nuclear Systems and Nuclear Energy Issues" (Tashkent, Uzbekistan); 9th Kitov International Scientific and Practical Conference "Information Technologies and Mathematical Methods in Economics and Management" (Moscow, Russia); 54th ASRC International Workshop "Nuclear Fission and Structure of Exotic Nuclei" (Sakura-2019) (Tokai, Japan); 6th All-Russian Conference "Technologies of Design and Debugging of Complex Technical Systems" (Moscow, Russia); 33rd CBM Collaboration Meeting (Darmstadt, Germany); 17th Workshop on Nuclear Physics (WONP-2019) (Havana, Cuba); 15th Cryogenics IIR International Conference and Exhibition (Prague, Czech Republic); International Scientific Conference of Students, Postgraduates and Young Scientists "Lomonosov 2019" (Moscow, Russia); 26th Scientific and Practical Conference of Students, Postgraduates and Young Experts at Dubna University (Dubna, Russia); annual conference "Polynomial Computer Algebra" (St. Petersburg, Russia); All-Russian Conference "Physical and Analytical Chemistry of Natural and Techno-Based Systems, New Technologies and Materials — Khodakovskiy's Readings" (Dubna, Russia); 25th All-Russian Conference of Physics Students and Young Scientists (Sevastopol, Simferopol, Russia); 2nd International Conference on Radioanalytical and Nuclear Chem-

istry (RANC-2019) (Budapest, Hungary); 4th International Conference on Nuclear Structure and Dynamics (NSD2019) (Venice, Italy); Physics Preparatory Group Meetings in Granada before and after CERN Council Open Symposium on the Update of European Strategy for Particle Physics (Granada, Spain); 10th International Particle Accelerator Conference (IPAC'19) (Melbourne, Australia); International Conference on Nuclear Data for Science and Technology (ND2019) (Beijing, China); European MOOCs Stakeholders Summit (EMOOCs2019) (Naples, Italy); international scientific conference "Sakharov Readings 2019: Environmental Problems of the 21st Century" (Minsk, Belarus); Meeting on Matrix Elements for the Double-Beta-Decay Experiments (MEDEX'19) (Prague, Czech Republic); 49th Tulinov International Conference on Physics of Interaction of Charged Particles with Crystals (Moscow, Russia); international conference "Chemistry, Physics and Biology of Colloids and Interfaces" (CPBCI) (Eger, Hungary); NOνA Collaboration Meeting (Brighton, UK); Jet Security Conference 2019 (Moscow, Russia); International Conference on Precision Physics and Fundamental Physical Constants (FFK-2019) (Tihany, Hungary); 2019 International Conference on Applications of Nuclear Techniques (CRETE19) (Crete, Rithymna Beach, Greece); 18th International Conference on Strangeness in Quark Matter (SQM 2019) (Bari, Italy); 7th International Conference on Radiation in Various Fields of Research (Herceg Novi, Montenegro); 28th COMET Collaboration Meeting (Tokyo, Japan); JOIN 2 Developer Meeting in the L (Library & Documentation) Group (Hamburg, Germany); CHAOS 2019: 12th International Conference on Chaotic Modeling, Simulation and Applications (Chania, Greece); SENSE Detector School "Ultimate Low-Light Level Sensor Development" (Schloss Ringberg, Germany); 38th International Workshop on Nuclear Theory (IWNT) (Borovets, Bulgaria); 10th Alexander Friedmann International Seminar on Gravity and Cosmology and 4th Symposium on the Casimir Effect (St. Petersburg, Russia); 2nd International Scientific Forum "Nuclear Science and Technology" (Almaty, Kazakhstan); 26th International Workshop on Hadron Structure and Spectroscopy (IWHSS 2019) (Aveiro, Portugal); German–Russian Roadmap for the Cooperation in Education, Science, Research and Innovation Kick-Off (Berlin, Germany); Meeting of the Mixed Russian–German Commission on Scientific and Technical Cooperation (Berlin, Germany); 7th European Conference on Neutron Scattering (ECNS-2019) (St. Petersburg, Russia); 21st International Workshop on Radiation Imaging Detectors (IWORID 2019) (Chania, Greece); 15th International Conference on Magnetic Fluids (ICMF 2019) (Paris, France); European Physical Society Conference on High Energy Physics (EPS-HEP2019) (Ghent, Belgium); 19th International Balkan Workshop on Applied Physics and Materials Science (IBWAP 2019) (Constanta, Romania); 14th International Conference on Advanced Nanomaterials (ANM 2019) (Aveiro, Portugal); 14th JUNO Collaboration Meeting (Beijing, China); Conference and School on Classical and Quantum Integrable Systems (CQIS-2019) (St. Petersburg, Russia); 3rd Russian Conference "Graphene: Molecule and 2D Crystal" (Novosibirsk, Russia); 20th International Conference on Radiation Effects in Insulators (REI-20) (Nursultan, Kazakhstan); 8th International Conference on New Frontiers in Physics (ICNFP 2019) (Kolimbari, Greece); 6th International Conference on the Chemistry and Physics of the Transactinide Elements (TAN'19) (Wilhelmshaven, Germany); Euroschool on Exotic Beams (Aarhus, Denmark); ISTC–CERN–JINR Summer School "Introduction to High Energy Physics and Accelerator Physics" (Almaty, Kazakhstan); 21st International Conference on Surface Modification of Materials by Ion Beams (SMMIB-2019) (Tomsk, Russia); 21st International Workshop on Computer Algebra in Scientific Computing (CASC 2019) (Moscow, Russia); 36th Mazurian Lakes Conference on Physics (Piaski, Poland); 24th European Conference on Few-Body Problems in Physics (24 EFB) (Guilford, UK); workshop "Light Clusters in Nuclei and Nuclear Matter: Nuclear Structure and Decay, Heavy Ion Collisions, and Astrophysics" (Trento, Italy); Workshop on Efficient Neutron Sources (ENS 2019) (Villigen, Switzerland); Seminar on Numerical and Symbolic Scientific Computing (Varna, Bulgaria); 21st Mendeleev Congress on General and Apllied Chemistry (St. Petersburg, Russia); 21st Colloque GANIL (GANIL 2019) (Strasbourg, France); International Conference on Advanced Scientific Computing (ICASC 2019) (Sinaia, Romania); conference "Nuclear Physics in Astrophysics IX" (NPA IX) (Schloss Waldhausen, Germany); conference "QCD on the Light Cone: From Hadrons to Heavy Ions" (LC2019) (Palaiseau, France); 24th International Workshop "High Energy Physics and Quantum Field Theory" (QFTHEP'2019) (Sochi, Russia); 22nd International Conference on Cyclotrons and Their Applications (Cape Town, RSA); 21st International Summer School on Vacuum, Electron and Ion Technologies (VEIT 2019) (Sozopol, Bulgaria); international conference "Russian Supercomputing Days" (Moscow, Russia); 37th HADES Collaboration Meeting (Cracow, Poland); 12th International Workshop on Cooling Methods (COOL 2019) (Novosibirsk, Russia); 3rd J-PARK Symposium (J-PARK2019) (Tsukuba, Japan); 26th Nuclear Physics Workshop (Kazimierz Dolny, Poland); 2019 Joint Workshop on Future Charm-Tau Factory (Moscow, Russia); 9th International Conference "Modern Problems of Nuclear Physics and Nuclear Technologies" (Tashkent, Uzbekistan); 13th International Conference "Interaction of Radiation with Solid" (Minsk, Belarus); ATLAS Overview Week (Berlin, Germany); workshop "DARIA Project: Compact Neutron Sources in Russia" (Kaliningrad, Russia); International Conference on New Frontiers in Nuclear Physics (Varanasi, India); 29th COMET Collaboration Meeting and In-

tegration Workshop (Tsukuba, Japan); SuperNEMO Collaboration Meeting (Lége-Cap-Ferret, France); All-Russian Conference "Ecotoxicology-2019" (Tula, Russia); Isospin, Structure, Reactions and Energy of Symmetry Conference (ISTROS) (Častá-Papiernička, Slovak Republic); 14th All-Russian Scientific Conference "Membranes-2019" (Sochi, Russia); Workshop on New Approaches to MNT Reaction Studies (Darmstadt, Germany); Colloquium Towards CP Violations in Neutrino Physics (Prague v19) (Prague, Czech Republic); Worlshop on EXPERT@SuperFRS@FAIR Project (Warsaw–Cracow, Poland); 24th International Conference on Computing in High Energy and Nuclear Physics (CHEP-2019) (Adelaide, Australia); 28th International Conference on Ultrarelativistic Nucleus–Nucleus Collisions "Quark Matter 2019" (Wuhan, China); All-Russian Scientific Forum for Young Scientists "Open Science 2019" (Gatchina, Russia); Seminar Dedicated to the Launch of the Neutron Radiography and Tomography Facility at the BBP-K Reactor (Almaty, Kazakhstan); 15th International Conference on Modern Trends in Activation Analysis (MTAA-15) (Mumbai, India); 2019 International Workshop on the High Energy Circular Electron–Positron Collider (Beijing, China); scientific and technical seminar "Production of Alpha Emitters and Prospects for Development of Radiopharmaceuticals Based on Them" (Obninsk, Russia); School of XFEL and Synchrotron Radiation Users (SFEL2019) (Liptovský Ján, Slovak Republic); conference-forum "Research and Innovation Staff Exchange" (RISE) with SSHARE Project Kick-off Meeting (Minsk, Belarus); Calorimetry for High Energy Frontier Conference (CHEF 2019) (Fukuoka, Japan); international conference "Challenges and Opportunities for International Cooperation in Natural Sciences" (Hanoi, Vietnam); All-Russian Scientific and Technical Conference "Neutron-Physical Problems of Nuclear Energy" (Obninsk, Russia); International Workshop on Applications of Nuclear Spectroscopy and Related Techniques to Materials Science (Hoshimin, Vietnam); International Symposium on Superheavy Elements (SHE2019) (Hakone, Japan); Workshop on IAEA Project "Enhancing Coastal Management in the Adriatic and the Black Sea by Using Nuclear Analytical Techniques" (Vienna, Austria); 32nd International Symposium on Superconductivity (ISS-2019) (Kyoto, Japan); International Year of the Periodic Table 2019 Closing Ceremony (IYPT 2019) (Tokyo, Japan); ArgonCube Collaboration Meeting (Bern, Switzerland); seminar "Horizons of the JINR–Azerbaijan Cooperation in the Fields of Nuclear Physics, Particle Physics and Detectors of Particles" (Baku, Azerbaijan); 16th Baksan School on Astroparticle Physics "Particles and Cosmology" (Terskol, Russia); conference "New Trends in High Energy Physics" (Odessa, Ukraine); international school "JINR Days in Bulgaria" (Borovets, Bulgaria); international conference "Relativistic Nuclear Physics: from Hundreds of MeV to TeV" (RNP-2019) (Stará Lesná, Slovak Republic); IT-School for Young Scientists "Modern IT Technologies for Solving Scientific Challenges" (Vladikavkaz, Russia); 8th Annual Conference of Young Scientists and Specialists of JINR (Alushta-2019) (Alushta, Russia); 13th Russian Summer School-Seminar "Methods of Radiation Hardness Evaluation and Assurance for Electronic Products" ("Radiation Hardness – 2019") (Yalta, Russia); international conference "Mathematical Modeling and Computational Physics" (MMCP2019) (Stará Lesná, Slovak Republic); 26th International Conference on Integrable Systems and Quantum Symmetries (ISQS-26) (Prague, Czech Republic); 19th JINR–ISU Baikal Summer School on Physics of Elementary Particles and Astrophysics (Bolshiye Koty, Russia); Workshop of DERICA Project (in the framework of ICNFP 2019) (Kolimbari, Greece); 19th Lomonosov Conference on Elementary Particle Physics (Moscow, Russia); international workshop "Supersymmetries and Quantum Symmetries" (SQS'2019) (Yerevan, Armenia); 8th International Pontecorvo Neutrino Physics School (Sinaia, Romania); 13th International Scientific Workshop in Memory of Professor V. P. Sarantsev "Problems of Colliders and Charged Particle Accelerators. Applied Research on Accelerators" (Alushta, Russia); 2019 European School of High-Energy Physics (CERN–JINR School) (St. Petersburg, Russia); international conference "Topics in Theoretical and Mathematical Physics" dedicated to the 110th anniversary of Academician N. N. Bogoliubov (Moscow–Dubna, Russia); Kamchatka School on Elementary Particle Physics and Related Topics (Paratunka, Russia); 23rd International School on Nuclear Physics, Neutron Physics and Applications (Varna, Bulgaria); 27th International Symposium on Nuclear Electronics and Computing (NEC'2019) and International Student School "Big Data Mining and Distributed Systems" (in the framework of NEC'19) (Budva, Montenegro); NICA Days 2019 and 4th MPD Collaboration Meeting (Warsaw, Poland); School for Physics Teachers from JINR Member States at CERN (Geneva, Switzerland); KLTP/CAS–BLTP/JINR Joint Workshop on Physics of Strong Interacting Systems (Guangzhou, China); Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States (Hanoi, Vietnam).

DEVELOPMENT OF THE JINR INTERNATIONAL COLLABORATION AND RELATIONS OF THE YEAR 2019

1.	Number of short-term visits to JINR by specialists from the Member States (not counting Russian specialists)	1014
2.	Number of visits of specialists from other countries, including visits from the Associate Members	798 405
3.	Number of visits by JINR specialists to the Member States (not counting missions within Russia)	1481
4.	Number of visits by JINR specialists to other countries, including visits of specialists to the Associate Members	1748 505
5.	Number of conferences, schools, and meetings held by JINR	88
6.	New cooperation agreements (memoranda of understanding), addenda to existing ones	43

CONFERENCES, SCHOOLS, AND MEETINGS HELD BY JINR IN 2019*

No.	Name	Place	Date	Number of participants
1.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	21–22 January	62
2.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	22–23 January	71
3.	Workshop of the CMP and Neutron Physics Subgroup of the International Working Group for JINR Strategic Long-Range Planning	Dubna	23 January	29
4.	Workshop of the Detector Advisory Committees of the MPD and BM@N Projects	Dubna	23 January	50
5.	Meeting of the Programme Advisory Committee for Condenced Matter Physics	Dubna	24–25 January	70
6.	15th Winter School on Theoretical Physics "Complex Systems and Advanced Materials"	Dubna	28 January – 14 February	32
7.	Meeting on the Project of Prospective Heavy Ion LINAC for RIB Research at JINR	Dubna	7–8 February	90
8.	8th Open Robotic Tournament (CyberDubna 2019)	Dubna	8–10 February	172
9.	29th meeting of the Joint Committee on the IN2P3–JINR Cooperation	Dubna	12–13 February	16
10.	Workshop of the Relativistic Heavy Ion and Spin Physics Subgroup of the International Working Group for JINR Strategic Long-Range Planning	Dubna	21 February	10
11.	125th session of the JINR Scientific Council	Dubna	21–22 February	107
12.	Meeting of the Nuclear Physics Section of the Physical Sciences Department of the Russian Academy of Sciences (NPS PSD RAS)	Dubna	14–15 March	55
13.	Meeting of the Working Group under the Committee of Plenipotentiaries Chairman on Financial Issues of JINR	Dubna	20–21 March	29
14.	International workshop "Infinite and Finite Nuclear Matter"	Dubna	20–22 March	27
15.	Meeting of the JINR Finance Committee	Dubna	22–23 March	69

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

No.	Name	Place	Date	Number of participants
16.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States	Dubna	25–26 March	89
17.	Workshop on the Construction of a New Inealastic Neutron Scattering Spectrometer	Dubna	28–29 March	20
18.	Seminar “Horizons of the JINR–Azerbaijan Cooperation in the Fields of Nuclear Physics, Particle Physics and Detectors of Particles”	Baku, Azerbaijan	8–11 April	25
19.	16th International Baksan School on Astroparticle Physics ”Particles and Cosmology”	Terskol, Russia	10–18 April	70
20.	Days of Physics in Dubna – 2019	Dubna	12–14 April	233
21.	23rd International Scientific Conference of Young Scientists and Specialists of JINR (AYSS-2019)	Dubna	15–19 April	210
22.	3rd Collaboration Meeting of the MPD and BM@N Experiments at the NICA Facility	Dubna	16–17 April	149
23.	Conference “New Trends in High-Energy Physics”	Odessa, Ukraine	12–18 May	80
24.	RAD-TEST Workshop 2019	Dubna	13–17 May	56
25.	International School on Nuclear Physics “JINR Days in Bulgaria”	Borovets, Bulgaria	21–22 May	75
26.	Workshop on Computer Algebra	Dubna	23–24 May	45
27.	International conference “Relativistic Nuclear Physics: from Hundreds of MeV to TeV” (RNP-2019)	Stará Lesná, Slovak Republic	26 May – 1 June	50
28.	IT School for Young Scientists “Modern IT Technologies for Solving Scientific Challenges”	Vladikavkaz, Russia	27–28 May	70
29.	Baikal Collaboration Workshop	Dubna	28–31 May	35
30.	International symposium “The Present and Future of the Periodic Table of Chemical Elements”	Dubna	30–31 May	86
31.	14th International Workshop on Particle Correlations and Femtoscopy (WPCF2019), dedicated to the 100th anniversary of M. I. Podgoretsky	Dubna	3–7 June	70
32.	International Student Practice, Stage 1 (South Africa)	Dubna	3–21 June	24
33.	International workshop “SPD at NICA”	Dubna	4–8 June	117
34.	10th meeting of the Machine Advisory Committee on the NICA Project	Dubna	5–6 June	35
35.	27th International Seminar on Interaction of Neutrons with Nuclei “Fundamental Interactions and Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics” (ISINN-27)	Dubna	10–14 June	108
36.	8th Annual Scientific Conference of Young Scientists and Specialists of JINR in Alushta (Alushta-2019)	Alushta, Russia	10–17 June	80
37.	Meeting of the Programme Advisory Committee for Condenced Matter Physics	Dubna	17–18 June	68
38.	Workshop of the CMP and Neutron Physics Subgroup of the International Working Group for JINR Strategic Long-Range Planning	Dubna	18 June	15

No.	Name	Place	Date	Number of participants
39.	International Workshop of the Detector Advisory Committees of the MPD and BM@N Projects	Dubna	18 June	50
40.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	19–20 June	63
41.	95th meeting of the Nuclear Physics European Collaboration Committee (NuPECC)	Dubna	21–22 June	27
42.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	24–25 June	68
43.	13th Russian Summer School-Seminar "Methods of the Evaluation and Assurance of Radiation Hardness for Electronic Products ("Radiation Hardness – 2019")	Yalta, Russia	24–28 June	60
44.	International conference "Current Problems in Radiation Genetics"	Dubna	27–28 June	75
45.	Programme for Polish Students "Team for the Future of NICA" (TeFeNICA)	Dubna	30 June – 31 August	65
46.	International conference "Mathematical Modeling and Computational Physics"	Stará Lesná, Slovak Republic	1–5 July	80
47.	69th International Conference on Nuclear Spectroscopy and Nuclear Structure "Fundamental Problems of Nuclear Physics, Nuclei at Borders of Nucleon Stability, High Technologies" (Nucleus-2019)	Dubna	1–5 July	320
48.	Scientific School for the Winners of Olimpiads from Schools of the Czech Republic	Dubna	1–5 July	25
49.	Scientific School for Physics Teachers from the Czech Republic and Slovakia	Dubna	1–5 July	16
50.	Multidisciplinary School-Seminar (Summer School and Workshop "105 Element")	Dubna	7 July – 7 August	30
51.	International Student Practice, Stage 2 (Azerbaijan, Bulgaria, the Czech Republic, Poland, Romania, and the Slovak Republic)	Dubna	8–26 July	101
52.	26th International Conference on Integrable Systems and Quantum Symmetries	Prague, Czech Republic	8–12 July	82
53.	19th JINR–ISU Baikal Summer School on Physics of Elementary Particles and Astrophysics	Bolshiye Koty, Russia	12–19 July	72
54.	13th Joint APCTP–BLTP JINR Workshop "Modern Problems in Nuclear and Elementary Particle Physics"	Dubna	15–19 July	71
55.	Helmholtz International Summer School "Quantum Field Theory at the Limits: From Strong Fields to Heavy Quarks"	Dubna	22 July – 2 August	84
56.	23rd Summer School for Young Scientists and Specialists (Lipnya-2019)	Dubna	26–28 July	60
57.	International school "Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems"	Dubna	28 July – 2 August	52

No.	Name	Place	Date	Number of participants
58.	31st Summer International Computer School (ICS-2019)	Dubna	3–17 August	86
59.	Helmholtz International Summer School "Cosmology, Strings and New Physics"	Dubna	4–17 August	65
60.	International scientific seminar "Experimental Methods in Particle Physics", dedicated to the 85th anniversary of Professor I. A. Golutvin	Dubna	8 August	75
61.	Workshop of DERICA (in the framework of the conference "New Frontiers in Physics")	Kolimbari, Greece	21–25 August	22
62.	International workshop "Supersymmetries and Quantum Symmetries" (SQS'19)	Yerevan, Armenia	26–31 August	110
63.	8th International Pontecorvo Neutrino Physics School	Sinaia, Romania	1–10 September	83
64.	18th Workshop on High Energy Spin Physics (DSPIN-19)	Dubna	2–6 September	51
65.	13th International Scientific Workshop in Memory of Professor V. P. Sarantsev "Problems of Colliders and Charged Particle Accelerators. Applied Research on Accelerators"	Alushta, Russia	3–8 September	110
66.	27th European School on High Energy Physics (ESHEP-2019) (CERN–JINR School)	St. Petersburg, Russia	4–17 September	130
67.	International Student Practice, Stage 3 (Belarus, Cuba, Serbia, South Africa)	Dubna	9–27 September	21
68.	International Bogoliubov Conference "Problems of Theoretical and Mathematical Physics" dedicated to the 110th anniversary of N. N. Bogoliubov's birth	Moscow – Dubna, Russia	9–13 September	144
69.	Scientific seminar in memory of V. B. Priezzhev on the occasion of his 75th birthday	Dubna	10 September	60
70.	Kamchatka School on Physics of Elementary Particles and Related Topics	Paratunka, Russia	12–15 September	70
71.	International workshop "Theory of Hadronic Matter under Extreme Conditions"	Dubna	16–19 September	74
72.	126th session of the JINR Scientific Council	Dubna	19–20 September	116
73.	9th Report Seminar of the National Group of Ukraine at JINR	Dubna	21 September	21
74.	23rd International School on Nuclear Physics, Neutron Physics and Applications	Varna, Bulgaria	23–28 September	117
75.	27th International Symposium on Nuclear Electronics and Computing (NEC'19) and International Student School "Big Data Mining and Distributed Systems" (in the framework of NEC'19)	Budva, Montenegro	30 September – 4 October	220
76.	18th meeting of the Joint Coordination Committee on JINR–RSA Cooperation	Dubna	8–11 October	10
77.	4th Collaboration Meeting of the BM@N Experiment at the NICA Facility	Dubna	14–15 October	119

No.	Name	Place	Date	Number of participants
78.	5th meeting of the Joint Coordination Committee on Serbia–JINR Cooperation	Dubna	16–18 October	14
79.	Meeting of the Working Group under the Committee of Plenipotentiaries Chairman on Financial Issues of JINR	Dubna	17–18 October	28
80.	International conference “Radiobiological Basis of Radiation Therapy” marking the 60th anniversary of the first radiobiological experiments at JINR	Dubna	17–18 October	82
81.	NICA Days 2019 and the 4th MPD Collaboration Meeting	Warsaw, Poland	22–25 October	290
82.	Joint CERN–Japan–Russia International Accelerator School “Ion Collider Physics”	Dubna	29 October – 6 November	71
83.	12th International Scientific School for Physics Teachers from JINR Member States at CERN	Geneva, Switzerland	3–10 November	24
84.	Joint KFTP CAS–BLTP JINR Workshop on Physics of Strong Interacting Systems	Guangzhou, China	6–11 November	82
85.	Meeting of the JINR Finance Committee	Hanoi, Vietnam	21–22 November	75
86.	Session of the Committee of Plenipotentiaries of the Governments of the JINR Member States	Hanoi, Vietnam	25–26 November	90
87.	Baikal Collaboration Workshop	Dubna	3–6 December	60
88.	International Workshop on the Use of Nuclear Physics Methods for Cultural Heritage Research	Dubna	16–17 December	36

Meetings of the JINR Science and Technology Council, training courses “JINR Expertise for Member States and Partner Countries” (JEMS-10,11,12,13,14), and internships for young scientists and specialists of the CIS countries were also held. Besides, JINR assisted in organizing and conducting the international workshop “Subcritical Nuclear Systems and Problems of Nuclear Energy”, ISTC–CERN–JINR Summer School “Introduction to High Energy Physics and Accelerator Physics”, Workshop on Numerical and Symbolic Scientific Computing, and some other events held in 2019.

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, 25–26 March. JINR CP session and the festive celebration at the Culture Centre “Mir” on the occasion of the JINR Foundation Day

Hanoi (Vietnam), 25–26 November. A regular session of the JINR CP

Hanoi (Vietnam), 21–22 November. A regular meeting of the JINR Finance Committee

Dubna, 19–20 September.
The 126th session
of the JINR Scientific Council

Dubna, 17–18 June. The 50th meeting of the Programme Advisory Committee for Condensed Matter Physics

Dubna, 21–22 January. A regular meeting of the Programme Advisory Committee for Particle Physics

Dubna, 22 January. A joint meeting
of the Programme Advisory Committees for Particle Physics and Nuclear Physics on JINR Neutrino Programme

Dubna, 19–20 June. The 51st meeting of the Programme Advisory Committee for Particle Physics. The PAC members and young scientists — the authors of the best poster reports

Dubna, 22–23 January. A regular meeting of the Programme Advisory Committee for Nuclear Physics. Discussing poster reports

Moscow, 6 February. The ceremony of opening the International Year of the Periodic Table of Chemical Elements. RF Government Chairman and Chairman of the Organizing Committee on preparation and holding of the Year of the Periodic Table D. Medvedev is getting acquainted with a mock-up model of the Factory of Superheavy Elements at FLNR (*photo: government.ru*)

Dubna, 12–13 February. The 29th meeting of the Joint Committee on IN2P3–JINR Cooperation

Moscow, 8 February. JINR Director V. Matveev, Governor of the Moscow Region A. Vorobyov and Rector of the Bauman MSTU A. Aleksandrov signed an agreement on cooperation in establishment of an International School of Engineering in Dubna (*photo by the press-service of the Governor and Government of the Moscow Region*)

Dubna, 25 March. The ceremony of inauguration of the SHE Factory. Left to right: JINR Director Academician V. Matveev, Director of the UNESCO Division of Science Policy and Capacity Building P. E. Oti-Boateng, Plenipotentiary of the Government of Russia to JINR RF Minister of Science and Higher Education M. Kotyukov, Plenipotentiary of the Government of the Republic of Bulgaria to JINR Professor L. Kostov, and President of the CERN Council U. Bassler

Dubna, 8 February. Ambassador Extraordinary and Plenipotentiary of the Arab Republic of Egypt to Russia I. Nasr (fourth from right) on a visit to JINR

Dubna, 26–27 March. JINR is visited by the leaders
of scientific centres of the National Academy of Sciences of the Republic of Belarus

Dubna, 1–5 April. The participants of the 11th international training programme for decision-makers in science and international scientific cooperation JEMS

Dubna, 21–22 June.
The participants of the 95th meeting of NuPECC on an excursion to the Flerov Laboratory of Nuclear Reactions

Dubna, 2–4 June. The visit of President of the Bulgarian Academy of Sciences Academician J. Revalski to JINR

Dubna, 20 September. At the meeting of the President of the Academy of Sciences of Uzbekistan B. Yuldashev (centre) with JINR Director Academician V. Matveev and Vice-Director M. Itkis

Garni (Armenia), 28 October. The JINR delegation in the Garni Geophysical Observatory

Dubna, 9 November. Academician and Honorary Secretary of the French Academy of Sciences C. Bréchignac (centre) visited JINR

Moscow, 11 December. The joint meeting of the Presidium of STC of the Rosatom State Corporation and leaders of JINR, in which JINR Director RAS Academician V. Matveev and Rosatom Director General A. Likhachev signed a Cooperation Agreement

Mexico (Mexico), 12 October. Signing of the Memorandum
on mutual understanding between JINR and the community of scientific-research institutes of Mexico

Dubna, 16–18 October. Meeting of the Joint Coordination Committee on JINR–Serbia Cooperation

Tokyo (Japan), 5 December. The JINR delegation took part
in the official closing ceremony of the International Year of the Periodic Table of Chemical Elements

Dubna, 14 October. A literary-musical programme “You are beautiful, my world in rhymes” dedicated to the 75th anniversary of birth of Academician A. Sissakian

Dubna, 25 December. The festive evening dedicated to the 70th anniversary of the Blokhintsev Universal Public Library of JINR

Dubna, 17 May. The festive opening of the exhibition of the Bulgarian Cultural Institute “Bulgaria — the Birthplace of the Cyrillic Alphabet” in the JINR Cultural Centre “Mir”

Dubna, 15 February. The Slovak folklore group
“Grupa mocnego uderżenia” — participants of the gala-festival of the Czech–Slovak culture

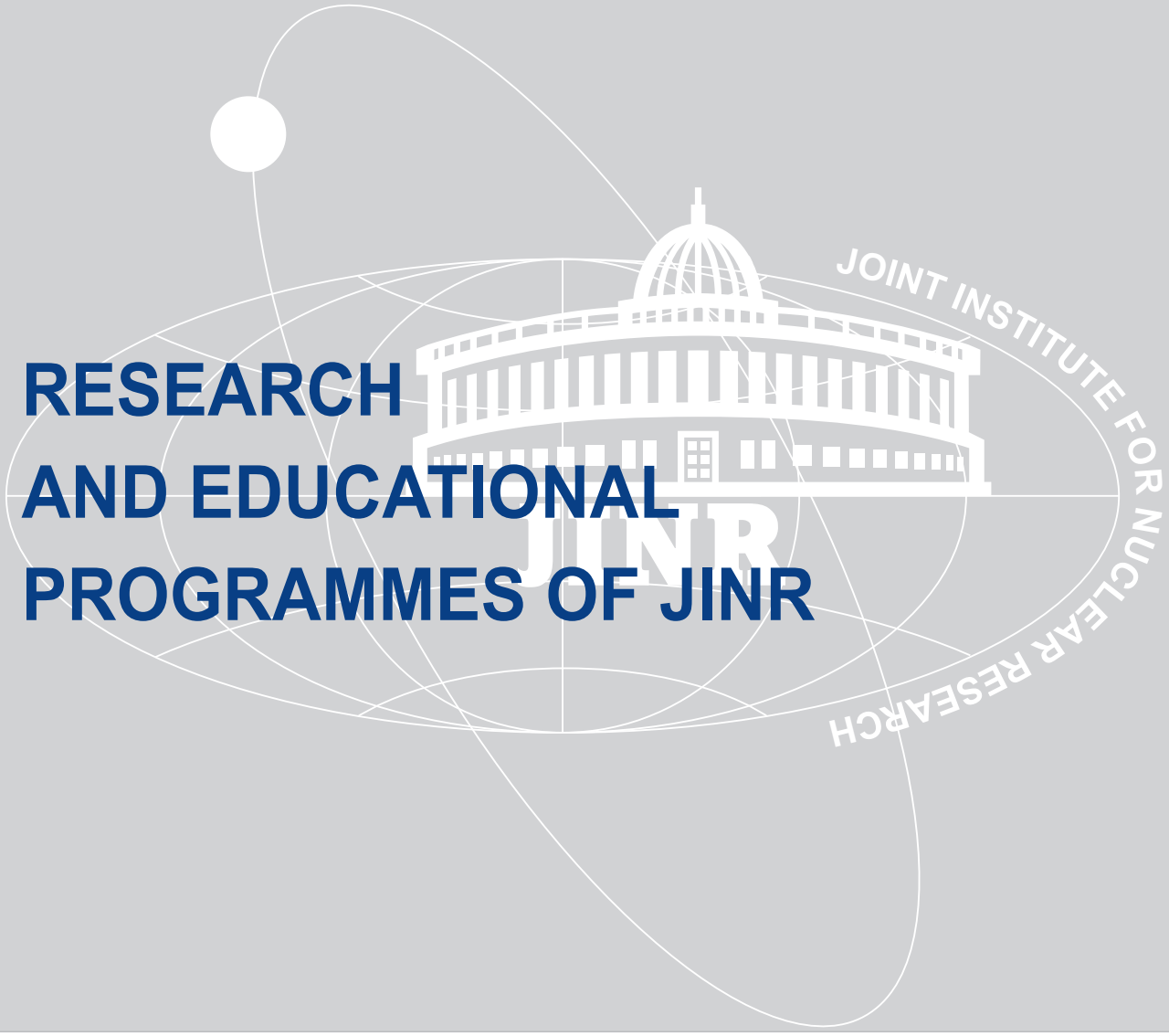
Dubna, 9–10 February. The VIII Open Robotics Tournament of the Upper-Volga Educational Cyber Network “CyberDubna-2019”

Dubna, 3–4 August. Awarding ceremony for the winners of the jubilee 20th tennis tournament dedicated to the memory of Venedikt and Boris Dzhelepov

Dubna, 29 September. The 50th anniversary track and field run named in honor of Academician V. Veksler

2019

RESEARCH AND EDUCATIONAL PROGRAMMES OF JINR



BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

In 2019 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 programmes of JINR Laboratories. The research resulted in about 480 publications in peer-reviewed journals and proceedings of international conferences and four monographs. Most of the results were obtained in cooperation with scientists from the JINR Member States, Brazil, China, Egypt, France, Germany, India, Italy, South Africa, and other countries. The Laboratory has become a site for organization of international conferences, workshops, schools for young scientists in various fields of theoretical physics. In 2019, more than 800 scientists participated in 15 international conferences, workshops and schools organized at the Laboratory. One of them was the Internationl Conference on Problems of Theoretical and Mathematical Physics dedicated to the 110th anniversary of the birth of N. N. Bogoliubov. The international collaboration was supported by grants of the Plenipotentiaries of the Governments of Bulgaria, the Czech Republic, Hungary, Poland, the Slovak Republic, Romania, and the JINR Directorate; the collaboration with Armenia was based on the Smorodinsky–Ter-Martirosyan Programme; with Polish theorists, on the Bogoliubov–Infeld Programme; with Czech theorists, on the Blokhintsev–Votruba Programme; and with Romanian theorists, on the Titeica–Markov Programme. 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 (Beijing) are functioning, as well as the active cooperation with theorists from CERN. Fourteen research projects and one conference were supported by the RFBR grants, 3 research projects by the RSF, and 2 research projects by the BASIS Foundation. 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), in particular. More than 150 PhD students and young scientists from the JINR Member States participated in the DIAS-TH schools. The Laboratory plays the role of the training centre for young scientists and students from many countries. Currently, about one third of the scientific personnel are young scientists and PhD students. Within the JINR fellowship programme for non-Member States, several researchers from China, India, Iran, and Tajikistan have been working at BLTP on the long-term basis.

SCIENTIFIC RESEARCH

Fundamental Interactions of Fields and Particles

Theoretical investigations in 2019 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.

An ab initio three-loop quark model calculation of the W-exchange contribution to the nonleptonic two-body decays of baryons was made. The W-exchange contributions appear in addition to the factorizable tree graph contributions and are not suppressed in general. The previously developed covariant confined quark model was used to calculate the tree graph as well as the W-exchange [1].

The standard representation of the (inverse) Radon transform was extended to the case involving parton distributions. The new additional contribution which is essentially related to the generalized transverse-momentum dependent parton distribution and double-distribution functions was discovered. The important relationship of this term with the Sivers function was presented for the first time [2].

Within the QCD light-cone sum rules at the leading order, the gravitational form factors $A(t)$ and $B(t)$ for the valence quark combinations in a nucleon were calculated for the first time. Also, the predictions for the gravitational form factor $D(t)$ (D-term contributions) were presented. Comparison with experimental data and with the results of different models revealed good agreement [3].

The approach to numerical optimization of the perturbation series that supplements (an alternative) $\{\beta\}$-expansion was elaborated in the Bjorken sum rule and realized there in order of N^{3}LO. It was found that an optimized sum of all radiative contributions to the $S_{\rm Bj}$ sum rule leads to better agreement with experimental data [4].

The most general master-integral for a two-loop massless correlator of two composite vertices with the Bjorken fractions x and y was studied. The corresponding integral and Mellin moments thereof were evaluated in terms of the hypergeometric functions of two and three variables — the Kampé de Férriet and Lauricella functions — which were reduced to a finite sum of univariate hypergeometric and simpler functions in a number of cases important for applications [5].

An independent derivation of the Unruh effect was obtained from the point of view of a statistical approach with the Zubarev density operator. The universality of the Unruh effect was substantiated from the point of view of the statistical approach for real and complex scalar fields, as well as fermion fields. It was shown that in the case of scalar fields, infrared divergences arise and a consistent way of regularizing them was proposed. The exact duality of the statistical approach with the Zubarev operator and the geometrical approach that considers space with conical singularity in describing acceleration effects was revealed. Thus, it was demonstrated that non-trivial geometry with conical singularity, in particular, describing cosmic strings, follows from the density operator in flat space [6].

Corrections to the chiral vortical effect were calculated and the nonperturbative formula for the finite mass was substantiated. The quantum-field corrections in the axial current were calculated up to the third order in the derivatives of the velocity, in particular, those related to acceleration. The concept of angular velocity and acceleration as real and imaginary chemical potentials was verified and confirmed [7].

For a twisted (vortex) Dirac particle in nonuniform electric and magnetic fields, the relativistic Foldy–Wouthuysen Hamiltonian was derived including high-order terms describing new effects. The result obtained showed for the first time that a twisted spin-1/2 particle possesses a tensor magnetic polarizability and a measurable (spectroscopic) electric quadrupole moment. The tensor magnetic polarizability of the twisted electron can be measured in a magnetic storage ring because a beam with initial orbital tensor polarization acquires horizontal orbital vector polarization. The electric quadrupole moment is rather large and strongly influences the dynamics of the intrinsic orbital angular momentum. Three different methods of its measurement were proposed: freezing the intrinsic orbital angular momentum and two resonance methods [8].

In the framework of the quasipotential method in quantum electrodynamics, the contribution of light pseudoscalar, axial vector and scalar mesons to the interaction operator of a muon and a proton in a muonic hydrogen atom was calculated. The parametrization of the transition form factor of two photons to mesons, based on the experimental data on the transition form factors and QCD asymptotics, was used. Numerical estimates of the contributions to the hyperfine structure of the spectrum of the S and P levels were presented. Using the obtained result for the hyperfine interaction of a muon and a proton due to meson exchanges, similar contributions in the case of muonic ions of lithium, beryllium and boron were estimated [9].

It was shown that spontaneous breakdown of chiral symmetry in QCD leads to the deviation from the generally accepted picture of vector and axial-vector dominance for some electroweak anomalous processes with mesons. The exceptional role of anomalities is caused by the well-known shift-ambiguity in the triangle quark diagrams of AVV and AAA types. Accounting for surface terms arising there allowed us to ensure the fulfillment of anomalous Ward's identities but violated the vector and axial-vector dominance [10].

New additional renormalization of kaon fields was obtained in the framework of the NJL model taking into account the mixing of the axial vector fields K_{1A} and K_{1B} in off-diagonal transitions between axial vector and pseudoscalar kaons. As a result, a new version of the coupling constant of the kaon–quark interactions was obtained. The standard value for the kaon weak decay constant F_K was found. With this coupling constant the processes $\tau \to \nu K$, $\tau \to \nu K[\omega, \varphi]$ were described in agreement with experimental data [11].

The master integrals were calculated for the 3-particle cuts with 2 loops, and 4-particle cuts with 1 loop. The results were verified numerically and

their consistency with previously known solutions was shown [12].

Two-loop 2-, 3- and 4-point diagrams with the elliptic structure with two masses m and M were calculated. The results were presented as series with binomial coeffcients in the integral representation and the representation in terms of hypergeometric functions [13].

The explicit expression for the R-ratio of electron–positron annihilation into hadrons, which properly accounts for the effects due to continuation of the spacelike perturbative QCD results into the timelike domain, was obtained at an arbitrary loop level. It was shown that the higher-order π^2-terms strongly affect the evaluation of the strong running coupling [14].

Global polarization of Λ and anti-Λ hyperons in $\mathrm{Au}+\mathrm{Au}$ collisions at collision energies $\sqrt{s_{NN}} = 4-40$ GeV in the midrapidity region and total polarization, i.e., averaged over all rapidities, were studied within the scope of the thermodynamical approach. The relevant vorticity was simulated within the model of the three-fluid dynamics (3FD). It was found that the performed rough estimate of the global midrapidity polarization quite satisfactorily reproduced the experimental STAR data on the polarization, especially its collision-energy dependence. The total polarization increases with the collision energy rise, which contrasts with a decrease in midrapidity polarization. This suggests that at high collision energies polarization reaches high values in the fragmentation regions [15].

Within the relativistic mean-field models with effective hadron masses and couplings dependent on the scalar field, which were developed over the past years, properties of the nuclear matter were studied for finite baryon density, zero and non-zero temperature, and for different isospin compositions. The results were applied to the description of hybrid stars and heavy-ion collision processes at laboratory energies below $2A$ GeV. The influence of the pasta phase on the quark–hadron phase transition was considered. Models of the equation of state were studied, which allow the existence of compact stars-twins with the same masses but different radii. The presence or absence of such objects could be checked by the mission NICER within the NASA program. A satisfactory description of pion characteristics of heavy-ion collisions was demonstrated. Also, our models of the equation of state of the hadronic matter describe properly the thermodynamic characteristics of the first-order nuclear liquid–gas phase transition in coincidence with the existing data [16].

The properties of non-ideal pion gas with a dynamically fixed number of particles and an arbitrary isotopic composition were investigated. The spectrum of pions was calculated in the self-consistent Hartree approximation. General expressions for the correlation functions between the numbers of pions of various charges were derived, and their behavior was analyzed for the temperature approaching from above the maximal critical temperature of the Bose–Einstein condensation T_c. It was shown that in the case of a system with an equal average number of π^+, π^- and π^0 mesons, the variance of the system charge, i.e., the difference between the number of π^+ and π^- mesons, diverges at $T \to T_c$, while the variances of the total number of pions and a relative abundance of charged and neutral pions remain finite at the critical point. A pion gas with a small isospin imbalance was examined in detail; the effective masses, chemical potentials, and critical temperatures for various types of pions were calculated and the highest critical temperature was determined, above which a system of pions can exist in a non-condensed phase [17].

The properties of QCD in the parameter space "temperature – baryon density – magnetic field" were studied for the first time in lattice simulations. A tentative phase diagram of this system was drawn. It was found that for pseudo-critical temperature, effects of the nonzero magnetic field and baryon density can be just added. At the same time, the width of the phase transition exhibits nontrivial behavior: it decreases with baryon density at low values of the magnetic field and grows with baryon density at large values of the magnetic field, with the flipping value $eB \sim 0.6$ GeV^2. The conductivity of the 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 nonzero magnetic field leads to an increase in conductivity in the parallel direction. In the perpendicular direction the conductivity is a decreasing function of the magnetic field demonstrating the magnetoresistance phenomenon in QGP [18].

Theory of Nuclear Systems

In 2019, 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.

It was shown that at supernova conditions neutrinos exhibit exo- and endoenergetic scattering on hot nuclear mater. From an analysis of energy transfer due to neutrino–nucleus scattering, it was demonstrated that the average energy transfer changes from positive to negative values when neutrino energy is about four times the temperature. Similar features were found for neutrino scattering on magnetized nucleon gas [19].

A drastic reduction by two orders of magnitude of the $B(E1; 3^-_1 \to 2^+_1)$ strength along the Mo isotopic chain was observed experimentally (Institut Laue–Langevin, Grenoble). The quasiparticle random phase approximation and the cluster model were applied to

explain the mystery of this evolution. Both models reproduce the trend and predict that this sharp drop is due to the interference effect between the neutron and proton contributions to the matrix element of the $E1$ transition [20].

A two-step scheme to search vortical toroidal states (TS) in (e, e') reaction was suggested. In the first step, QRPA calculations are used to determine promising candidates for toroidal states. These states should have distinctive toroidal distribution of the convective nuclear current and significant $B(M2)$ and $B(E1)$ values. In the second step, these states are checked to reproduce the pattern of the experimental data for $E1$ and $M2$ transversal form factors in electron scattering to back angles. A description of the interference between spin and orbital currents indicates that a vortical toroidal flow in the chosen state indeed takes place [21].

Recent experimental studies of the structure of ^{96}Zr have shown that the shape of this nucleus can change dramatically with increasing excitation energy. The structure of ^{96}Zr based on the collective quadrupole Bohr Hamiltonian was studied. It was shown that this approach allows one to describe all the peculiarities of the structure of ^{96}Zr at low excitation energies. It was also shown that this nucleus is spherical in the ground state with a 100% probability but becomes deformed if the excitation energy reaches 1.6 MeV. This result indicates the possibility of radical changes in the shape of the nucleus upon its excitation [22].

Using the improved scission-point model, the mass and charge distributions of fragments resulting from the fission of californium isotopes were calculated and compared with the available experimental data. The change of the shape of mass and charge distributions with increasing excitation energy was predicted for future experiments [23].

The possibility of application of the dinuclear system model to the simultaneous description of α decay, cluster radioactivity, and spontaneous fission was investigated. The half-lives of cluster decay and spontaneous fission for the nuclei ^{232,234,236}U, ^{236,238}Pu, ^{242}Cm, and ^{248}Cf were calculated within the same approach and compared with the existing experimental data. The cluster radioactivity in the ^{248}Cf nucleus was predicted [24].

The possibilities for production of yet unknown neutron-rich isotopes $^{261-265}$Md were explored in the multinucleon transfer reactions with stable beams bombarding on Cf and Es targets. The production of a given isotope of neutron-rich Md was optimized by appropriate choices of projectile–target combinations and bombarding energies. The production cross sections of neutron-rich Md isotopes in the $0n$ and $1n$ evaporation channels of multinucleon transfer reactions were compared. The prospects for the use of radioactive beams in the production of new Md isotopes were discussed [25].

Partial cross sections of the $n\alpha$ and dt collisions in the quantum state $J^\pi = 3/2^+$ near the dt-threshold, taken from an available R-matrix analysis, were fitted using the semianalytic multi-channel Jost matrix with a proper analytic structure and some adjustable parameters. As a result of such an analytic continuation, it was found that the previously established $3/2^+$ resonance (at 47 keV) and its shadow pole (at 80 keV) are both split in overlapping pairs. Apart from studying the properties of a specific nuclear state, it was also proved for a general multi-channel problem that the Coulomb forces change the topology of the Riemann surface as well as destroy the so-called mirror symmetry of the S-matrix [26].

Confinement-induced resonances in atom–ion quantum mixtures confined in hybrid traps were studied for small atom–ion mass ratios. Specifically, an ion confined in a time-dependent radio-frequency Paul trap with linear geometry was considered, while the atom was constrained to move into a quasi-one-dimensional optical waveguide within the ion trap. The impact of the ion intrinsic micromotion on the resonance position was evaluated. It was found that the energy of the ion provided by the oscillating radio-frequency fields can affect the resonance position substantially. This notwithstanding, the peculiar phenomenology of those resonances regarding perfect transmission and reflection is still observable. These findings indicate that the intrinsic micromotion of the ion is not detrimental for the occurrence of the resonance and that its position can be controlled by the radio-frequency fields. This provides an additional means for tuning atom–ion interactions in low spatial dimensions [27].

Among various understandings of the term "resonance" in quantum mechanics, the two most common interpretations are as follows. (1) Resonance is a complex energy value producing a pole to the scattering matrix analytically continued to the so-called unphysical energy sheet(s). (2) Resonance is a complex eigenvalue of the complexly deformed Hamiltonian under consideration. In the case of the Friedrichs–Faddeev model, it was proven that the resonances understood in the senses (1) and (2) are equivalent. Notice that the Friedrichs–Faddeev model is quite universal. Various concrete quantum-mechanical Hamiltonians, in particular, the two-particle ones with short-range interactions, admit a reduction just to the Friedrichs–Faddeev model [28].

For the first time, analytical formulas were obtained for calculating amplitudes of the population of atomic levels as a result of interactions of the atom with the EM field of the laser. The interaction potential of an atom with a field is recorded in the dipole approximation. The mathematical apparatus of the model is based on complex scaling of the Stark Hamiltonian and on a number of mathematical theorems that accompany such a description. For the first time, a series was proposed that describes the amplitude of the probability of population of an atomic level. It consists of the sum of the products of polynomials and standard adiabatic ex-

ponents. Semi-analytical calculations are in satisfactory agreement with the numerical calculations [29].

Two-dimensional movement of a slow quantum particle was studied in the field of a central long-range potential decreasing in the limit of large distance r as a power function $r^{-\beta}$ with the exponent $\beta \in (1,2)$. For this particle, low-energy asymptotics of the scattering phase shifts and differential cross section were found. A simple approximation for the energies of weakly bound states was established [30].

The structure in the K^+/π^+ ratio was studied, which appears in the heavy ion collisions (Au + Au and Pb + Pb) at energies $\sqrt{s_{NN}} \sim 7-10$ GeV. The Polyakov loop extended Nambu–Jona-Lasinio model was used as it describes both chiral phase transition and deconfinement. In the mean field approach the chiral phase transition line can play the role of freeze-out, as in the PNJL model the chiral phase transition line divides the hadron phase and the quark–gluon phase. Therefore, one can estimate the K/π ratio along the phase diagram instead of using $\sqrt{s_{NN}}$. It was shown that the splitting of multiplet mass in dense matter is responsible for the difference in the behavior of the K^+/π^+ and K^-/π^- ratios; the "peak" structure was interpreted as a sequence of the chiral symmetry restoration and subsequent deconfinement effect; the "horn" is more sensible to the curvature of the phase diagram at high μ_B than order of the chiral phase transition (several modifications of the PNJL model were used, including strong vector coupling to the model phase diagram); the peak depends on the properties of the matter (strangeness neutrality, or chemical baryon potential of a strange quark) [31].

The combined approach based on solution of the Dyson–Schwinger equations for quark propagators and Bethe–Salpeter equation for bound states was employed at non-zero temperature. A competition of bound states and quasi-free two-quark states was found at $T = O(100$ MeV). This indication of pseudo-scalar meson dissociation below the anticipated QCD deconfinement temperature calls for an improvement of the approach, which is based on an interaction adjusted to the meson spectrum at $T = 0$ [32].

The correctness of the Planck and Ott formalisms of relativistic thermodynamics of a moving body was investigated. The equivalence of the dynamical Hamiltonian of a system to the fundamental thermodynamic potential in addition to the principle of entropy invariance was required and the first law of thermodynamics was derived. It was found that in the case of momentum being an independent variable in the Hamiltonian, the Lorentz transformations of the thermodynamic quantities belong to the Planck formalism. However, if it is supposed that the velocity is an independent variable in the Hamiltonian (though it is not correct from the point of view of the relativistic dynamics), the Lorentz transformations of the thermodynamic quantities belong to the Ott formalism. It demonstrates that the Ott formalism cannot be appropriate. Moreover, it was proven that in the Planck description the first law of thermodynamics is covariant and the Legendre transform of the Lagrangian is preserved. However, in the Ott description the first law of thermodynamics is not covariant and the Legendre transform is violated. Thus, it was demonstrated that only the Planck formulation of relativistic thermodynamics of a moving body is properly defined and the Ott formalism should be discarded [33].

A theoretical analysis of elastic scattering and momentum distributions of clusters in breakup reactions of exotic halo-nuclei ^{8}Be, ^{8,12,14}Be was performed. Conclusions were made on the decisive role of periphery of these nuclei to establish the mechanism of their scattering and breakup into clusters. The microscopic optical folding potentials and the Kisslinger potential were applied for calculations of elastic and inelastic pion–nucleus scattering in the energy region of the 33 pion–nucleon resonance. It was found that parameters of the pion–nucleon amplitude differ essentially from those for the pion scattering on free nucleons ("in-medium effect") [34].

The Bethe–Salpeter–Faddeev formalism was generalized to the case of a nonzero orbital moment of particles in a nucleon pair. The binding energy of the triton and the amplitudes for the states $1S0$, $3S1$, $3D1$, $3P0$, $1P1$, and $3P1$ were calculated. The results were compared with the nonrelativistic case. The contributions of the relativistic P and D states to the binding energy of the triton were estimated [35].

Theory of Complex Systems and Advanced Materials

Theoretical investigations in 2019 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 ensembles of determined fractal structures was theoretically investigated. Their positions in space and orientation were assumed to be random. In the standard analysis, only three parameters can be determined from SAS data: the fractal dimension, and the lower and upper limits of the fractal range. It was shown that the self-similarity of deterministic fractal structures allows one to obtain their additional characteristics in real space. Exactly solvable models that describe SAS from such systems were proposed and studied. The developed models make it possible to understand how to extract additional information about the fractal structures and analytically describe the intensities of SAS. The models offer effective computational algorithms as well. The main examples are the generalized Cantor fractal and some of its variations, which model mass, surface, and multifractal structures. The differences in the SAS data between deterministic and ran-

dom fractal structures were investigated. The limits of applicability of the proposed models and the prospects for future studies of deterministic fractal structures were discussed [36].

The low-density expansions for the energy, chemical potential, and condensate depletion of the homogeneous dilute dipolar Bose gas were obtained by regularizing the dipole–dipole interaction at long distances. It was shown that the leading term, proportional to the density, allows a simple physical interpretation and consistently describes the thermodynamic stability of the system. The long-range asymptotics were obtained analytically for the normal and anomalous one-particle correlation functions and the pair distribution function. The properties of the two-body scattering with zero relative momentum for the dipole–dipole interaction were discussed; in particular, the asymptotics of the wave function and a correction to the scattering length for small values of the dipolar range were derived [37].

The theory of superconductivity of strongly correlated electrons on the honeycomb lattice within the $t-J$ model was formulated [38].

A series of papers on quantum magnetism in oxides of transition $5d$ elements with strong spin-orbit interaction was finished [39].

The measure of entanglement production by statistical operators was defined. Conditions were established showing when entanglement production gets maximal and when it is zero, which is essential for quantum measurements and quantum information processing [40].

The dimer model on the rectangle with free boundary conditions was considered. Exact expressions for the coefficients in the asymptotic expansion of the free energy in the volume up to the 22nd order were derived. Surprisingly, it was found that the ratio of the coefficients for strip and square geometries tends to 1/2. Furthermore, it was predicted that the coefficients in the free energy expansion for arbitrary rectangle are related to the coefficients for square. A simple exact expression for the free energy of open strips of an arbitrary width was also derived. In the framework of conformal field theory it was shown that the corner contribution to the free energy for the dimer model on rectangular lattices with free boundary conditions is equal to zero [41].

The elliptic Bailey lemma was formulated on the basis of the univariate rarefied elliptic beta integral. It leads to a generalized operator star-triangle relation and a new solution of the Yang–Baxter equation written as an integral operator with a rarefied elliptic hypergeometric kernel [42].

The 6j-symbols, or Racah coefficients, for tensor products of infinite-dimensional unitary principal series representations of the group $SL(2,C)$ were constructed. These symbols were found earlier by Ismagilov, and his result was rederived (up to some slight difference associated with equivalent representations) using the Feynman diagrams technique. The resulting 6j-symbols are expressed either as a triple integral over complex plane, or as an infinite bilateral sum of integrals of the Mellin–Barnes type [43].

The exact laws of large numbers were established for two time additive quantities in the Raise and Peel model, the number of tiles removed by avalanches and the number of global avalanches happened by given time. The validity of conjectures for the related stationary state correlation functions then follows. The proof was based on the technique of Baxter's $T-Q$ equation applied to the associated XXZ chain and on its solution at $\Delta = -1/2$ obtained by Fridkin, Stroganov and Zagier [44].

The thermal conductivity behavior was theoretically investigated in perspective nanomaterial — polycrystalline graphene. It was shown that the role of grain boundaries in suppression of heat transport can grow significantly in a wide temperature range with decreasing size of a grain. It was found as well that the heat transport can be suppressed significantly even at room temperature if grain boundaries have breaks in misorientation angles along the grain line. Besides, it was shown that the experimentally observed increase of Young's modulus in single-layer graphene with low density of point defects can lead to a noticeable enhancement of the heat transport [45].

It was shown that a current sweep along IV-characteristic of the Josephson nanostructure superconductor–ferromagnet–superconductor may lead to regular magnetization dynamics with a series of specific phase trajectories. It was demonstrated that an external electromagnetic field can control the dynamics of magnetic moment within a current interval corresponding to a Shapiro step and produce a specific transformation of precession trajectories. As an effect of the coupling between magnetization and spin-orbit interaction, the appearance of the DC component of superconducting current was demonstrated and its role in the transformation of IV-characteristics in the resonance region was clarified. A periodicity in the appearance of magnetization reversal intervals under current pulse with increase in Josephson to magnetic energy relation, Gilbert damping and spin-orbit interaction was found. The presented results might be used for developing novel resonance methods of determination of the spin-orbit coupling parameter in the non-centrosymmetric materials and for creation of memory elements based on Josephson nanostructures [46].

Modern Mathematical Physics: Gravity, Supersymmetry and Strings

The topics of main focus in the theme in 2019 were:

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

Five-dimensional holographic renormalization group flows were constructed, including those with AdS fixed points and hyperscaling violating fixed points. In

the framework of holographic duality, the corresponding finite temperature phases were found, for which free energy was calculated and phase diagrams were studied [47].

The Lagrangian geometry of algebraic varieties was studied. Given a smooth compact simply-connected algebraic variety, a family of finite-dimensional Kähler manifolds was constructed whose elements are the equivalence classes of Lagrangian submanifolds satisfying the new D-exactness condition. In connection with the theory of Weinstein structures, these moduli spaces turn out to be related to the special Bohr–Sommerfeld geometry constructed previously. This enabled us to extract from the moduli spaces some stable components and conjecture that they are not only Kähler but also algebraic [48].

A new twistorial field formulation of a massless infinite spin particle was developed. The quantization of such a world-line infinite spin particle model was carried out without any gauge fixing. As a result, a twistorial infinite spin field was constructed and its helicity decomposition was derived. Using the field twistor transform, the space-time infinite (continuous) spin field was constructed, which depends on the coordinate four-vector and additional commuting Weyl spinor. The equations of motion for infinite spin fields in the cases of integer and half-integer helicities were derived. It was shown that the infinite integer-spin field and infinite half-integer-spin field form the $N = 1$ infinite spin supermultiplet. The corresponding supersymmetry transformations were formulated and their on-shell algebra was derived. As a result, the field realization of the infinite spin $N = 1$ supersymmetry was found [49].

The gauge dependence of one-loop divergences in a general matter-coupled $6D$, $N = (1, 0)$ supersymmetric gauge theory in the harmonic superspace formulation, with the gauge-fixing term involving one real parameter ξ_0 was studied. As compared to the minimal gauge, $\xi_0 = 1$, the divergent part of the general-gauge effective action contains a new term depending on ξ_0. It vanishes for the background superfields satisfying the classical equations of motion, so that the S-matrix divergences are gauge-independent. In the case of the $6D$, $N = (1, 1)$ SYM theory, some divergent contributions in the non-minimal gauges do not vanish off shell, as opposed to the minimal gauge [50].

A new family of self-gravitating axially symmetric, rotating boson stars in the two-component Friedberg–Lee–Sirlin model minimally coupled to Einstein's gravity in four spacetime dimensions was studied. Subject to the usual synchronization condition, the model admits spinning hairy black hole solutions with two different types of scalar hair. The domain of existence of solutions was explored and some of their physical properties were addressed. The solutions exhibit close similarity to the corresponding boson stars and Kerr black holes with synchronized scalar hair in the $O(3)$-sigma model coupled to Einstein gravity and to the corresponding solutions in the Einstein–Klein–Gordon theory with a complex scalar field [51].

Novel $N = 2$ and $N = 4$ supersymmetric extensions of the Calogero–Sutherland hyperbolic systems were obtained by gauging the $U(n)$ isometry of matrix superfield models. The bosonic core of the $N = 2$ models was the standard A_{n-1} Calogero–Sutherland hyperbolic system, whereas the $N = 4$ model contained additional semi-dynamical spin variables and was an extension of the $U(2)$ spin Calogero-Sutherland hyperbolic system. Two different versions of the $N = 4$ model were constructed, with and without the interacting center-of-mass coordinate in the bosonic sector [52].

A brief review of deformed $N = 8$ supersymmetric mechanics as a generalization of $SU(2|1)$ mechanics was given. It was based on the worldline realizations of the supergroups $SU(2|2)$ and $SU(4|1)$ in the appropriate $N = 8$, $d = 1$ superspaces. The corresponding models are deformations of the standard $N = 8$ mechanics models by a mass parameter m [53].

Fermion modes localized on the kink in the $1+1$ dimensional ϕ^4 model coupled to the Dirac fermions with back-reaction were studied. Using numerical methods, self-consistent solutions of the corresponding system of coupled integral-differential equations were constructed and dependences of the scalar field of the kink and the normalizable fermion bound states on the values of the parameters of the model were investigated. It was shown that the back-reaction of the localized fermions significantly modifies the solutions; in particular, it results in spatial oscillations of the profile of the kink and violations of the reflection symmetry of the configuration [54].

A particular case of the Stephani solution for the shear-free perfect fluid with uniform energy density and nonuniform pressure was presented. These models are characterized by the spatial curvature depending on time. The properties of the cosmological model obtained on the basis of exact solution of the Stephani class were analyzed, and it was adapted to the recent observational data. The spatial geometry of the model was investigated. It was shown that, despite possible singularities, the model can describe the current stage of evolution of the universe [55].

It was shown that phase portrait of the Toda system coincides with the Hasse diagram of Bruhat order on the Weyl group, and hence Bruhat cells in real Lie groups meet dual cells if and only if the corresponding elements in the Weyl group are Bruhat-comparable. A system of first integrals of the Toda flow was also constructed, based on the systematic use of representations of the group [56].

The bound and scattering states were found for the 1D Dirac Hamiltonian distorted by a static background built from delta-function potentials. After introducing the most general delta potential, for the Dirac equation differences in the spectra of "mass-spike" and "electrostatic" delta-potentials were analyzed in detail [57].

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

In 2019, the research and educational project DIAS-TH was successfully continued. There were the following activities in the framework of DIAS-TH:

- XV Winter School on Theoretical Physics "Complex Systems and Advanced Materials", 28 January – 1 February, Dubna;
- Helmholtz International Summer School "Quantum Field Theory at the Limits: From Strong Fields to Heavy Quarks", 22 July – 2 August, Dubna;
- International School "Advanced Methods of Modern Theoretical Physics: Integrable and Stochatic Systems", 28 July – 2 August, Dubna;
- Helmholtz International Summer School "Cosmology, Strings, New Physics", 4–17 August, Dubna;
- Regular seminars for students and postgraduates were organized;
- Computer processing of video records of lectures was continued;
- Website of DIAS-TH was supported.

CONFERENCES AND MEETINGS

Fifteen conferences, workshops and schools were organized in 2019:

- XV Winter School on Theoretical Physics "Complex Systems and Advanced Materials", 28 January – 1 February, Dubna;
- International Workshop "Infinite and Finite Nuclear Matter", 20–22 March, Dubna;
- XIV International Workshop "Particle Correlations and Femtoscopy" (WPCF2019), 2–8 July, Dubna;
- XXVI International Conference "Integrable Systems and Quantum Symmetries", 8–12 July, Prague, Czech Republic;
- BLTP/JINR – APCTP/Korea Joint Workshop "Modern Problems in Nuclear and Elementary Particle Physics", 14–20 July, Dubna;
- Helmholtz International Summer School "Quantum Field Theory at the Limits: From Strong Fields to Heavy Quarks", 22 July – 2 August, Dubna;
- International School "Advanced Methods of Modern Theoretical Physics: Integrable and Stochatic Systems", 28 July – 2 August, Dubna;
- Helmholtz International Summer School "Cosmology, Strings, New Physics", 4–17 August, Dubna;
- International Workshop "Supersymmetries and Quantum Symmetries" (SQS'19), 26–31 August, Yerevan, Armenia;
- VIII International Pontecorvo Neutrino Physics School, 1–10 September, Sinaia, Romania;
- XVIII International Workshop "High Energy Spin Physics" (DSPIN-19), 2–6 September, Dubna;
- International Bogoliubov Conference "Problems of Theoretical and Mathematical Physics" dedicated to the 110th anniversary of the birth of N. N. Bogoliubov (1909–1992), 9–13 September, Dubna and Moscow, Russia;
- II International Workshop "Theory of Hadronic Matter under Extreme Conditions", 16–19 September, Dubna;
- XXIII International School "Nuclear Physics, Neutron Physics and Applications", 23–28 September, Varna, Bulgaria;
- BLTP/JINR – KLTP/CAS Joint Workshop "Physics of Strong Interacting Systems", 6–11 November, Guangzhou, China.

COMPUTER FACILITIES

In 2019, a high-resolution projector with a laser light source, digital sound amplifying equipment, a system for audio-video broadcasting and recording of events were commissioned in the conference hall of BLTP. Software was developed to control the entire complex of new equipment through a convenient user interface implemented with the use of a wall-mounted LCD touch screen. A new server was purchased to support resource-demanding computing, it has the total number of computing cores 36 (2 Intel Xeon Gold 6254 processors), 1.5 terabytes of RAM. To upgrade computers at workplaces, 14 PCs were purchased. Extention of technical support was purchased and updated versions were installed for Mathematica, Maple, Origin Pro, Intel Parallel Studio.

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VEKSLER AND BALDIN LABORATORY OF HIGH ENERGY PHYSICS

The activity of the Veksler and Baldin Laboratory of High Energy Physics in 2019 was focused on the implementation and further development of the NICA complex project (the Nuclotron–NICA, MPD, BM@N and SPD subprojects), and participation in the experiments at world-class accelerator centres.

MOST IMPORTANT RESULTS IN THE DEVELOPMENT OF THE NICA COMPLEX

Nuclotron–NICA Project

Booster and Beam Transfer Channels

The main efforts of the accelerator division in 2019 were targeted to the assembling and commissioning of the Booster synchrotron.

HILac–Booster beam transfer line is one of the key elements that provides ions transfer from the ion sources to accelerators with minimal losses. The mounting of the transfer line was finished in July and commissioned in December 2019.

In 2019, the mounting of the Booster subsystems was completed with the installation of the cryomagnetic system. On 23 December, Booster commissioning was officially started. It includes the following stages:

- tuning of the power supply and test of the energy evacuation system;
- test of the vacuum system;
- test of the thermometry and cooling of the cryomagnetic system;

and has to be finished by the end of May 2020. The next stage — test with the ion beam — will start in June 2020.

The civil works on the Booster–Nuclotron transfer line were completed in 2019. Installation, mounting and commissioning of the Booster–Nuclotron transfer line elements are scheduled for 2020.

Collider Ring

The plans on the assembly of the Nuclotron–Collider transfer line and collider ring are strongly correlated with the civil works flow. The status of the collider complex construction by the end of 2019 is as follows:

- piles 100% readiness;
- reinforced concrete structures $> 90\%$ readiness;
- metal structure installation $> 75\%$ readiness;
- facades installation 10% readiness;
- roofs 30% readiness;
- earth works and temporary roads 90% readiness.

The common delay in the construction is about a year. The main reason is accepted changes in the project after start of the construction, which brings the increase in the building area from 20 to 30 thousand squared meters. It leads to the expansion of the piles field, reinforced concrete and metal structures, roofing and walling areas as well as corresponding increase of engineering equipment — ventilation, refrigeration and power supply systems.

It is expected to start mounting of the collider dipole magnets in the 1st collider arc section, the assembly of the Nuclotron–Collider transfer line and the mounting of the first RF stations in the 3rd quarter of 2020 (see Table 1).

Manufacturing and testing of the collider subsystems equipment were continued in 2019. Almost 35% of the dipoles and 10% of the quadrupoles were assembled and underwent certification on the test bench.

Table 1. Nuclotron–Collider transfer line equipment status

Subsystem	Readiness	Delivery to JINR
Magnets	95%	March 2020
Vacuum chambers and diagnostics	70%	June 2020
Power supplies	10%	August 2020

Detailed information on the collider construction status is available in the 2019 annual review report at http: // nucloweb. jinr. ru / nica / MAC / 20Jan16_Rpt _to_ MAC.pdf.

Cryogenic Complex

The NICA complex includes three SC accelerators and for its operation the power of the existing cryogenic complex has to be significantly extended from 4 to 10 kW of refrigerating capacity at 4.5 K. One of the key elements of the cryogenic complex is the new compressor station which has to be installed in a new building constructed for this purpose. In contrast to the experts' opinion, it was decided to engage the Stroytechinvest company, which has no experience in industrial construction as the main contractor. It leads to the delay in the construction from February 2020 to September 2020.

An upgrade of the cryogenic complex in other directions is going on according to the schedule, and the following equipment has been delivered and installed:

- 1000 m^3 helium gasholder;
- 40 m^3 liquid helium tank;
- 1000 l/h helium liquefier;
- 2 kW satellite refrigerator;
- 1300 kg/h nitrogen liquefier;
- 500 kg/h nitrogen recondenser;
- two 6600 Nm^3/h helium screw compressors;
- three 10740 Nm^3/h nitrogen turbo compressors;
- five 20 Nm^3 nitrogen receivers.

Computing Infrastructure

The computer offline cluster of the Veksler and Baldin Laboratory of High Energy Physics is one of the four basic components of the distributed computer information infrastructure of the NICA project. The cluster is based on a modular principle and consists of computer and communication equipment, cooling, power supply and fire suppression systems.

In October 2019, the cluster was put into operation in the following configuration: 3500 cores and two disk arrays of 3.5 PB each. In the nearest future, it will be expanded to 5000 CPU cores and 2×5 PB disk arrays.

The cluster has an internal 100 Gb/s Ethernet network, connected to the cluster network at 200 Gb/s and to the laboratory network at 100 Gb/s.

User Infrastructure

In 2019, the NICA innovation centre design proposed by the general contractor Arena company was approved. The deadline for the documentation preparation is September 2020.

MPD Experiment

SC Magnet

All civil works in the MPD building have to be completed in the 1st quarter of 2020, after that the process of the MPD magnet installation starts.

The MPD magnet yoke has already been delivered in Dubna, the magnet cryostat with SC coil is ready for cold tests.

Time Projection Chamber

The Time Projection Chamber (TPC) is the main tracking detector of the MPD experiment. The production and tests of structural elements and equipment for installation of the TPC inside the MPD were completed. In 2019, ten out of 24 readout chambers (ROCs) were produced, the verification tests of the readout electronics were started. Status of the TPC readout electronics is presented in Table 2.

Time-of-Flight System

By the end of 2019, the purchase of all detector materials was completed, 25% of all mRPCs were assembled, and the rest will be ready until October 2020. The assembled time-of-flight sectors are passing tests on cosmic rays.

FHCal

The MPD forward detector consists of two arms located at 3.2 m from the interaction point. Each arm consists of 45 individual modules. All modules were produced and now are under tests on the cosmic rays. The production of the Front-End Electronics was completed at the end of 2019. The designing of the support platform for FHCal is close to completion.

ECal

The production of the MPD electromagnetic calorimeter modules was started at two sites in Russia. Start of the production in China is expected soon. First ECal modules will be produced in the 3rd quarter of 2020.

Table 2. Schedule of the work on the TPC readout electronics

Subsystem	Completion date
Testing FEC v1.0	February 2019
SAMPA V4 chips received at Dubna 4500 (all)	June 2019
32 preproduced FE cards (version 2.1) assembled (1/2ROC)	July 2019
Testing of half ROCs equipped with FE cards	August–December 2019
Production of FE cards for 1 ROC and its testing	December 2019 – April 2020
Instrumentation and test of ROCs 2, 3, 4	May 2020
Production of FE cards for 5–14 ROCs (total 14)	July 2020
Production of FE cards for the rest 10 ROCs (total 24)	August 2020

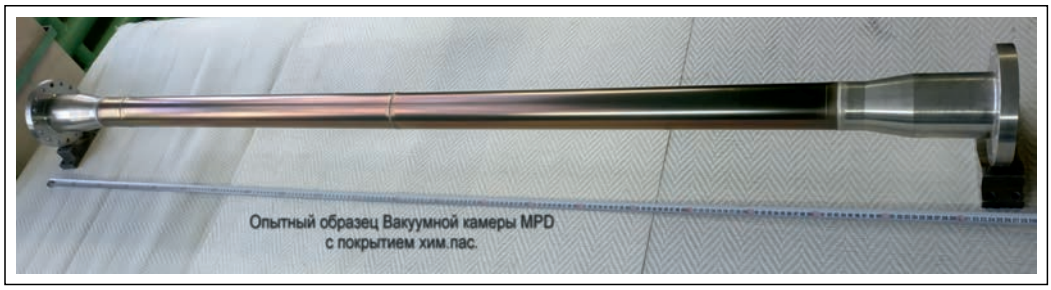

Fig. 1. Prototype of the MPD beam pipe

Beam Pipe

The MPD beam pipe will consist of three parts: central, made of beryllium, and two end parts made of aluminum alloy (Fig. 1).

The production contract for two beryllium beam pipes with the inner diameter of 62 mm was signed in 2019. The production contract for the aluminum parts of the beam pipe is under preparation.

Milestones of the MPD Assembling

Milestones of the MPD assembling are described in Table 3.

MC Simulation and Data Analysis

Five MPD Physics Working Groups (PWG) are created, which cover all MPD physics cases:

- global observables;
- spectra and yields of light flavor hadrons and hypernuclei;
- flow, correlations and fluctuations;
- electromagnetic probes;
- heavy flavor.

In 2019, several reports on the MPD construction status and feasibility study results were given, including those at the international conferences "Quark Matter 2019" and "Strangeness in Quark Matter 2019".

BM@N Experiment

Data Analysis

The BM@N (Baryonic Matter at the Nuclotron) is the first experiment carried out at the Nuclotron accelerator of the NICA complex. The BM@N scientific programme comprises studies of dense nuclear matter in heavy-ion beams of the intermediate energy range between the energies of the SIS-18 and NICA/FAIR facilities. The first experimental run was performed in the carbon beam interaction with different nuclear fixed targets.

In 2019, the physics analysis of the obtained experimental data on Λ-hyperon production was performed for interactions of the carbon beam with kinetic energies of 3.5, 4 and 4.5A GeV on C, Al, Cu and Pb nuclei. Results on the cross sections and yields of Λ hyperons were obtained and compared with the predictions of the DCM-QGSM and UrQMD models (Fig. 2).

Spectrometer Status

In 2019, the BM@N team continued the spectrometer preparation for the heavy-ion runs, permanently expanding detectors subsystems:

- Hybrid central tracker based on 7 GEM detectors with the size of the sensitive area of 163×39 cm, which were assembled and tested in collaboration with CERN, and three stations of forward silicon microstrip detectors will operate at the expected rate $\sim$ few 10^5. The readout electronics of the tracker partially based on IDEAS chips (Norway) was developed.

- For the operation at the rate $\sim$ few 10^6, expected in 2022, four wide-aperture STS microstrip silicon detector planes were developed in cooperation with the CBM collaboration. The TDR was approved in December 2019.

Table 3. Schedule of MPD assembling

Stage of assembly	Date
MPD hall and pit are ready to store and unpack yoke parts	April 2020
Magnet yoke assembly for the alignment test	May–June 2020
Solenoid is ready for transportation from ASG (Italy)	June 2020
Solenoid delivery in Dubna	July 2020
Assembly of magnet yoke and solenoid	August 2020
Preparation for switching on the solenoid (cryogenics, power supply, etc.)	September 2020
Magnetic field measurement	November 2020
Installation of support frame	December 2020
Installation of the detector subsystems, electronics platform, cabling	January–April 2021
Commissioning	May 2021
Readiness for the cosmic ray tests	June 2021

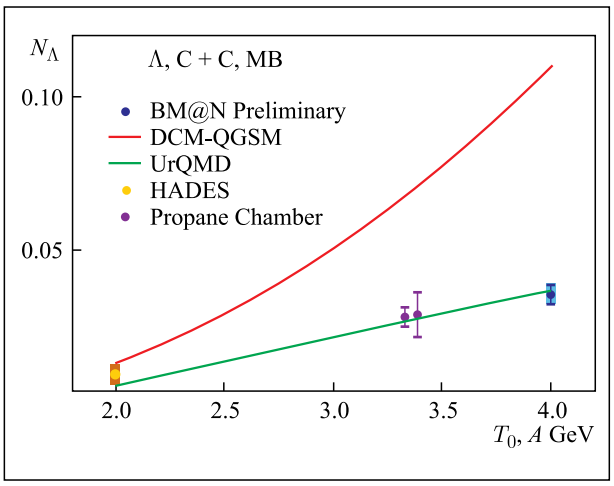

Fig. 2. Yields of Λ hyperons in the BM@N experiment in comparison with models of other experiments

• The outer tracker includes three cathode strip chambers (CSCs) of 113 × 107 cm for recording tracks for the near time-of-flight system (manufactured) and two large CSCs of 219 × 145 cm for the far time-of-flight system (designed).

• A hadron calorimeter (FHCal) based on MPD and CBM modules to be used in high-intensity heavy-ion beams was manufactured and installed.

The vacuum beam pipe in upstream direction from the target was manufactured and installed. The target station operating with several targets in vacuum was developed.

SPD Experiment

In the framework of the SPD project, the following important results were obtained in 2019.

The first version of SPD CDR was presented at a meeting of the PAC for Particle Physics. Several versions of the SPD magnetic system were considered: hybrid (toroid in the centre + 2 Helmholtz coils in each end face), 6 Helmholtz coils with different configurations of current switching and solenoid.

The first version of tracking in SPD based on the Kalman filter was developed. The momentum resolution for different versions of the magnetic system was obtained. The simulation was carried out to study the Drell–Yan processes, charmonium and direct photons production. The formation of the SPD collaboration was started; a Commission for the preparation of the SPD Constitution was established.

PARTICIPATION IN EXPERIMENTS AT EXTERNAL ACCELERATORS

Experiments at the Large Hadron Collider

ALICE

During 2019, the femtoscopic correlation analysis of identical charged kaons was finished for p–Pb collisions at 5.02 TeV (per pair of nucleons). The radii of the emission source found during the fit versus pair transverse momentum and the event centrality are shown in Fig. 3 together with the same data obtained before. One can see a good agreement between both types of the kaon pairs.

Such a type of the correlations was studied for the first time in proton–nucleus collisions. The comparison of the radii of the emission source with the ones obtained before for pp and Pb–Pb collisions showed that the radii of the source in p–Pb collisions are closer to those created in pp collisions than in Pb–Pb ones. These phenomena can be an indication of weakness/absence of collective effects in emitting sources in p–Pb interactions and disfavor models with large initial size or strong collective expansion at low multiplicities [1].

The analysis of coherent J/ψ and ρ^0 production in Pb–Pb ultra-peripheral collisions at an energy of 5.02 TeV (per pair of nucleons) was finished in 2019. The differential cross sections were determined and compared with different theoretical model predictions (Fig. 4). The main result is as follows: the best agreement with the models was shown in the assumption of moderate effect of gluon shadowing. Besides, the first measurements of the coherent photo-production of ρ meson and resonance-like object with the mass near 1700 MeV/c^2 were performed [2].

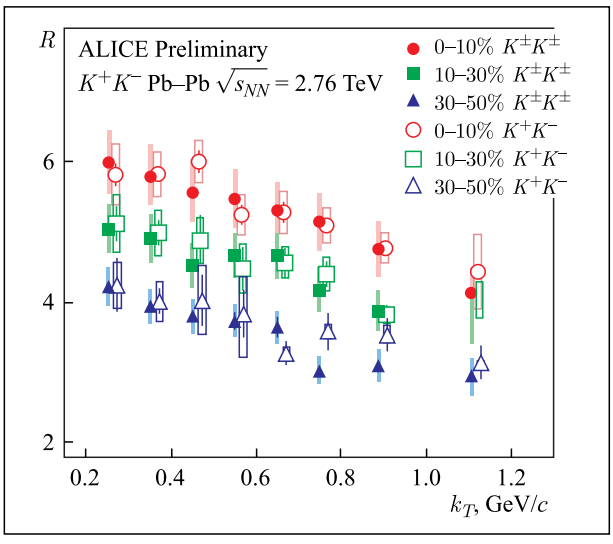

Fig. 3. Radii of the emission source of $K^+K^-$and identical kaon pairs versus pair transverse momentum and event centrality

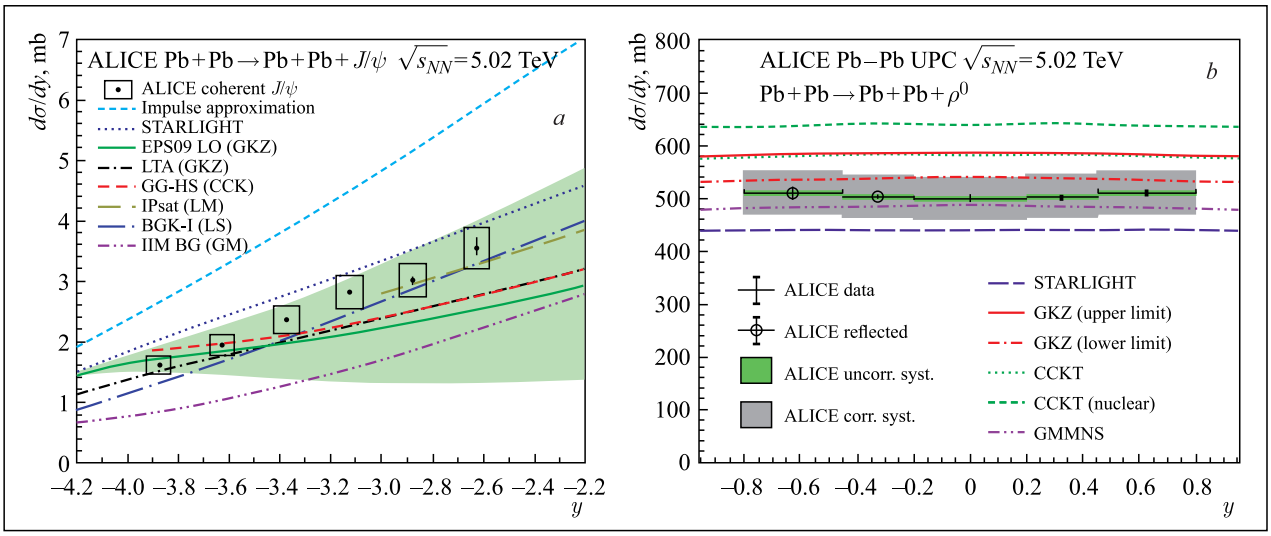

Fig. 4. *a*) Comparison of differential cross sections of the coherent J/ψ production with predictions of various models. *b*) Comparison of differential cross sections of the coherent ρ^0 production with predictions of various models

ATLAS

In 2019, the ATLAS group members were engaged in the following activities: experimental data analysis, simulation of a new process including SUSY particles, participation in the ATLAS detector upgrade programme for high-luminosity environment at HL-LHC as well as QCD analysis of the DIS data.

Cross sections of associated production of a Higgs boson decaying into b-quark pairs and an electroweak gauge boson, W or Z, decaying into leptons were measured as a function of the gauge boson transverse momentum. The measurements were performed in kinematic fiducial volumes defined in the "simplified template cross-section" framework. The results were obtained using 79.8 fb^{-1} of proton–proton collisions recorded by the ATLAS detector at the LHC at a centre-of-mass energy of 13 TeV. All measurements were found to be in agreement with the Standard Model predictions, and limits were set on the parameters of an effective Lagrangian sensitive to modifications of the Higgs boson couplings to the electroweak gauge bosons (Fig. 5).

Participation in the ATLAS detector upgrade programme included irradiation of the optical fibres at the IBR-2 reactor to check radiation hardness of the materials for the applications in the ATLAS detector operating at the HL-LHC. A radiation-resistant analogue signal pre-shaper for the ATLAS endcap hadron calorimeter was designed, and a special setup was developed to measure characteristics of prototypes and then integrated circuits and their certification. The electrical characteristics were measured at this stand, and an agreement was found with the expected ones. The developed circuit of the pre-shaper was used to design the prototype of a solid-state chip. Once the chip is manufactured, its characteristics will also be studied at this stand.

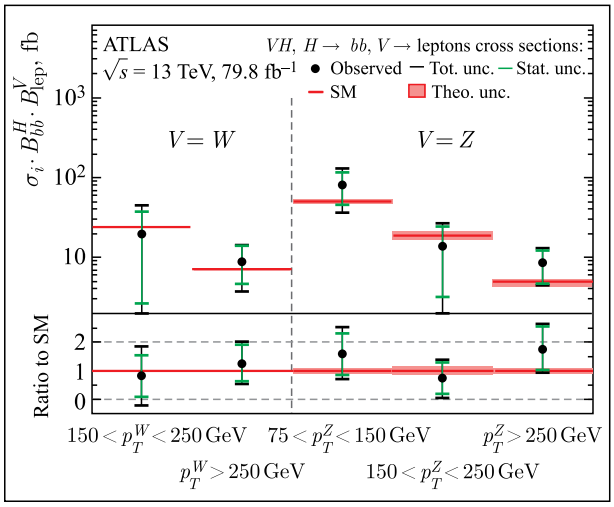

Fig. 5. Measured VH, $V \to$ leptons simplified template cross sections times the $H \to \bar{b}b$ branching ratio

CMS

In 2019, the JINR group took part in data processing and physics analysis of data collected during the LHC Run 2 (2015–2018) with the proton beams at an energy of 13 TeV and a luminosity up to $2.14 \cdot 10^{34}$ cm$^{-2} \cdot$ s^{-1}.

A search was performed for a narrow resonance decaying to a pair of muons (Fig. 6, *a*) [3]. No significant deviation from the Standard Model (SM) predictions was observed. The 95% CL upper limits were set on the production cross section of this process (Fig. 6, *b*) [3].

The measurements of the differential cross section for the Drell–Yan process, based on proton–proton collision data at a centre-of-mass energy of 13 TeV, collected by the CMS experiment, are in good agreement with the previous ones at $\sqrt{s} = 8$ TeV and consistent with studies of angular characteristics of muons produced in this process [4, 5].

During the CMS Phase-1 Upgrade, the front-end electronics of Hadron Barrel (HB) calorimeter were re-

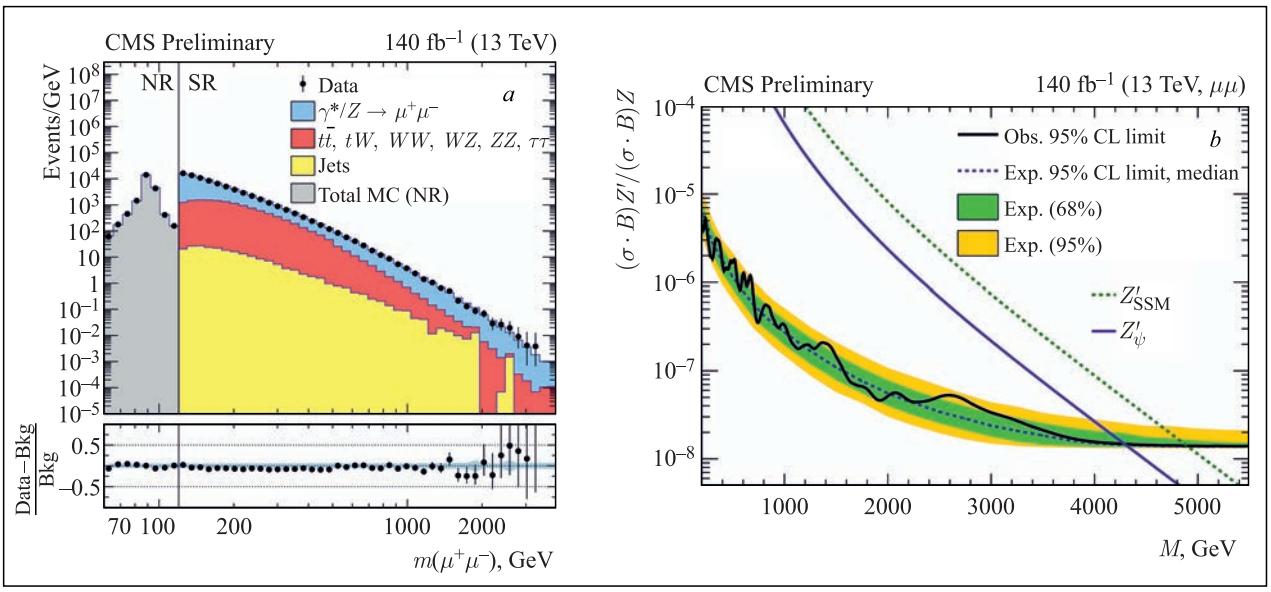

Fig. 6. *a*) The invariant mass distribution of pairs of muons observed at $\sqrt{s} = 13$ TeV in data (black dots with statistical error bars) and expected from the SM processes (stacked histograms) [3]. *b*) The upper limits at 95% CL on the product of production cross section and branching fraction for a spin-1 resonance, relative to the product of production cross section and branching fraction of a Z boson, for the dimuon channel [3]. The shaded bands correspond to the 68% and 95% quantiles for the expected limits. Theoretical predictions for the spin-1 Z'_{SSM} and Z'_{ψ} resonances are shown for comparison

placed with new ones. The JINR group established a test-stand for long-term burn-in tests of readout electronics components using SiPMs for the HB calorimeter. The test-stand infrastructure was fully prepared, namely, the water-cooling system of the readout modules, low-voltage power supply system, SiPMs bias voltage supply system, fiber optic communication system of the readout electronics, as well the crates with the data-acquisition and trigger systems, control and data recording.

In the framework of the CMS Phase-2 Upgrade, the JINR physicists participated in the Cathode Strip Chambers (CSC) electronics upgrade in four muon stations ME1/1, ME2/1, ME3/1 and ME4/1. A total of 180 chambers were replaced from CMS, moved to the surface laboratory, refurbished with the new electronics, tested and finally reinstalled in the experimental cavern. For ME1/1 chambers, 72 new cooling circuits were manufactured.

Experiments at the CERN Super Proton Synchrotron

COMPASS

In 2019, COMPASS continued the analysis of data collected in 2002–2018.

COMPASS performed the most comprehensive resonance-model fit of $\pi^-\pi^-\pi^+$ states using the results of previously published partial-wave analysis (PWA) of a large data set of diffractive-dissociation events from the reaction $\pi^- + p \to \pi^-\pi^-\pi^+ + p$ recoil with a 190 GeV/c pion beam [6]. The PWA results are subjected to a resonance-model fit using Breit–Wigner amplitudes to simultaneously describe a subset of 14 selected waves using 11 isovector light-meson states. For the first time, the t' dependence of the phases of the production amplitudes was determined and it was confirmed that the production mechanism of Pomeron exchange is common to all resonances.

The transverse spin asymmetries measured in semi-inclusive lepto-production of hadrons, when weighted with the hadron transverse momentum P_T, allow for the extraction of important transverse-momentum-dependent distribution functions [7]. The results are compared to the standard unweighted Sivers asymmetries and used to extract the first transverse moments of the Sivers distributions for u and d quarks.

COMPASS published the results on the measurement of hard exclusive π^0 muo-production on the proton using 160 GeV/c polarized μ^+ and μ^- beams of the CERN SPS impinging on a liquid hydrogen target. From the average of the measured μ^+ and μ^- cross sections, the virtual-photon proton cross section is determined as a function of the squared four-momentum transfer between initial and final protons in the range $0.08\ (\mathrm{GeV}/c)^2 < |t| < 0.64\ (\mathrm{GeV}/c)^2$. These results provide important input for modelling the Generalized Parton Distributions (GPD). In the context of the phenomenological Goloskokov–Kroll model, the statistically significant transverse–transverse interference contribution constitutes clear experimental evidence for the chiral-odd GPD $\bar{E}_T$.

NA61/SHINE

In 2019, the activity of the NA61/SHINE collaboration was aimed at the detector upgrade programme for

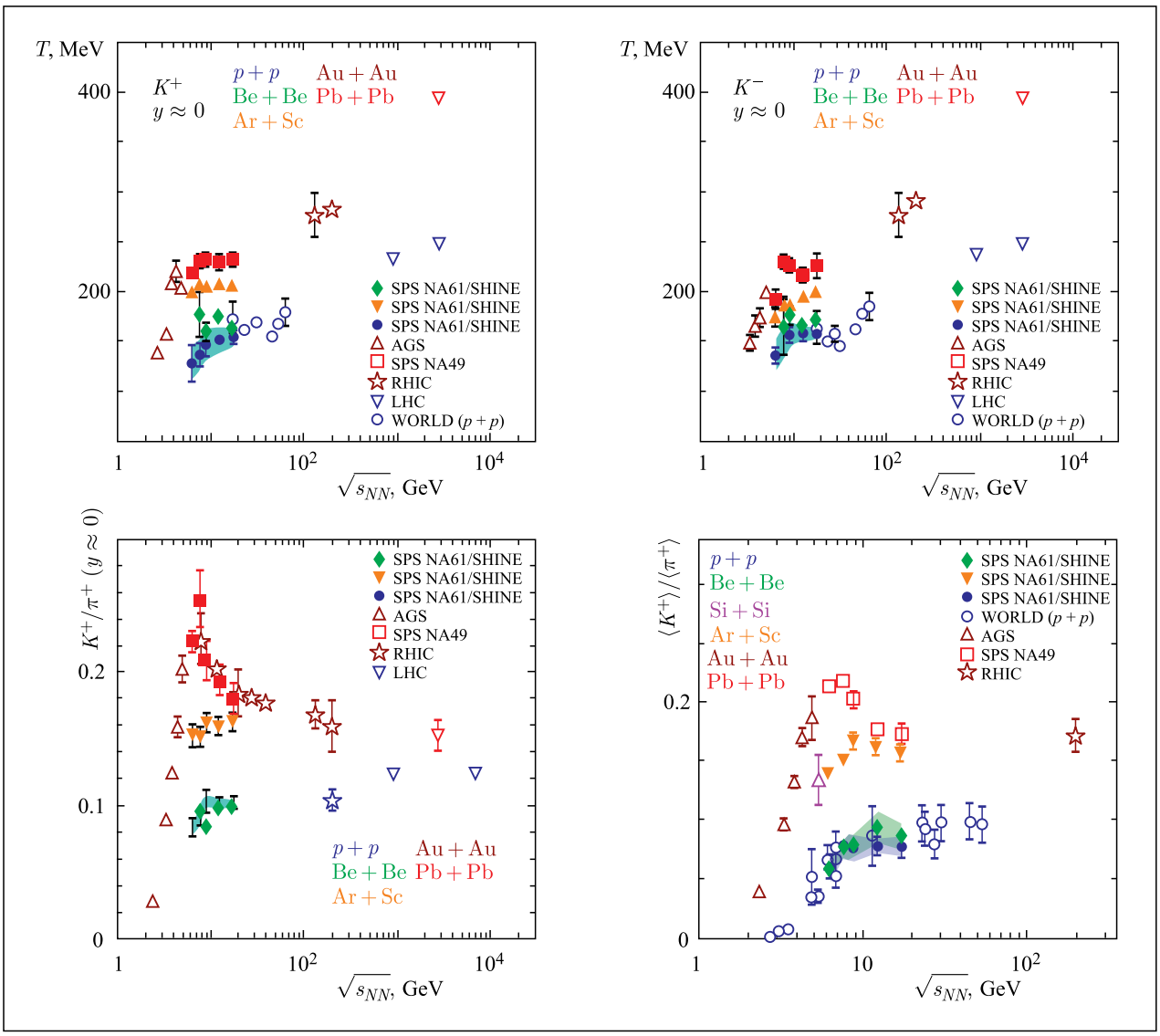

Fig. 7. Inverse slope parameter of mid-rapidity transverse mass spectra of K^+ and K^- mesons as a function of collision energy for $p+p$, Be + Be, Ar + Sc and Pb + Pb/Au + Au collisions (top). K^+/π^+ ratio at mid-rapidity and $\langle K^+\rangle/\langle\pi^+\rangle$ ratio in full 4π phase space as a function of collision energy for $p+p$, Be + Be, Ar + Sc and Pb + Pb/Au + Au collisions (bottom)

post-LS2 running in parallel to the physics analysis of data collected before 2019.

The most recent results relate to the particle production properties as well as event-by-event fluctuations in p+p, Be + Be and Ar + Sc interactions at beam energies of 19/20, 30, 40, 75/80 and 158A GeV.

Figure 7 shows the current status of the well known "step" and "horn" plots. In Pb + Pb collisions such structures were predicted due to mixed phase of hadron gas (HG) and quark–gluon plasma (QGP). A rapid "horn" change was found in energy dependence of K/π in central Pb + Pb and Au + Au, which was interpreted as due to the onset of deconfinement. The NA61 experiment supplemented these data with the new measurements on $p+p$, Be + Be and Ar + Sc reactions, which exhibit unexpected and very interesting features:

• The energy dependence shows plateau similar to the one observed in $p+p$ interactions.

• The results from Be + Be collisions are close to those from $p+p$ interactions.

• The new data on Ar + Sc interactions show dependence on collision energy qualitatively similar to the $p+p$ data, but the plateau is at significantly higher level.

The $p+p$ results obtained by NA61 have been considered as a possible hint of the onset of deconfinement in small systems.

Surprisingly, there is no indication of "horn" structure in the Ar + Sc data.

NA62 (NA48/2)

The analysis of the NA48/2 and NA62 experimental data was continued in 2019.

The first NA62 result on the search for the $K^+ \to \pi^+\nu\bar{\nu}$ decay based on a small subsample of the data collected in 2016 (corresponding to $1.21\cdot10^{11}$ K^+ decays) was published [8] (Fig. 8). The single event sensitivity

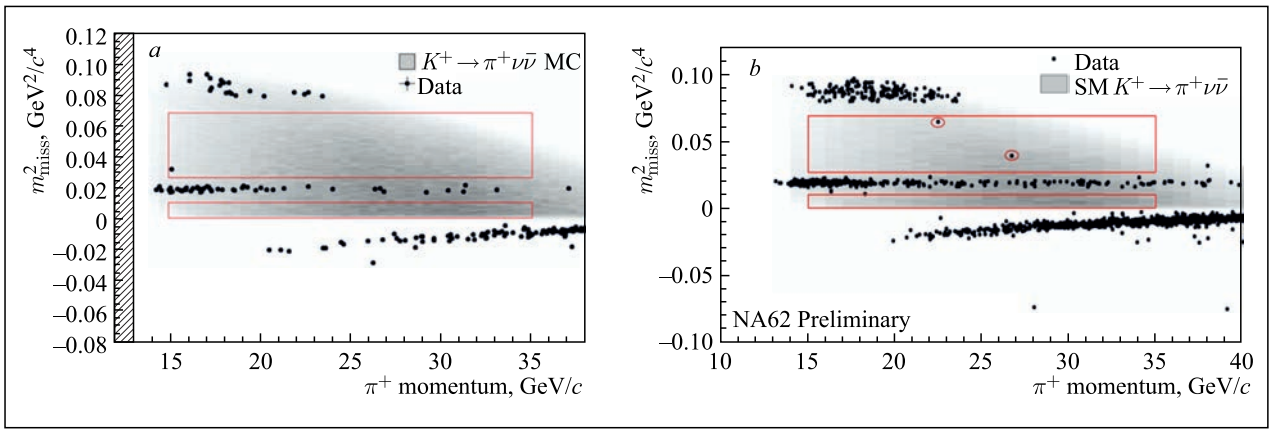

Fig. 8. *a*) One $K^+ \to \pi^+\nu\bar{\nu}$ decay candidate revealed in the signal area (red rectangles) as a result of the blind analysis of the data collected by NA62 in 2016; *b*) two $K^+ \to \pi^+\nu\bar{\nu}$ decay candidates revealed in the NA62 signal area (red rectangles) after the blind analysis of data collected in 2017

was $3.15 \cdot 10^{-10}$, corresponding to 0.267 of the Standard Model events. One signal candidate was observed while the expected background was 0.152 events. This leads to an upper limit of $14 \cdot 10^{-10}$ on the $K^+ \to \pi^+\nu\bar{\nu}$ branching ratio at 95% CL. An analysis of the data collected in 2017 resulted in the selection of two more $K^+ \to \pi^+\nu\bar{\nu}$ candidates. With the total expected background of 1.65 ± 0.31 events, the selected three candidates lead to the upper limit of $18.5 \cdot 10^{-10}$ at 90% CL for the $K^+ \to \pi^+\nu\bar{\nu}$ branching ratio.

The final article on the results of the NA48/2 analysis of the rare decay $K^\pm \to \pi^\pm\pi^0\ e^+e^-$ was published [9]. The obtained results are based on $1.7 \cdot 10^{11}$ charged kaon decays recorded in 2003–2004. A sample of 4919 candidates with 4.9% background contamination allows the determination of the branching ratio $\mathrm{BR} = (4.24 \pm 0.14) \cdot 10^{-6}$. A study of the kinematic space shows evidence for a structure-dependent contribution in agreement with predictions based on Chiral Perturbation Theory (ChPT). Several P- and CP-violating asymmetries were also evaluated.

The results of the search for the π^0 decays to a photon and an invisible massive dark photon in the NA62 experiment at the CERN SPS were published [10]. From a total of $4.12 \cdot 10^8$ tagged π^0 mesons, no signal was observed. Assuming a kinetic-mixing interaction, limits were set on the dark photon coupling to the ordinary photon as a function of the dark photon mass, improving on previous searches in the mass range 60–110 MeV/c^2. The results are interpreted in terms of an upper limit of the branching ratio of the electro-weak decay $\pi^0 \to \gamma\nu\bar{\nu}$, improving the current limit by more than three orders of magnitude.

On the basis of the NA62 experimental data, a new search for the double neutrinoless kaon decays $K^+ \to \pi^-e^+e^+$ and $K^+ \to \pi^-\mu^+\mu^+$ was performed at the world best level of sensitivity [11]. These decays violate lepton number conservation, and their detection would reveal neutrino Majorana nature that would assume modification of the Standard Model. Expected estimated background in the signal region was found to be 0.16 ± 0.03 and 0.91 ± 0.41 events, while the number of the observed events is 0 and 1, correspondingly. It leads to the upper limits for the branching ratios $2.2 \cdot 10^{10}$ and $4.2 \cdot 10^{11}$ at 90% confidence level, correspondingly. The obtained result improves the world data precision on the eventual lepton number non-conservation. The 2018-year data analysis will further improve the result precision.

NA64

In 2019, the JINR group participated in the analysis of 2016–2018 runs data performed by the collaboration and continued working on the development of a new straw-tube based chambers for the spectrometer upgrade.

In a search for sub-GeV dark matter production mediated by a new vector boson A', called dark photon in

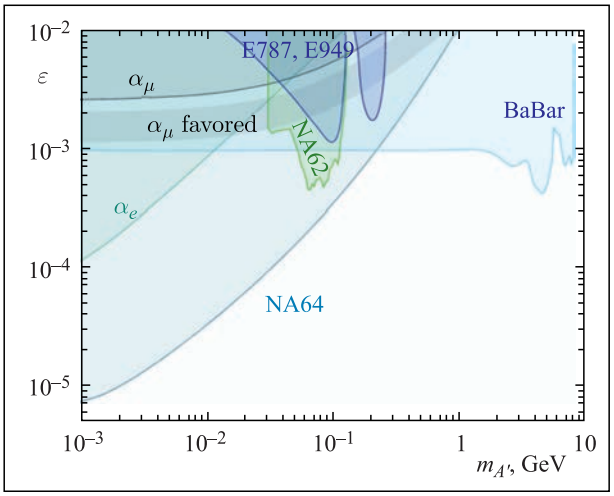

Fig. 9. The NA64 90% CL exclusion region in the $(m_{A'}, \varepsilon)$ plane. Constraints from the E787 and E949, BaBar and recent NA62 experiments, as well as the muon α_μ favored area, are also shown

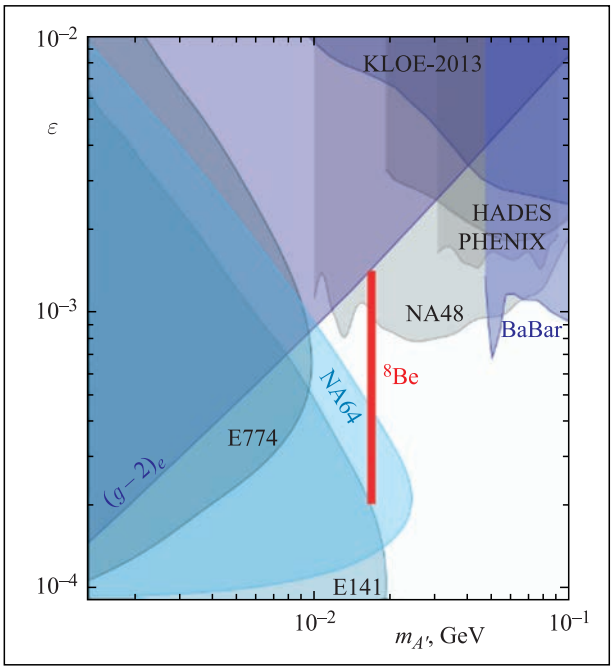

Fig. 10. The 90% CL exclusion areas in the $(m_X;\varepsilon)$ plane from the NA64 experiment (blue area). For a mass of 16.7 MeV, the $X-e^-$ coupling region excluded by NA64 is $1.2\cdot10^{-4} < \varepsilon_e < 6.8\cdot10^{-4}$. The full allowed range of ε_e explaining the ^{8}Be* anomaly, $2.0\cdot10^{-4} < \varepsilon_e < 1.4\cdot10^{-3}$, is also shown (red area). The constraints on the mixing from the experiments E774, E141, BaBar, KLOE, HADES, PHENIX, NA48, and bounds from the electron anomalous magnetic moment $(g-2)_e$ are also shown

missing energy events, from the analysis of the data collected in the years 2016, 2017 and 2018 with $2.84\cdot10^{11}$ electrons on target, no evidence of such a process has been found. The results were published in "Physical Review Letters" and highlighted as "the Editor's suggestion" [12] (Fig. 9).

A combined analysis of the data samples (8.4×10^{10} eot) collected in 2017 and 2018 in the direct search for a new X (16.7 MeV) boson that could explain the anomalous excess of e^+e^- pairs observed in the decays of the excited ^{8}Be* nucleus ("beryllium anomaly") was performed. The X boson could be produced in the bremsstrahlung reaction $e^-Z\to e^-ZX$ by a high-energy beam of electrons incident on the active target and observed through its subsequent decay into e^+e^- pair. No evidence for such decays was found. This allows setting new limits on the $X-e^-$ coupling in the range $1.2\cdot10^{-4} < \varepsilon_e < 6.8\cdot10^{-4}$, excluding part of the parameter space favored by the beryllium anomaly [13] (Fig. 10).

The NA64 experiment was highlighted by CERN Vice-Director-General E. Elsen in the New Year presentation: "... From a wide variety of fixed-target experiments I chose NA62 and NA64 as the most indicative in terms of the potential for discovering new physics at SPS. Analysis of data collected during 2016–2018 with electrons allowed NA64 to achieve a record sensitivity for the region of light dark matter parameters, as well as significantly advance in the search for other new weakly interacting particles."

EVENTS

1. The 3rd Collaboration Meeting of the MPD and BM@N Experiments at the NICA Facility was held on 16–17 April.

2. International Workshop "SPD at NICA" was held at VBLHEP on 4–8 June.

3. On 11 October, in Mexico, the Collaboration Agreement was signed with:
- National Autonomous University of Mexico,
- Institute for Nuclear Science,
- Meritorious Autonomous University of Puebla,
- Research & Advanced Studies Centre,
- University of Colima,
- Autonomous University of Sinaloa.

4. The 4th MPD Collaboration Meeting of the MPD Experiment was held at Warsaw University of Technology on 22–25 October. Five Polish scientific centres became participants of the MPD collaboration:
- Jan Kochanowski University;
- National Centre for Nuclear Research (NCBJ), Otwock;
- University of Wroclaw;
- Warsaw University of Technology;
- University of Warsaw.

5. The 4th Collaboration Meeting of the BM@N Experiment at the NICA Facility was held on 14–15 October.

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DZHELEPOV LABORATORY OF NUCLEAR PROBLEMS

NEUTRINO PHYSICS AND RARE PHENOMENA, ASTROPHYSICS

The Baikal neutrino telescope is one of the three largest operating detectors in terms of the effective volume and effective area for natural neutrino flux observation and the largest in the Northern Hemisphere. The most important achievement in 2019 is the construction of the fourth and the fifth clusters of the deep underwater detector in Lake Baikal as the next step to the full-scale **Baikal-GVD** detector. The detector-2019 consists of 1440 optical modules assembled on 40 vertical strings (8 strings in each cluster) distributed at the depth of 750–1250 m. The effective volume of the deep underwater detector GVD-2019 with 5 clusters reaches 0.25 km^3 [1]. It is about 60% of the effective volume of the Antarctic detector IceCube for such investigation. Preliminary data analysis for 2016–2018 and, partially, for 2019 allowed selecting the first six events with energies above $\sim$ 100 TeV, where the astrophysical neutrino flux exceeds the atmospheric neutrino background [2].

During 2019, significant part of the work within the **Daya Bay** collaboration was devoted to the development of the Global Neutrino Analysis (GNA) framework. Implementing of the tutorial, which already contains 64 lessons, was started, and documentation was considerably improved [3]. The complete Daya Bay model was implemented within the GNA. It is now ready for the next round of the data analysis in 2020.

By the end of 2019, more than 15 000 large PMTs were tested for the **JUNO** experiment at a special setup, which includes scanning stations developed at JINR. The JINR group is fully responsible (including financial aspect) for the design, mass production, and tests of the whole HV system for the JUNO PMTs, including 20 000 large and 25 000 small ones. In 2019, the design of the Top Tracker (TT) support was completed and approved by the collaboration. The producer company was chosen by the bidding procedure. Development of the DAQ and data analysis software is going on.

In 2019, the **Borexino** collaboration presented the results of the search for nonstandard neutrino interactions [4]. The analysis was performed by the JINR DLNP researchers. The model-independent limits on the neutrino and antineutrino fluxes from the astrophysical sources were found [5]. The final analysis of the geoneutrino fluxes from the Earth performed with the complete Borexino dataset is accepted for publication [6]. A comprehensive review of the experimental geoneutrino study was published [7].

During 2019, within the **NOνA** experiment, new results of neutrino oscillation parameter measurements were obtained with an active participation of the JINR researchers. Data-taking with the neutrino and antineutrino beams produced by the FNAL accelerator complex with the proton beam of a record power ($\sim$ 800 kW) and a combined analysis of muon neutrino disappearance and electron neutrino appearance channels allowed measuring the following neutrino oscillation parameters: $|\Delta m^2_{23}| = 2.48^{+0.11}_{-0.06} \cdot 10^{-3}\,\text{eV}^2$ and $\sin^2\theta_{23}$ in the ranges of 0.53–0.60 and 0.45–0.48 for the normal hierarchy of neutrino masses. The data exclude most values near $\delta_{\text{CP}} = \pi/2$ for the inverted mass hierarchy by more than 3σ and favor the normal neutrino mass hierarchy by 1.9σ and the θ_{23} values in the upper octant by 1.6σ [8]. The NOνA experiment will continue data-taking until 2024 with the aim to improve the neutrino mass hierarchy and to determine δ_{CP}.

The NOνA remote operation center and the computing infrastructure at JINR are routinely operating. Members of the NOνA group at JINR are actively involved in the experiment with the tasks of physics analysis coordination, management of the online and offline software, hardware tests, and expert duties during the detector operation.

Within the **SuperNEMO** project, the final results on ^{100}Mo ($T^{2\nu\beta\beta}_{1/2} = (6.81 \pm 0.01\,(\text{stat.}) \pm 0.40\,(\text{syst.})) \times$

$\times 10^{18}$ y) [9] for the NEMO-3 spectrometer were presented to the community. The two-electron energy sum, single-electron energy spectra, and distribution of the angle between the electrons were presented with an unprecedented statistics of $5 \cdot 10^5$ events and a signal-to-background ratio of ~ 80. Clear evidence for the validity of the Single State Dominance (SSD) model was found for this transition, confirming the ability of the tracko-calo technique to test the bb-decay mechanism.

In 2019, the progress of the **EDELWEISS** experiment was completely due to the development of new unique detectors able to detect nuclear recoils with the energies from ~ 20 eV. The results of searching for low-mass dark matter particles (below 1 GeV/c^2) were published [10]. In addition, due to synergy between EDELWEISS and CUPID-Mo experiments the identification results for $\alpha/\gamma(\beta)$ backgrounds were obtained. In 2019, the prime target of this joint experiment was the best $0\nu2\beta$ limit for ^{100}Mo [11].

The breakthrough made by EDELWEISS due to creation of detectors sensitive to the nuclear-recoil energy range below 100 eV opens up completely new possibilities not only for DM search, but also for neutrino study with CEνNS. Because of significant uncertainties in low-energy quenching, only next-generation cryogenic bolometers, as those already developed by EDELWEISS, with their unprecedented low-energy threshold and the ability to suppress background events can provide $\sim 1\%$ precision for measurement of CEνNS up to $\mathcal{O}(10)$ eV. Such accuracy, which is supposed to be achieved in the new Ricochet experiment, R&D of which is carried out on the basis of EDELWEISS with the active participation of JINR, will allow verification of various extensions of the Standard Model (SM) and will considerably extend our understanding of the electroweak sector. To conduct the experiment, a study was begun of the potential location of the setup near the ILL research reactor (France) and near the VVER-1200 reactor of the Novovoronezh NPP.

Within the **GERDA** experiment, in November 2019, the design Phase II exposure of 100 kg $\cdot$ y was reached. That allowed stopping the data-taking in order to start the transition phase to the next-generation project LEGEND. With a total exposure of 82.4 kg $\cdot$ y (Phase I + Phase II), no $0\nu\beta\beta$ signal was observed, and a lower half-life limit of $T^{0\nu}_{1/2} > 0.9 \cdot 10^{26}$ y (90% CL) was derived. The $T^{0\nu}_{1/2}$ sensitivity, assuming no signal, is $1.1 \cdot 10^{26}$ y. Combining the latter with those from other $0\nu\beta\beta$-decay searches yields a sensitivity of 0.07 to 0.16 eV to the effective Majorana neutrino mass [12].

Within the **νGEN/GEMMA-III** project, new low-threshold high-purity germanium detectors with a mass of 1.5 kg each and resolution of 100 eV were produced [13]. Their performance was tested at JINR. After those tests, in November 2019, the first detector was moved to the Kalinin Nuclear Power Plant (KNPP). The spectrometer was installed at about 10 m from the center of the KNPP reactor core under an enormous neutrino flux of about $5 \cdot 10^{13}$ cm$^{-2} \cdot$ s^{-1}. Reactor surrounding and constructive materials (overburden equivalent to about 50 m w.e.) allow the cosmogenic background to be considerably suppressed. Other backgrounds are suppressed by passive shielding from polyethylene, lead, copper, and nylon. Moreover, for further decreasing of the cosmogenic background, a plastic muon veto was created and tested.

The **DANSS** detector started to operate at unit 4 of the KNPP in 2016. It registers about 4000 neutrinos per day with a background less than 2–3% (both values are the world's best now). Due to a lifting gear, the operating detector can be moved by 2 m, thus measuring the neutrino energy spectrum as a function of the distance. In addition to the reactor diagnostics, this feature allows investigating short-range neutrino oscillations in the way independent of any questionable assumptions about the theoretical neutrino spectrum. An updated full-scale analysis of the 2016–2019 data was performed with improved estimation of all background sources and systematic errors. The world's best model-independent restriction on the existence of a sterile neutrino was obtained [14].

The gamma-ray observatory **TAIGA** is intended for the energy range above 30 TeV. The observatory combines several IACTs (Imaging Atmospheric Cherenkov Telescopes) with a net of comparatively cheap wide-angle non-imaging optical detectors — HiSCORE detectors. The combination of two complementary methods of gamma-ray separation allows building a device with a large area at a relatively low price. TAIGA will include a network of 500 HiSCORE detectors and up to 16 IACTs covering an area of 5 km^2 and muon detectors with a total sensitive area of 2000 m^2 distributed over an area of 1 km^2. Since TAIGA will be the northernmost gamma observatory, its location provides some advantages for observing the sources with large declinations. Within the TAIGA project, JINR is responsible for the mechanical platform of the IACT. The first IACT takes data since 2016, and JINR is responsible for production and tests of the third IACT in 2019.

The **OPERA** experiment data analysis is close to completion. In 2019, publications were made that reported the results on derivation of neutrino oscillation parameters from the combined analysis of ν_μ disappearance and appearance of ν_τ and ν_e [15] and on seasonal variation of the atmospheric muon flux [16]. Continuing to study tau-neutrino physics with emulsion technology, the Dubna group took part in R&D on the DsTau project aimed at measuring the cross section of tau-neutrino production, searching of intrinsic charm in $p-A$ interactions.

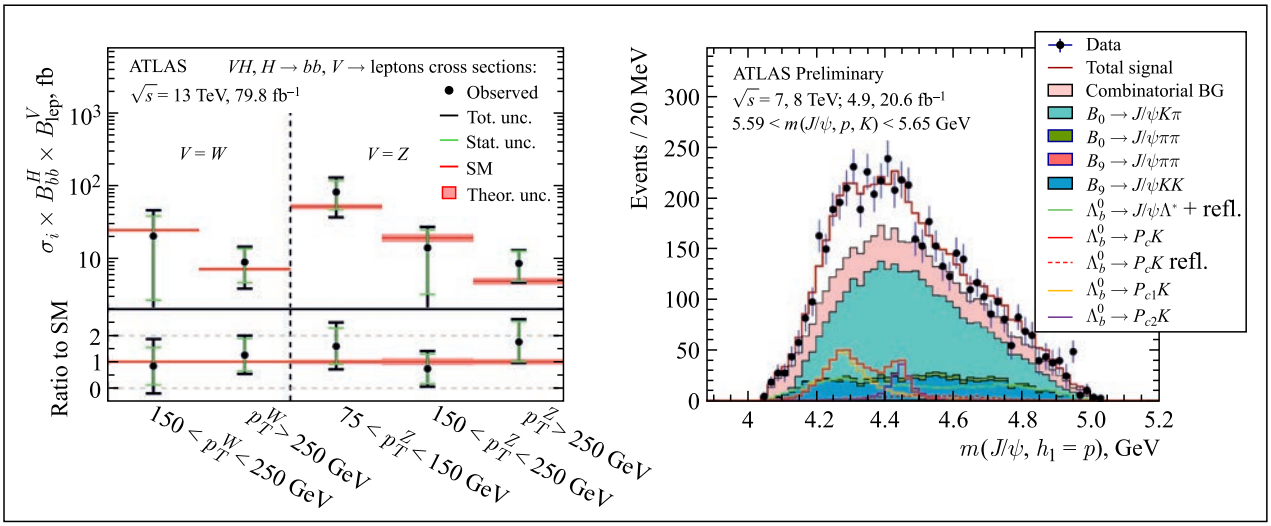
Within the **ATLAS** project, the cross sections of associated production of a Higgs boson decaying into bottom quark pairs and an electroweak gauge boson, W or Z, decaying into leptons are measured as a function of the gauge boson transverse momentum (at the left of the figure). The cross sections are measured for Higgs bosons in a fiducial volume with rapidity $|y_H| < 2.5$ [17]. The results are obtained using 79.8 fb^{-1} of proton–proton collisions recorded by the ATLAS detector at the Large Hadron Collider (LHC) at a centre-of-mass energy of 13 TeV. All measurements are found to be in agreement with the SM predictions, even in high p_T^V (> 250 GeV) regions that are most sensitive to enhancements from potential anomalous interactions between the Higgs boson and the electroweak gauge bosons. Limits are set on the parameters of an effective Lagrangian sensitive to modifications of the Higgs boson couplings to the electroweak gauge bosons.

A study of $J/\psi p$ resonances in the $\Lambda_b \to J/\psi p K$ decays with large $m(pK^-)$ invariant masses is performed in the ATLAS experiment at the LHC. The analysis is based on a combined sample of the pp collision data at centre-of-mass energies $\sqrt{s} = 7$ and 8 TeV corresponding to the integrated luminosities of 4.9 and 20.6 fb^{-1}, respectively. Although the model with two or more pentaquark states is preferable, the data do not rule out the model without pentaquarks (at the right of the figure). The pentaquark masses and widths obtained using the model with two pentaquarks are consistent with those from the LHCb experiment [18, 19].

Within the **COMPASS** project, a preliminary result for the pion-induced inclusive production of the double J/ψ final state was obtained. The total cross sections were measured for the ammonia, tungsten, and aluminium target and found to be $(8.8 \pm 2.2\,(\text{stat.}) \pm 2.4\,(\text{syst.}))$, $(3.4 \pm 4.3\,(\text{stat.}) \pm 5.8\,(\text{syst.}))$, and $(14.3 \pm 7.7\,(\text{stat.}) \pm 4.5\,(\text{syst.}))$ pb/nucleon, respectively. The double J/ψ invariant mass spectrum does not exhibit any statistically significant resonant structure around the kinematic threshold, and so there is no evidence of 4c tetraquark states predicted by some models. The obtained kinematic distributions are in agreement with the production of the double J/ψ via the Single-Parton Scattering (SPS) mechanism. No evidence of the pion-induced Intrinsic Charm (IC) mechanism was found. A journal publication based on the result is under preparation.

Within the **BESIII** experiment, the group from JINR analyzed data of the light meson pair production in the energy range of 2–3 GeV and around the J/ψ peak in order to measure the cross section of a number of exclusive processes. The cross section for exclusive reactions with the final states $\omega\pi^0$, $\omega\eta$, and $\varphi\eta$ was measured, and a preliminary estimation of the relative phase between the strong and electromagnetic amplitudes was obtained. The results of the prompt J/ψ production cross section measurements in the e^+e^- annihilation at the center-of-mass energies from 3.81 to 4.60 GeV were verified using decays of J/ψ to e^+e^- [20].

In 2019, within the **Mu2e** project, JINR scientists assembled two cathode strip chambers and a cosmic muon test bench based on those chambers to test Cosmic Ray Veto (CRV) modules of the Mu2e veto system. JINR scientists developed the procedure for making the CRV module of the 4-layer scintillation strips and aluminum spacers. The length of such modules will be from 2.5 to 7 m, and the weight of one module is



Measured VH, $V \to$ leptons reduced stage-1 simplified template cross section times the $H \to bb$ branching ratio (left). The $\chi 2$ fits of the $m(J/\psi p)$ distribution in the signal region with the hypothesis of two pentaquarks P_{c1} and P_{c2} with spin-parity $3/2^-$ and $5/2^+$, respectively (right)

several tonnes. The pilot modules were produced and tested at Virginia University (USA). The DLNP collaboration members developed and tested the procedure of filling the fiber holes with synthetic rubber (SKTN) to increase the light yield of the modules to 40–50%. The 7-m modules will be filled with SKTN to provide effective operation for several years of the Mu2e data run. The samples of SKTN synthetic rubber and the scintillator strips filled with SKTN were tested for radiation hardness at the JINR neutron facility (neutron fluence up to $1.6 \cdot 10^{15}$ cm^{-2}). They showed very good resistance to neutron irradiation and could be used in the veto system counters during the physics run. Finally, the CRV module assemble procedure [21] was developed.

The DLNP scientists and the colleagues from the Ioffe Institute (St. Petersburg) are developing an efficient solar-blind photodetector that can be used for BaF_2 fast component readout in Mu2e phase II. The main feature of this photodetector is that it suppresses the low component of BaF_2 scintillation with the 320-nm peak luminosity and detects the fast component with the 230-nm peak and the flash time less than 1 ns [22].

Within the **MEG-2** experiment, scientists from DLNP participated in the assembly of the WaveDREAM crates for the new readout electronics and in the test run with the cylindrical drift chamber on the muon beam. A working demo version of the 3D Event Display web application for online visualization of experimental data was developed and installed on a web server [23].

Within the **COMET** project, straw tubes of a new design with 12-μm-thick walls and 4.97 mm in diameter were successfully manufactured. The uniformity of the cylinder diameter is a crucial point for the straw tubes. Straw tubes must pass a cylindrical shape uniformity test in order to be approved for operation. This parameter is controlled by a special optical device. The straw tube is placed perpendicularly to a laser beam, and its diameter is measured with an accuracy of 0.1 μm. The straw tube is scanned at a pressure of 1–2 bar. This method of testing is used to assess uniformity of the cylinder diameter at different points. During the test, the straw pipes made showed excellent characteristics and performance.

In 2019, the study of the optical parameters (energy resolution, decay time, relative light yield, non-uniformity of the light distribution along the length) of a new (engineering) Saint-Gobain LYSO crystal was continued. In addition, the study of the optical parameters of the Chinese crystal (JT Crystal Technology Co., Ltd.) began. It was found that the light output of the LYSO engineering crystal is approximately 20% greater than that of the previously produced crystals, but the energy resolution is almost the same. The decay time is slightly shorter. The non-uniformity of the light yield along the crystal length was studied. The standard deviations of the light yield along the crystal length for a group of 10 samples relative to their average value are about 10–19%.

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. The processing of the physical data previously obtained in Mainz (Germany) with significant participation of the DLNP scientists also continues. These data are obtained using the polarized proton (deuteron) target created by the DLNP employees [24, 25].

Within the **ARIEL** project, the main result in 2019 is the release of the first version of the Monte Carlo unweighted event generator MCSANCee for Bhabha scattering and electron–positron annihilation into the Z boson and the Higgs boson. Detailed comparisons of the MCSANCee results with those of alternative calculations, WHIZARD and CalcHEP, were made. The calculation of the process $e^+e^- \to \tau^+\tau^-$, $\mu^+\mu^-$ with longitudinal polarization of the initial state is completed. A new version 6.45 of the package DIZET, a library for the calculation of the electroweak radiative corrections, was created. Now KKMC, the basic code for extraction of $\sin\theta_W^{\rm eff}$ by fitting to the 8-TeV NC DY (ATLAS) data, uses this version of DIZET. Electroweak radiative corrections to the basic processes $e^+e^- \to ZH$ [26] and Bhabha scattering [27] are calculated with allowance for polarization.

APPLIED RESEARCH AND ACCELERATORS PHYSICS

A fundamentally new detector, the **Precision Laser Inclinometer** (**PLI**), was developed and put into operation at JINR, which makes it possible to detect angular oscillations of the Earth's surface in the frequency range of 10^{-6} to 4 Hz with the maximum sensitivity of $2.4 \cdot 10^{-11}$ rad/Hz$^{1/2}$. Five complete inclinometer sets were manufactured and supplied to CERN for monitoring LHC deformations [28]. Up to date, three of them have been successfully put into operation. A trilateral Addendum was signed by JINR, European Gravitational Observatory VIRGO (Italy), and CERN to start using the PLI for stabilization of active elements of Interference Gravitational Antenna (IGA VIRGO) against angular microseismic oscillations. In August

and October 2019, two PLIs were installed in the experimental hall of the Northern Mirror of IGA VIRGO. They showed stable performance for several months.

The main goal of the research at the **Medico-Technical Complex (MTC)** is to carry out medico-biological and clinical investigations into tumour treatment, upgrade equipment and instrumentation, and develop new techniques for treatment of malignant tumours and for associated diagnostics with medical hadron beams of the JINR Phasotron. The following main results were obtained in 2019.

Regular sessions aimed to investigate proton therapy efficiency for treating different kinds of neoplasm were performed in collaboration with the Russian Medical Academy of Postgraduate Education (Moscow) and the Radiological Department of the Dubna hospital. During the year, four treatment sessions with the total duration of 17 weeks were carried out. Twenty new patients were fractionally treated with the medical proton beam. The total number of the single proton irradiations (fields) was about 2000. Other 13 patients were irradiated using the ^{60}Co gamma-therapy unit "Rokus-M" (800 fields). The statistical analysis of the clinical data for different nosologies treated at the MTC was continued. The results are very close to those of other proton therapy centres [29, 30].

Since 2016, the SC200 superconducting cyclotron for hadron therapy has been jointly developed by JINR and ASIPP (Hefei, China). According to the Collaboration Agreement, two cyclotrons should be manufactured in China: one will operate in the Hefei Medical Centre and the other will be used for the medico-biological research at JINR. The SC200 cyclotron designed for Hefei is currently under construction [31]. The main systems are manufactured and tested. A high-power feeding test was performed for the Radio Frequency (RF) accelerating system [32]. The RF system can stably operate in a $\sim$ 50-kW continuous wave state. The Penning cold cathode ion source was tested [33]. The measured intensity of the extracted beam was as high as 200 μA. The magnetic field mapping and shimming of SC200 are under way. The experimental map with good isochronism is obtained over a wide range of radii. The physical design of the compact superconducting cyclotron **SC230** was performed at DLNP. The cyclotron will produce a $>$ 230-MeV beam for proton therapy and medico-biological research.

In 2019, within the **R&D of new semiconductor detectors**, a multienergy tomographic reconstruction algorithm was developed. A possibility of identifying gold in a salt solution was demonstrated with the Timepix3 detector data. An algorithm for clustering of data from PLD-based pixel detectors was also developed. The Kalan-4 microtomograph developed at DLNP IBD was equipped with a Widepix MPX3 1×15 X-ray camera with 1-mm-thick CdTe sensors. Its field of view is 14 by 210 mm, and the pixel pitch is 55 μm. Adjustment of all elements and investigation of various samples are underway. An idea of using an assembly of three detectors in series based on Si, GaAs:Cr, and CdTe to increase the number of energy thresholds at X-ray tomographic scanning was proposed and implemented. A prototype of the SPECT system based on the Timepix detector and encoding aperture was developed. Its spatial resolution was 1 mm [34–36].

In 2019, within the project **"Development of Experimental Techniques and Applied Research with Slow Monochromatic Positron Beams"**, the focus of the work was the study of the defect distribution in various materials by the Positron Annihilation Spectroscopy (PAS) method and the development of the experimental base. Vacuum and magnetic elements of the positron ordering and transportation setup were mounted in the experimental channel for the beam formation and transport to the target with a sample. They are components of the PALS spectrometer (Positron Annihilation Lifetime Spectroscopy), which is under construction in the Electron Cooling Sector of DLNP [37]. For the same purpose, the final assembly and tuning of the RF resonator is carried out. A system for reactive etching of samples based on an ion source was developed to advance possibilities created to provide the capabilities of research by the PAS method. Its testing is under preparation.

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FLEROV LABORATORY OF NUCLEAR REACTIONS

CONSTRUCTION OF THE ACCELERATOR COMPLEX "FACTORY OF SUPERHEAVY ELEMENTS" BASED ON THE DC-280 CYCLOTRON

In 2019, the priority tasks of the Flerov Laboratory of Nuclear Reactions were the start-up of the Factory of Superheavy Elements (SHE Factory) whose key element is the DC-280 cyclotron and the construction of a state-of-the-art complex with cutting-edge physics instruments for the synthesis of superheavy elements and study of their properties. The highest priority was given to the commissioning of the SHE Factory, attaining of beam design parameters at DC-280, and launch of test experiments employing a new gas-filled recoil separator (GFS-2) [1–4].

A Rostechnadzor statement of the facility compliance with the requirements of the technical regulations and a commissioning approval permit from the Ministry of Housing of Moscow Oblast were received. On 19 March 2019, an FMBA sanitary and epidemiological statement on compliance of ionizing radiation sources (ECR ion source and DC-280) with radiation protection and safety standards was received. On 20 December 2019, an FMBA sanitary and epidemiological conclusion certificate was obtained for the approval of work with nuclear and radioactive materials in experimental halls of II class of the SHE Factory.

The DC-280 cyclotron was officially commissioned on 25 March 2019. The total operation time of DC-280 in 2019 was $\sim$3470 h. Beams of ^{84}Kr, ^{12}C, ^{40}Ar, and ^{48}Ca were produced. By the end of the year, the following ion beam intensities were achieved: $^{12}C^{+2}$ (5.8 MeV/nucleon) — 10 pμA particles, $^{40}Ar^{+7}$ (4.88 MeV/nucleon) — 10.4 pμA particles, $^{48}Ca^{+7}$ (5 MeV/nucleon) — 5.1 pμA particles, and $^{84}Kr^{+14}$ (5.9 MeV/nucleon) — 1.44 pμA particles. To test GFS-2, the beams of ^{40}Ar and ^{48}Ca ions were transported from DC-280 to the target unit and GFS-2 stopper via a transportation channel.

Construction of Experimental Setups of the Factory of Superheavy Elements. The first experimental setup for the ongoing studies of superheavy nuclei at the SHE Factory is the gas-filled recoil separator. During 2019 the launching of all the units of GFS-2 was completed. The optical elements of the separator are configured as $Q_{1,v}\ D_{1,h}\ Q_{2,h}\ Q_{3,v}\ D_2$. The quadrupole lens $Q_{1,v}$ focuses vertically nuclei knocked out of the target to increase their transport efficiency through the gap of the dipole magnet $D_{1,h}$, where the products of complete fusion reactions — evaporation residues (ERs) — are separated from the bulk of the beam particles and background reaction products. ERs are then focused by two quadrupole lenses $Q_{2,h}$ and $Q_{3,v}$. The dipole magnet D_2 is used for additional separation of ERs from background particles.

Beam line components were mounted in front of the separator. Equipment was fabricated and installed to control the vacuum system of the beam line and separator, measure ion beams, supply gas into GFS-2, operate magnetic elements, and control and block vacuum system components.

First test experiments were conducted to determine the GFS-2 optimal parameters using α particles and the $^{\rm nat}$Yb(^{40}Ar, xn)$^{207-212}$Ra reaction products. The experiments showed that background event suppression is sufficient at the high special dispersion of an image in the focal plane. Experiments with the ^{48}Ca beam and the targets of $^{\rm nat}$Yb,^{174}Yb,^{170}Er, and ^{208}Pb have been launched. They aim at determining the transmission efficiency of the separator and target resistance under the irradiation with high-intensity heavy-ion beams.

The implementation of the experimental programme at the SHE Factory will commence upon completion of the GFS-2 testing programme. The synthesis of the isotopes of moscovium in the $^{48}\mathrm{Ca} + {}^{243}\mathrm{Am}$ reaction will be the first test experiment.

A pre-separator for chemical studies and nuclear spectroscopy was fabricated by the SigmaPhi Group (France) and prepared for transportation to Dubna. The delivery and installation work are planned for 2020.

The development of the cryogenic gas ion catcher is already underway. The following work was done in 2019: main components of the vacuum system were purchased; main gas cell components (VACUUM, Prague) were obtained; electrodes of the conical part of the gas cell were manufactured (VNITEP, Dubna); basic elements of the control system were purchased and tested; preparations for installing the setup, control and measurement systems in the experimental hall began.

SYNTHESIS OF NUCLEI AT STABILITY LIMITS AND THEIR PROPERTIES

According to the decisions taken by PAC and the Scientific Council of JINR, SHE Project was implemented in parallel with the FLNR scientific programme. A wide variety of scientific and applied investigations in heavy-ion physics were conducted using the U-400, U-400M, and IC-100 cyclotrons. The total operation time of the cyclotrons in 2019 was $\sim 20\,200$ h. Most of the operation time was spent on the implementation of the research programme focused on ^{22}Ne beams (U-400, SHELS, and MAVR), ^{46}Ti beams (U-400 and chemical setup), ^{48}Ca beams (U-400, CORSET, and SHELS), ^{40}Ar beams (U-400M, MASHA), ^{11}B and ^{15}N beams (U-400M, ACCULINNA-1, 2, and COMBAS). In addition, applied studies (NIIKP) were conducted at the U-400 and U-400M cyclotrons.

Spectroscopy of Heavy and Superheavy Nuclei. The spectroscopic studies of ^{254,252,250}No formed in the reaction involving ^{48}Ca and highly enriched Pb targets were performed. The investigations were aimed at studying electromagnetic and fission branches of the known K isomers in these nuclei. With regard to ^{250}No, an electromagnetic branch from the isomeric state with a $\sim$40-μs half-life was detected and confirmed. The observation of gamma-quanta (Fig. 1) and internal conversion electrons allowed establishing a complete decay scheme, including the determination of spin, parity, and excitation energy of the isomer. The measured fission branch now represents one of the few cases when the fission branch of an identified high-K isomer was reliably measured. As can be seen from the decay scheme (Fig. 2), the excitation energy of the isomer was firmly established at 1253 keV.

Nobelium isotopes in the ^{238}U(^{22}Ne, xn)$^{260-x}$No reaction were also studied. ^{256}No was successfully transported to the focal plane of SHELS. A transmission efficiency of 6% was deduced for these very slow ions synthesized in asymmetric complete fusion reactions. A short-lived high-K isomeric state was found

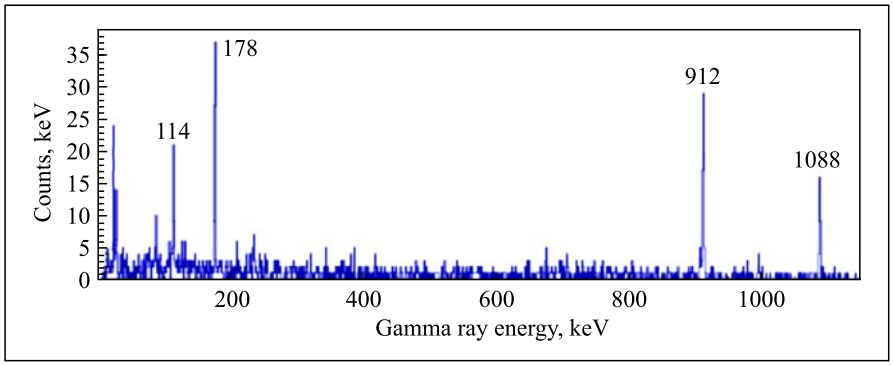

Fig. 1. Spectrum of gamma rays de-exciting the high-K isomer of ^{250}No

in ^{256}No, and a longer-lived isomeric state was observed in the neighbouring ^{255}No. The experimental evidence is under analysis.

The current status of SHELS and some of the experimental results are presented in [5, 6].

Chemistry of Transactinides. The main results were obtained in experiments studying the formation conditions of volatile Nh compounds and their chemical properties in inert gases. The online investigations with the thallium radionuclide ^{184}Tl synthesized in the ^{141}Pr(^{46}Ti, $3n$) reaction at the U-400 accelerator were carried out. Formed chemical species of thallium were studied using a new setup incorporating the features of the high-temperature recoil transfer chamber, SHELS separator, and cryodetector. The chemical species of

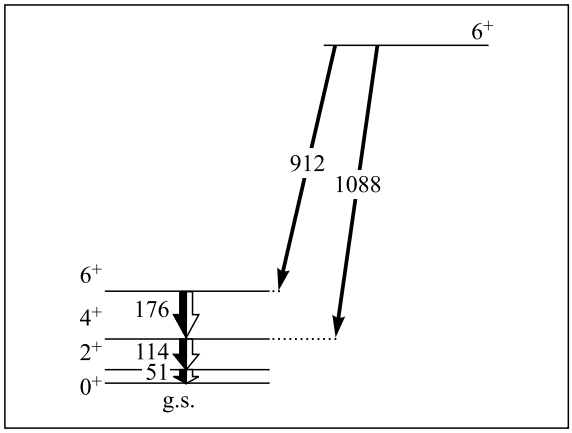

Fig. 2. Established decay scheme of the isomer in ^{250}No

the element, having a low adsorption on quartz and being highly volatile at room temperature, were observed in experiments on the study of the kinetics of the formation and yield of chemical reaction products at the one-atom-at-a-time level as a function of temperature, vapour content, and a composition of inert gases [7]. The capabilities of the setup demonstrated during the investigations proved to allow for experiments on the study of the chemical properties of nihonium using gas transport systems.

The FLNR JINR – PSI (Switzerland) collaboration continues studying and addressing questions on the potential use of single-crystal CVD diamonds as semiconductor detectors for high-temperature α spectroscopy in the chemistry of superheavy elements. Charge carrier mobility was studied in diamond solid-state detectors from room temperature up to 473 K [8].

Dynamics of Heavy-Ion Interaction, Fission of Heavy and Superheavy Nuclei. In 2019, the influence of nuclear shells on the formation of fission fragments of ^{248}Cf*, ^{254}Fm*, and ^{260}No* nuclei produced in heavy-ion reactions at excitation energies of 40–60 MeV was investigated. Mass and energy distributions (MEDs) of fragments obtained in the ^{16,18}O + ^{232}Th, ^{238}U and ^{22}Ne + ^{232}Th, ^{238}U reactions were measured at energies near and above the Coulomb barrier. MEDs were analyzed with a view to clarifying the contribution of quasi-fission process.

As to the compound nucleus ^{260}No* formed in the ^{22}Ne + ^{238}U reaction, an enhanced fragment yield was observed in the superasymmetric mass region 52–208 amu. This behaviour can be attributed to proton and neutron shells in the fragments, which are close to the double-magic ^{48}Ca and ^{208}Pb nuclei. It is to be noted that the dependence of the total kinetic energy and its dispersion on fragment masses also confirms the existence of a superasymmetric mode found in the mass distribution of fission fragments of ^{260}No*. In addition, bimodal fission (about 7%) was observed for the ^{260}No* compound nucleus at an initial excitation energy of 41 MeV, which is accounted for by the number of neutrons and protons in the fragments being close to the double-magic ^{132}Sn.

With regard to the MEDs of the fission fragments of ^{248}Cf* and ^{254}Fm* formed in the ^{16}O + ^{232}Th and ^{22}Ne + ^{232}Th reactions at the excitation energy $E^* = 40-45$ MeV, superasymmetric fission at a mass yield level of 10^{-5} was not observed.

An increased fragment yield was observed in the mass region $\sim 70-90$ u for ^{248}Cf*, ^{254,256}Fm* compound nuclei formed in the reactions of ^{16,18}O and ^{22}Ne with strongly deformed ^{238}U and ^{232}Th actinide targets, which is due to the influence of the closed shells $Z = 28$ and $N = 50$. The total kinetic energy of these fragments was found to be higher than that predicted by the liquid-drop model. MEDs for all of the reactions under investigation were shown to possess the properties typical of modal fission. The analysis showed that evaporation residue cross sections for such reactions were in good agreement with those predicted by the standard statistical model. The enhanced dispersion of the fragment mass distribution can be explained through the concept of multimodal nuclear fission. Consequently, there is no evidence of quasi-fission in the subbarrier region for systems of this kind [9].

The MEDs of fragments formed in the reaction of ^{48}Ca ions with strongly deformed ^{154}Sm nuclei were thoroughly analyzed. The quasi-fission contribution at all of the energies under investigation (below and above the Coulomb barrier) was found to be significant. The MEDs of fragments formed in the ^{40}Ca + ^{144}Sm reaction (assuming reaction partners are both spherical) at near barrier energies were additionally measured in November 2019 to study the influence of deformation of interacting nuclei on fusion–fission and quasi-fission. Experimental data are under analysis.

Theoretical studies of multinucleon transfer in reactions with actinides were also pursued. The calculations were performed within the multidimensional dynamic model, which was improved by enabling modeling of collisions of statically deformed nuclei with fixed mutual orientations [10]. The influence of projectile selection in the formation of the heaviest products was studied using the reactions of ^{48}Ca, ^{136}Xe, and ^{238}U with ^{251}Cf, the most massive target available. The projectile mass growth was shown to lead to an increase in the probability of nuclide formation in the region of transuranium elements with a large neutron excess.

Structure of Exotic Nuclei. In 2019, first experiments with high-intensive radioactive ^{6}He, ^{8}He, ^{9}Li, and ^{10}Be beams were carried out at the new ACCULINNA-2 fragment separator (U-400M accelerator) [11]. The first experiment was dedicated to searching for the ^{7}H nucleus and studying correlations between the products of its $t + 4n$ decay chain. The ^{8}He $(26\,A\cdot\text{MeV}) + d \rightarrow {}^{3}\text{He} + {}^{7}\text{H}$ reaction was chosen to populate the ^{7}H ground and excited states [12]. The greatest challenge in observing the ^{7}H formation was the registration of coincidences between low-energy ^{3}He particles ($E \sim 9-30$ MeV, $\theta \sim 8-26^\circ$ in laboratory system) with fast tritons ($E > 70$ MeV) emitted at forward angles in a narrow cone $\theta \leqslant 6^\circ$ with a fairly good angular resolution $\Delta\theta \sim 0.5^\circ$ and an energy resolution $\Delta E/E \sim 2\%$. In addition, 44 detectors based on stilbene crystals were used for neutron precise detection (energies and angles). The obtained results, namely, new data on the ground and first excited states of ^{7}H (Fig. 3), can be viewed as an important step toward simplifying the ^{7}H observation and demonstrate high performance capability of the ACCULINNA-2 facility. The potential decay channels of the ^{7}H system were analyzed theoretically in [13].

The second run focused on the study of the low-lying states of ^{10}Li populated in the $^{9}\text{Li}(d,p)^{10}\text{Li} \rightarrow n + {}^{9}\text{Li}$ reaction at an energy of 29 MeV/nucleon. A major feature of the experiment was the detection

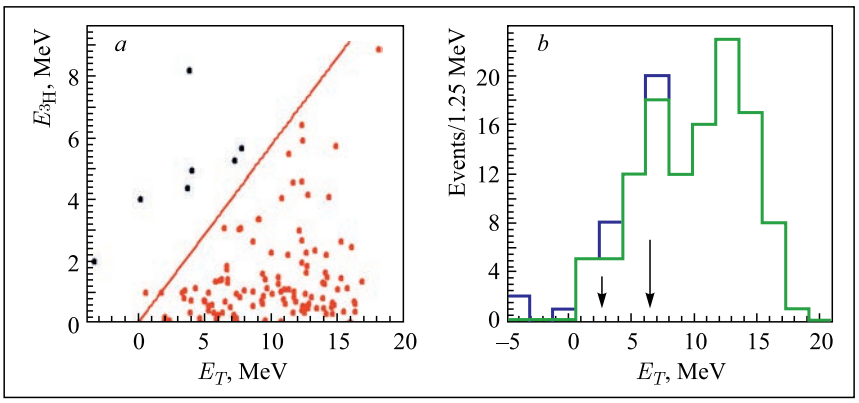

Fig. 3. *a*) Correlations between the ^{3}H energy in the ^{7}H center-of-mass frame and the ^{7}H missing mass energy. A kinematical limit for tritons produced in the ^{7}H decay is shown by the red line, and black points indicate a negligible level of background $\sim 10\%$. *b*) The missing mass spectrum of ^{7}H is shown for the observed 107 events presented below the line in panel *a*

of protons emitted backward in the laboratory system in coincidence with ^{9}Li and neutrons produced by the ^{10}Li break-up and emitted at forward angles. To determine the experimental energy resolution of the setup and the normalization of the missing mass spectrum of ^{10}Li, the ^{7}He* spectrum in the $^6\mathrm{He}(d,p)^7\mathrm{He} \to n + {}^6\mathrm{He}$ reaction was additionally measured. With due regard for both the gathered statistics (about 400 triple coincidences $p{-}^9\mathrm{Li}{-}n$) and good experimental energy resolution of ~ 230 keV (FWHM) over the ^{10}Li excitation energy, new data on low-lying states at ~ 0.5 and ~ 4 MeV are expected.

Reactions with Beams of Light Stable and Radioactive Nuclei. In 2019, most of the interest centered on the investigation of various reaction mechanisms leading to the formation of neutron-rich nuclei. Experiments were performed at heavy-ion accelerators in wide energy ranges, which was key in determining the channels of nuclear processes — from nucleon transfer reactions to fragmentation. The MAVR magnetic spectrometer in Dubna and the LISE facility in France were employed. An interesting result was obtained for the reaction with ^{18}O nuclei accelerated to 8.5 MeV/nucleon and directed onto the ^{238}U target. A significant increase in the cross section for the production of exotic nuclei was detected owning to the transfer of a large number of neutrons from the target nucleus to the nucleus of the bombarding particle.

The collision dynamics of exotic nuclei was studied on the basis of the numerical solution of the time-dependent Schrödinger equation taking into account spin-orbital interaction [14]. The cross sections for nucleon transfer and break-up were calculated as the main components of the total cross section of the reaction with weakly bound nuclei studied in FLNR JINR experiments for the $^{11}\mathrm{Li} + {}^{28}\mathrm{Si}$, $^3\mathrm{He} + {}^{194}\mathrm{Pt}$, ^{45}Sc, $^6\mathrm{He} + {}^{197}\mathrm{Au}$, and $^9\mathrm{Li} + {}^{28}\mathrm{Si}$ reactions (Fig. 4).

The manifestation of clustering in light atomic nuclei was studied with reference to deuteron reactions with ^{9}Be nuclei at low energies [15]. The folding atomic nuclei potential was calculated on the basis of a three-cluster model with the nucleus $^9\mathrm{Be} = n + \alpha + \alpha$. The main reaction channels, including those involving the transfer of large clusters, were analyzed within the

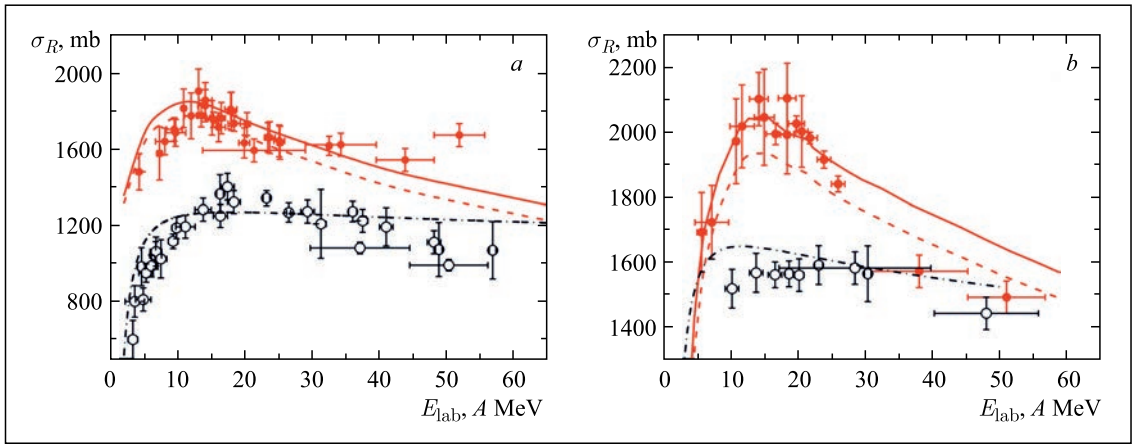

Fig. 4. The excitation function for $^{4,6}\mathrm{He} + \mathrm{Si}$ (*a*) and $^{7,9}\mathrm{Li} + \mathrm{Si}$ (*b*). Dashed lines show calculations using the time-dependent Schrödinger equation

framework of the coupled-channels model. In particular, the $^{9}\mathrm{Be}(d,\alpha)^{7}\mathrm{Li}$ reaction channel accompanied by the ^{5}He cluster transfer was found to give a significant contribution to the cross section in the low collision energy domain, which is confirmed by the data from previous experiments.

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

1. The formation of ion selective channels in polyethylene terephthalate (PET) film was studied under high-fluence irradiation with Xe and Bi ions with subsequent extensive exposure to soft ultraviolet radiation. The ion conductivity of PET film treated in such a manner and measured in solutions of various electrolytes was shown to increase by 5–7 orders of magnitude. The critical parameters of the process were defined. Moreover, the mechanism for the formation of ion-conducting channels in polymer within the subnanometer range was revealed [16].

2. Osmotic effects in nanoporous track membranes with the simultaneous registration of diffusion potential were studied. Transfer numbers were estimated, and the effect of the convective transport on the diffusion potential was determined.

3. Latent tracks in MgO, Al_2O_3, and $Y_3Al_5O_{12}$ were studied by molecular dynamics and high-resolution transmission electron microscopy. The morphology of tracks in these crystals was shown to be determined by the recrystallization of disordered regions surrounding ion trajectories [17].

4. Helium porosity in oxide dispersion-strengthened (ODS) steel containing Y–Ti–O nanoparticles both in crystalline and fully amorphous states was studied using low-energy helium ion implantation in combination with swift-heavy-ion irradiation [18].

5. The effect of swift-heavy-ion irradiation on the structure and properties of graphene oxide films was studied. A possibility of obtaining nanosized conductive regions of reduced graphene oxide and the formation of sp-hybridized carbon chains were demonstrated [19].

6. Methods for the formation of one- and two-layer super hydrophobic coatings on the surface of PET track membrane by electron beam dispersion of polymers in vacuum were developed. Using ultra-high molecular weight polyethylene (UHMW PE) and polytetrafluoroethylene (PTFE) as targets for dispersion, such a method allows fabrication of hydrophobic and super hydrophobic coatings with developed structures, respectively, on a membrane surface. It was shown that fabricated composite membranes could be used in membrane distillation [20].

7. A special method was developed and parameters were optimized for electroforming of chitosan glycolic acid nanofibers on the surface of track membrane. Structural, adsorption, and selective properties were investigated. Composite membranes based on glycolic acid nanofibers were found to be highly selective in aqueous solutions of Ce^{3+} and Nd^{3+} [21].

8. The impact of radiological releases from thermal power plants (i.e., Ulaanbaatar 4th Thermal Power Plant (TPP-4), Mongolia) on the environment was estimated using X-ray fluorescence spectrometry and gamma activation analysis. Coal, ashes, soil, and plant samples from the area surrounding the TPP-4 were collected and thoroughly analyzed. A number of samples were found to contain dangerously high levels of Pb, Bi, Th, and U.

9. As part of the expansion of the Laboratory building infrastructure, a setup was created for measuring the current of thermally stimulated depolarization of polymer electrets irradiated with high-energy heavy ions when heated at a constant speed.

10. Studies aimed at producing radionuclides with high specific activity for diagnostic and therapeutic applications in oncology and nuclear medicine were continued. Various methods for reactor- and accelerator-based production of terbium and platinum radioisotopes and their radiochemical separation from irradiated targets were studied. The production cross sections for the isotopes ^{149,150,151,152}Tb were for the first time experimentally measured using a stacked-foil technique in the ^{3}He energy range of 70–12 MeV. A thick target yield of ^{149}Tb was 39 MBq/(μA $\cdot$ h) or 230 MBq/μA upon saturation [22]. The ^{195m}Pt radionuclide can be produced from a double neutron capture by iridium: $^{193}\mathrm{Ir}(n,\gamma)^{194}\mathrm{Ir}(n,\gamma)^{195m}\mathrm{Ir}\beta^{-} \rightarrow {}^{195m}\mathrm{Pt}$. To characterize this method, ^{193}Ir-enriched iridium was irradiated at the IBR-2 reactor. The calculated neutron capture cross section and resonance integral for the $^{194}\mathrm{Ir}(n,\gamma)^{195m}\mathrm{Ir}$ reaction were 700 and 2500 b, respectively, while the specific activity of ^{195m}Pt amounted to $3.66 \cdot 10^{13}$ Bq/g at the end of irradiation [23]. The photonuclear method for producing platinum isotopes at MT-25 is currently under investigation. Further studies have suggested a possibility of increasing the specific activity of platinum by using the Szilard–Chalmers technique. The experimental data are analyzed.

11. The parameters of the DC-140 systems (i.e., magnetic, high-voltage, beam extraction) were measured, and the design of the multipurpose cyclotron was finalized for applied research. The main parameters of the facility were defined and agreed upon. The cyclotron will deliver beams of the accelerated ions ^{20}Ne through ^{209}Bi with energies up to 4.5 MeV/amu [24].

DEVELOPMENT OF CURRENTLY OPERATING FLNR ACCELERATOR COMPLEX

The FLNR group has pursued the U-400M cyclotron upgrade programme. The FLNR and the Mechanical and Instrumentation Engineering Corporation (Bryansk) entered into a contact under which the Bryansk Corporation agreed to disassemble and assemble the main coils. Preparations are underway for upgrading high-frequency acceleration system, replacing the vacuum system, upgrading the control system, and conducting magnetic measurements.

As part of the U-400R cyclotron upgrade programme, a design of a new experimental hall was finalized. The approval of the construction elements of building No. 131 is pending. In 2019, the following sections of the design documentation were approved: Technology Solutions, Radiation Safety, and Environmental Protection Activities.

CONSTRUCTION OF NEW AND DEVELOPMENT OF EXISTING EXPERIMENTAL SETUPS

Construction of a 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 separation of heavy nuclides produced in multinucleon transfer reactions. The following main results were obtained in 2019:

1. Additional laser equipment was installed in the Laboratory: an ionization channel based on three tunable solid-state titanium-sapphire lasers. The start-up and adjustment were completed. The laser wavelength measurement system was upgraded with a view to expanding the measuring range up to the UV region. Test experiments on selective resonance laser ionization using reference cell are planned for 2020.

2. Test experiments with the prototype of the tape station have continued at iThemba LABS (South Africa). The parameters of the facility were optimized, and its design was finalized to provide improved performance and reliability. The work on the final design of the station for GaLS has begun. A three-year grant from NRF (RSA) was received for the implementation of this part of the project.

3. To improve the efficiency and increase the transportation velocity of ions coming out of a gas cell, simulations of the S-shaped quadrupole ion guide were carried out. An ion emittance of 6.5–10 $\pi \cdot$ mm $\cdot$ mrad was reached at the separator inlet. An average kinetic energy amounted to 40 keV ($\sigma = 2.7$ eV), an average time of flight was 490 μs ($\sigma = 59\,\mu$s), and transport efficiency was $> 97.7\%$. These parameters proved to be better than those of the linear sextupole ion guide (SPIG). For example, transportation time was shown to decrease by a factor of 6. Thus, the S-shaped quadrupole ion guide was favoured over SPIG despite the simplicity of the latter.

4. Computations of fields in deflectors and electrostatic correctors of the ion beam were made. The corresponding parts of the setup were manufactured, including an output chamber and a diagnostic chamber with movable shutters, diagnostic components and a deflector. A primary beam channel, including a diagnostic system (a beam profile meter, a Faraday cup, etc.), was calculated and formed.

5. To carry out experiments on laser ionization of refractory elements near $N = 126$, possibilities for producing a high-spin $(9/2^-)$ isotope ^{191}Os (15 d) in the ^{192}Os(γ, n) reaction were explored using the MT-25 microtron. The content of the stable ^{192}Os isotope in natural osmium is 41%.

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FRANK LABORATORY OF NEUTRON PHYSICS

In 2019, the scientific programme of the Frank Laboratory of Neutron Physics was aimed at obtaining new results within the framework of four 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", 03-4-1128-2017/2019, headed by V. N. Shvetsov, Yu. N. Kopatch, E. V. Lychagin, and P. V. Sedyshev); in development of the FLNP basic facilities ("Development of the IBR-2 Facility with a Complex of Cryogenic Neutron Moderators", 04-4-1105-2011/2019, headed by A. V. Belushkin and A. V. Vinogradov); in 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).

CONDENSED MATTER PHYSICS

In 2019, the IBR-2 reactor operated for physics experiments within the framework of the FLNP User Programme for more than 100 d. 220 proposals for experiments were received from 17 different countries. The submitted proposals covered a broad spectrum of neutron research in physics (25%), materials science (35%), chemistry, geosciences, biology and applied sciences (41%). 196 proposals were selected for realization.

Structure Investigations of Novel Oxide, Intermetallic and Nanostructured Materials. The mineral magnetite (Fe_3O_4) is one of the first magnetic materials used by mankind since ancient times, and now it also finds wide application in the development of advanced technologies. It exhibits a number of unusual physical phenomena that have been the focus of extensive research for more than a century. Recently, the pressure-induced anomalous behavior of physical properties of magnetite in the vicinity of the structural phase transition at $P \sim 25-30$ GPa has been discovered. To clarify the nature of this phenomenon, the magnetic and electronic properties of magnetite were studied using neutron diffraction and ^{57}Fe synchrotron Mössbauer spectroscopy in the pressure range of 0–40 GPa and the temperature range of 10–300 K [1]. In the high-pressure phase, the formation of ferrimagnetic ordering at a temperature of $T_{NP} \sim 420$ K was observed, and its symmetry was deduced. The structural, magnetic, and electronic phase diagram of magnetite was determined in the studied range of thermodynamic parameters (Fig. 1).

Isothermal *in situ* neutron diffraction studies of Fe-xGa alloys were carried out in the temperature range from 405 to 470 °C [2]. It was found that isothermal annealing of Fe-27.2Ga and Fe-28.0Ga alloys in the $D0_3$ structural phase at temperatures from 405 to 470 °C leads to the $D0_3 \rightarrow L1_2$ phase transition. The analysis of time dependences of the intensities of fundamental and superstructure diffraction peaks revealed that the transition between the ordered structures $D0_3$ and $L1_2$ proceeds through the formation of disordered states in the sequence $D0_3 \rightarrow A2 \rightarrow A1 \rightarrow L1_2$, where $A1$ and $A2$ are disordered *fcc* and *bcc* structures (Fig. 2). A comparatively large change in the unit cell volume during the direct transition $D0_3 \rightarrow L1_2$ with a jump in the atomic volume of about 1% makes structural reorganization through a sequence of intermediate disordered states energetically favorable. During disordering

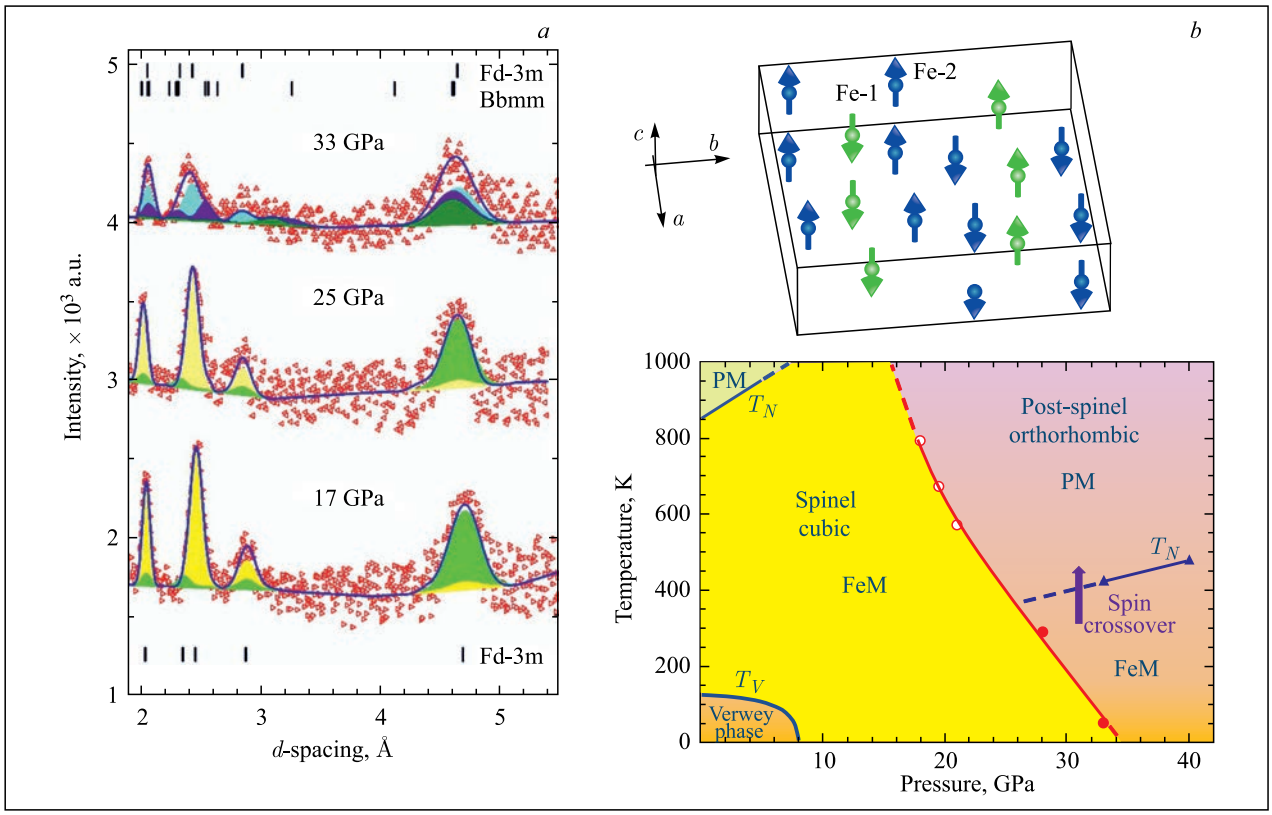

Fig. 1. *a*) Neutron diffraction patterns of magnetite measured with a diamond anvil high-pressure cell at pressures of up to 33 GPa on the DN-6 diffractometer and treated using the Rietveld method. The positions of diffraction peaks corresponding to initial cubic phase of Fd-3m symmetry and high-pressure orthorhombic phase of Bbmm symmetry are shown as vertical ticks. *b*) Magnetic structure of high-pressure orthorhombic phase of magnetite (top) and structural, magnetic, and electronic phase diagram of magnetite (bottom)

($D0_3 \rightarrow A2$) and ordering ($A1 \rightarrow L1_2$) transitions, the lattice deformation is homogeneous and very small ($\varepsilon \leqslant 0.001$), whereas during the first-order $A2 \rightarrow A1$ transition, the linear deformations are heterogeneous and large: $\varepsilon_c \approx 0.266$, $\varepsilon_{ab} \approx -0.117$. The rate of the $D0_3 \rightarrow L1_2$ transition changes significantly with changes in the annealing temperature and Ga content. With an increase in temperature from 405 up to 470 °C, the time needed for the formation of 50% of the $L1_2$ phase decreases by a factor of $\sim 4(5)$ for Fe-27.2Ga (or Fe-28.0Ga). An increase in the Ga content from 27.2 to 28.0 at. % results in an increase in the characteristic time of the transition by a factor of 1.5 to 2. The kinetics of the nucleation of the equilibrium $L1_2$ phase was analyzed within the framework of the Johnson–Mehl–Avrami–Kolmogorov (JMAK) model, which was done for the first time for these materials.

Investigation of Magnetic Fluids and Nanoparticles. Within the framework of the study of the effect of external electric and magnetic fields on the structure of magnetic fluids, a theoretical description of inhomogeneity in ferrofluids induced by an external electric field was given [3]. The obtained theoretical results show that the homogeneous distribution of dielectric particles in a dielectric carrier could become inhomogeneous under an applied electric field. The reason for the development of inhomogeneity is the polarization of particles and their interaction as dipoles. It was shown that the transition to an inhomogeneous distribution has a threshold character. The critical value of the applied field increases with increasing temperature, as well as with a decrease in the number of particles and their radius. The critical value of the applied field also increases with a decrease in the difference between the dielectric permittivity of the particles and the medium. The obtained distribution of the concentration of nanoparticles according to the proposed theoretical approach is in good agreement with the experimentally observed inhomogeneous distribution of ferrofluid particles under an external electric field.

Investigation of Carbon Nanomaterials. The investigations of a series of polystyrene/fullerene nanocomposite thin films were performed using X-ray and neutron reflectometry, as well as atomic force microscopy. Their aim was to determine the structural organization of carbon nanoparticles in nanocomposite thin films [4]. In these investigations, the structural organization of C_{70} fullerene in polystyrene thin films was studied for the first time. Both X-ray reflectometry measurements

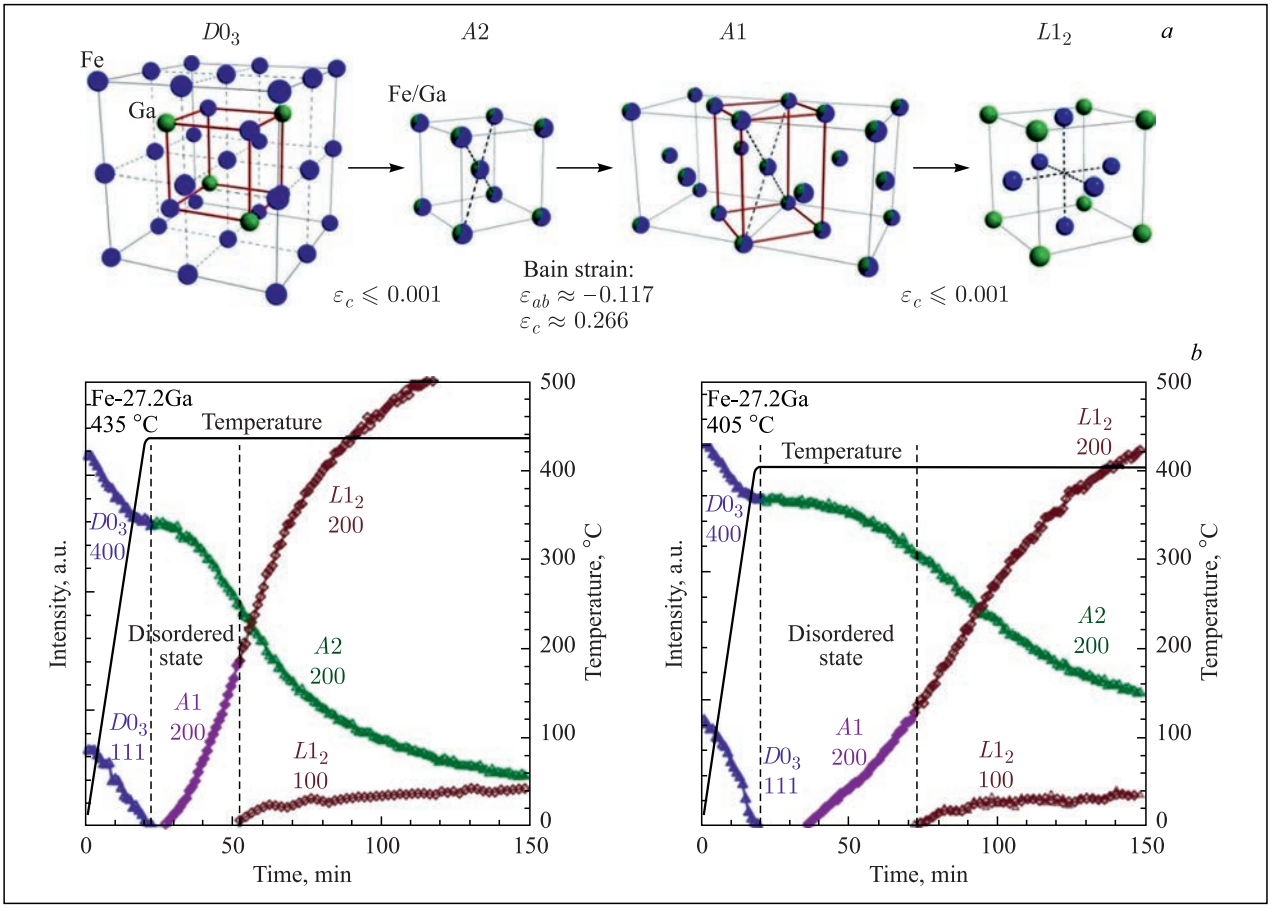

Fig. 2. *a*) Schematic diagram of $D0_3 \rightarrow A2 \rightarrow A1 \rightarrow L1_2$ structural transitions in Fe$\sim$ (27−28)Ga alloys during isothermal annealing from 405 to 470 °C. $D0_3$ and $A2$ are *bcc*-based ordered and disordered structures. $A1$ and $L1_2$ are fcc-based disordered and ordered structures. The lattice deformation is small for $D0_3 \rightarrow A2$ and $A1 \rightarrow L1_2$ transitions and large for the $A2 \rightarrow A1$ transition. *b*) Time evolution of intensities of fundamental ($D0_3, 400$ and $L1_2, 200$) and superstructure ($D0_3, 111$ and $L1_2, 100$) diffraction peaks upon rapid heating and subsequent isothermal annealing at 405, 435 °C (left scale). The disappearance of the $(D0_3, 111)$ peak corresponds to the $D0_3 \rightarrow A2$ transition, the appearance of the $(L1_2, 100)$ peak corresponds to the $A1 \rightarrow L1_2$ transition. The vertical lines mark the time range in which the structure is in a disordered state. The origin of the time scale corresponds to the beginning of the temperature rise

at room temperature and variable-temperature neutron reflectometry studies using the GRAINS reflectometer were performed. It was found that for a relative concentration of fullerene of 5 wt. %, a dense near-surface layer on a silicon substrate can be well resolved. It was shown that C_{70} fullerenes form a less dense near-surface layer on the substrate than C_{60} fullerenes, as a result of deeper penetration into polystyrene. Temperature studies by neutron reflectometry made it possible to determine the temperature dependence of film thickness and to evaluate the glass transition temperature of the system under study, as well as to trace the change in the structural organization of nanoparticles.

Investigation of Layered Nanostructures and Electrochemical Interfaces. Within the framework of the study of conditions for the formation and growth of surface structures on electrodes in lithium-ion batteries, the effect of electrolyte concentration on the formation of the solid electrolyte interphase (SEI) and subsequent electrochemical deposition of lithium on a planar metal (copper) electrode was studied using the GRAINS reflectometer in the *in-situ* mode [5]. Specular neutron reflectometry experiments on special electrochemical cells with model solid electrode/liquid electrolyte interfaces were carried out in addition to the electrochemical characterization (measurements of impedance and Coulomb efficiency, optical control). The two-stage character of deposition was confirmed, when, first, a dense near-surface layer consisting of the products of chemical interaction of lithium with the solvent is deposited on the surface of the electrode, and then a transition layer is formed, which corresponds to the beginning of the development of large microscopic inhomogeneities (needle-like structures). In the case of concentrated electrolytes, strong suppression of the growth of the near-surface layer is observed, which is similar to the previously studied effect of non-electroactive additives in the electrolyte, which results in a change in the morphology of needle-like structures.

Using *ex-situ* SANS experiments, the filling of the pores of a carbon cathode with the final product of the electrochemical reaction (lithium peroxide) during the discharge of lithium–oxygen cells was studied [6]. This type of batteries has a significantly higher capacity compared to the widely used lithium-ion batteries. However, their application meets a number of difficulties associated with the blocking of the diffusion of oxygen in the electrolyte because of the clogging of the pores with lithium peroxide. The SANS data made it possible to link the changes in the cathode at the nanometer scale with the electrochemical characteristics of the cells and helped to clarify the mechanisms that limit their capacity. It was shown that the oxygen transport pathways in the wetted cathode are blocked both by the passivation of the inner surface of the pores inside the carbon grains and by the growth of supramolecular structures (mesocrystals) in the intergrain space, and the nature of these phenomena significantly depends on the type of the organic solvent in the electrolyte, as well as the content of residual water molecules in it.

Investigations of Biological Nanosystems, Lipid Membranes and Lipid Complexes. Structural characteristics of nanocomposite series consisting of iron oxide nanoparticles embedded in the regular pores of amorphous silica matrix (SBA-15) were studied using small-angle neutron scattering (Fig. 3). Basing on the experimental data, a fundamental model describing the neutron scattering intensity distribution was proposed by assuming general composite structural features. The application of the model to SANS data confirmed the presence of iron oxide nanoparticles in the matrices under study, providing additional information on their shape, concentration, and size distribution [7].

Atomic and Molecular Dynamics. The vibrational spectra of Trans-1,3-cyclohexanediol, Cis-1,3-cyclohexanediol, Trans-1,2-cyclohexanediol, and Cis-1,2-cyclohexanediol compounds with a general chemical formula $C_6H_{12}O_2$ were studied using inelastic incoherent neutron scattering on the NERA spectrometer.

The presence of a plastic crystal phase was found only in *trans* isomers. An additional phonon density of states in the disordered glass phase was considered, and a comparison with $G(\nu)$ of rotational I-ordered crystal phases in these conformers was performed. At the temperature of liquid helium, the vibrational motions of protons involved in the formation of hydrogen bonds between molecules and molecular backbones were presumably observed. A comparison of the experimental data with the results of BDS and FT-IR studies and

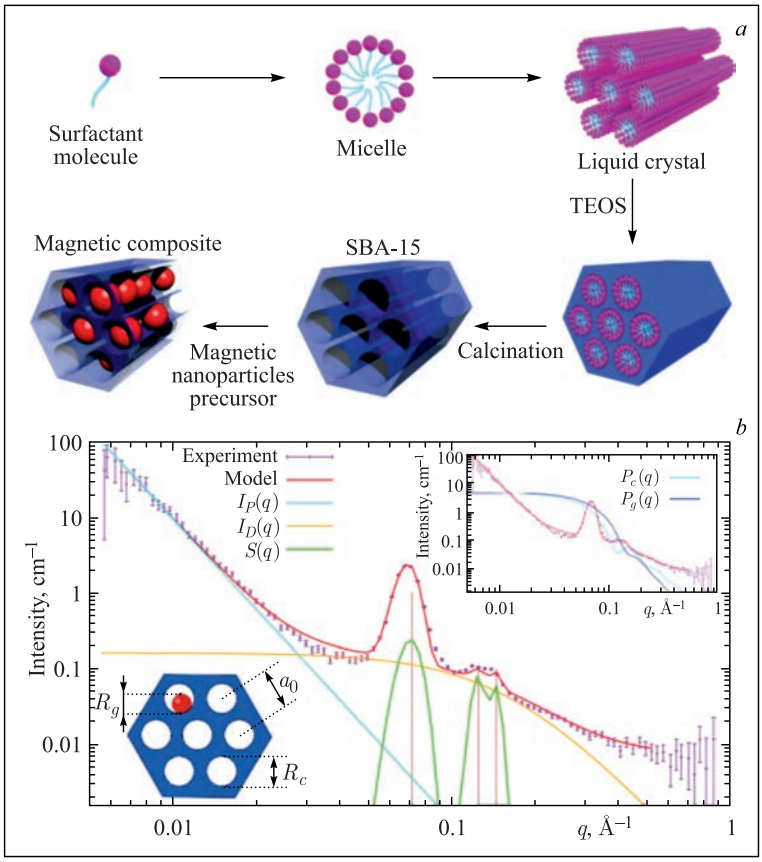

Fig. 3. *a*) A hierarchical model of the structure organization of magnetic nanoparticles through micellar organization, liquid crystal, process of calcination and embedding. *b*) Small-angle scattering curves with diffraction peaks, fitting functions, and model structural diagram corresponding to the obtained experimental data

the results of studies for analogous compounds in the glassy state of the rotational phase and crystal phases is in progress. We expect to determine the effect of the $\pi-\pi$ interaction between neighboring molecules on the vibrational dynamics, as well as to analyze the effects associated with O–H . . . O hydrogen bonds.

Applied Research. The first neutron experiments to study the evolution of the lattice deformation of AZ31 magnesium alloy at a room temperature as a function of the applied load, as well as experiments to study the dependences of macroscopic deformation on the applied stress at room and elevated temperatures (150 °C) were performed at the FSD (Fourier Stress Diffractometer). Cylindrical specimens were cut from a workpiece in longitudinal (RD) and transverse (TD) rolling directions of the initial material. Magnesium alloys belong to the group of lightweight structural materials and have unique properties such as high specific strength (yield strength-to-density ratio), excellent damping capacity, and high thermal conductivity. These properties predetermine their wide industrial application, for example, in the automotive and aerospace industries. The main limitation for a wider use of magnesium alloys is their low ductility and poor formability at a room temperature. The forming processes usually require different deformation paths, so it is very important to study the mechanical behavior of magnesium alloys, in which the deformation path changes at a room temperature.

For the samples under study, different behavior of macroscopic deformation was observed at room and elevated temperatures. This behavior, apparently, results from the fact that plastic deformation occurs through the glide of dislocations and formation of twins, which are activated at elevated temperatures. During the neutron experiment, the samples of AZ31 magnesium alloy were subjected to uniaxial compression followed by uniaxial tension. Diffraction spectra were recorded simultaneously by two 90°-detectors for two directions of the scattering vector: parallel to the applied load (detector AL) and perpendicular to the applied load (detector AR). In addition, for the TD sample, the experiment was carried out for two orientations of the sample: the initial one ("Orientation 1"), and after the sample was rotated by 90° around the axial axis ("Orientation 2"). The experimental results showed that the diffraction patterns exhibit significant changes in the intensity of some reflections under loading, caused by the twinning process. So, in the first part of the deformation path (compression), the twinning process was observed, which resulted in the appearance of (002) reflections, representing the orientation of extension twins. With a change in the deformation path to tension, the (002) reflection almost completely disappears, which is associated with the activation of the opposite process — detwinning. The lattice parameters a and c and microdeformation estimated from the broadening of diffraction peaks exhibit a similar rather complex deformation behavior for the specimens cut in the RD and TD directions.

The internal structural organization and phase composition of a fragment of the Chelyabinsk meteorite were studied using neutron diffraction, tomography methods, optical microscopy, and Raman spectroscopy [8]. The bulk mineral composition of the meteorite and spatial distribution of different components were determined. In addition to the previously found phases of olivine, orthopyroxene, plagioclase, and troilite, the obtained data of optical microscopy and neutron diffraction provide evidence of the presence of the kamacite (FeNi) phase in the studied meteorite fragment. A heterogeneous distribution of iron in the olivine and orthopyroxene phases was observed, and morphological calculations were made to analyze the spatial arrangement of metal components.

Instrument Development. In cooperation with the Institute of Nuclear Physics of the Ministry of Energy of the Republic of Kazakhstan (Almaty, Kazakhstan), the commissioning of a new radiography and tomography facility at the WWR-K steady-state research nuclear reactor was completed. The first experiments were performed using the neutron tomography method.

MULTIMODAL PLATFORM FOR RAMAN AND NONLINEAR OPTICAL MICROSCOPY AND MICROSPECTROSCOPY FOR CONDENSED MATTER STUDIES

The main goal of the theme is the development of the modern methods for highly sensitive detection (single units of molecules) and chemically selective, contrast visualization of organic molecules. The method will be based on spectroscopy of Coherent Anti-Stokes Raman Scattering (CARS) on molecules adsorbed on plasmonic nanostructured substrates. This method will provide 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 a study of photo- and upconversion luminescence based on promising core-shell nanostructures. In recent years, core-shell nanoparticles are at the forefront of hot research topics and offer a wide range of applications in biomedicine, optics, environmental science, materials, etc., due to their excellent properties such as versatility, tunability, and stability. The core-shell nanomaterials

containing noble metals are plasmonic nanomaterials, and therefore they can be employed for contrast imaging, various biomedical applications, etc.

The activities in 2019 were aimed at achieving the following major results.

SERS vs SECARS Spectra and Intensity Maps of Light Scattered from Organic Reporter Molecules. Realization of Contrast and Selective Imaging Method by Means of SECARS. Presently, the investigations around SERS are devoted, among other topics, to the clarification of physical mechanisms of laser light interaction with SERS-active surfaces and, in particular, of Surface-Enhanced Coherent Anti-Stokes Raman Scattering (SECARS), as well as to possible applications of SERS in biology, biochemistry, medicine, pharmacy, etc. In 2019, the study was aimed at revealing the possibilities of detecting reproducible SERS and SECARS signals from thionitrobenzonic (TNB) molecules adsorbed at the Au-NPs/CeO_2 SERS-active surface without destruction of the surface itself or the conjugates.

Thus, the intensity limits for CW (Continuous Wave) 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/μm^2, which corresponds to a peak intensity of 1.0 mW/μm^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.

The high chemical imaging contrast demonstrated by the recorded SECARS microimages of Au-NPs/CeO_2/Al/Al_2O_3 sample surfaces is promising in terms of reaching high SECARS detectability of the probed reporter molecules, as well as investigating the mechanisms of SECARS signal generation in further experiments.

Highly Sensitive Detection of Raman Spectra of Organic Molecules (Single Units) Using Dendritic Ag Nanostructures. The development of modern biosensing techniques to overcome the problem of reliable detection, identification, and structural study of diverse bioorganic molecules at ultralow concentrations is still an urgent objective of specialists in many spheres, including medicine, biology, forensics, ecology, pharmaceutics, and so on. In 2019, the so-called Ag corrosive deposition on a macroporous silicon (macro-PSi) template was used to grow 3D silver dendritic structure, which demonstrated an unprecedented sensitivity in SERS spectroscopy. Then, the minimum concentration of the 4-MBA solution was found, at which its molecules are still detected after adsorption on the silvered macro-PS.

To overcome the limitation of the 10^{-16} M lactoferrin concentration, at which it can be detected, the protection with graphene that was first successfully tested on R6G molecules was used. Despite the fact that the SERS spectrum intensity was relatively low, most of lactoferrin Raman bands were present there: 1002 cm^{-1} (Phe), 1290 cm^{-1} (Amide III), 1340 cm^{-1} (Trp), 1440 cm^{-1} (CH_2), 1605 cm^{-1} (Tyr), and 1642 cm^{-1} (Amide I). Thus, the ability to measure the SERS spectra of the human lactoferrin molecules adsorbed on the silvered PSi from the 10^{-6}–10^{-18} M water solutions was demonstrated.

Synthesis of Core-Shell Nanostructures $NaYF_4$: Yb^{3+}, Er^{3+}, Tm^{3+}@SiO_2 and Test on Bioimaging. The results on synthesis of $NaYF_4$: Yb,Er@SiO_2@Ag core-shell nanoparticles (CSNPs) for plasmon-enhanced upconversion luminescence (UCL) and preliminary bioimaging tests with neutrophil cells are highlighted.

To enhance the luminescence properties of the synthesized CSNPs, it was proposed to directly embed silver nanoparticles into the SiO_2 shell in parallel with its formation, which eliminates the multistage synthesis. A colloidal solution of AgNPs was added to a mixture of hexanecyclohexane-isopropyl alcohol followed by the formation of a SiO_2 shell. As a result of AgNPs embedding into the core-shell structure, the UCL yield was enhanced by a factor of 85 and 29 for structures with a shell thickness of 5 and 14 nm, respectively.

The first bioimaging test of synthesized core-shell nanoparticles as intracellular phosphors showed the possibility of obtaining contrast bioimages using neutrophil cells as an example.

Continuation of the Development of "Scan-CARS" Modality Option Integrated into the "NanoSP" Program of the Microspectrometer. In 2019, the activities to complete the development of "scan-CARS" modality started in 2018 were continued. During 2019, this software product was tested with various samples. This modality makes the CARS microspectrometer an advanced system for multicolor excitation experiments, such as scanning CARS and others.

NEUTRON NUCLEAR PHYSICS

In 2019, at FLNP the scientific activity in the field of neutron nuclear physics was carried out in the following traditional directions: investigations of time and space parity violation processes in neutron-nuclear interactions; studies of the fission process; experimental and theoretical investigations of fundamental properties

of the neutron; gamma-spectroscopy of neutron-nuclear interactions; atomic nuclear structure, obtaining of new data for reactor applications and nuclear astrophysics; experiments with ultracold neutrons, applied research using neutron activation analysis (NAA). The scientific programme to study the inelastic scattering of fast neutrons (TANGRA project) is being successfully implemented. A number of experiments in the field of fundamental physics and ultracold neutron physics were performed at the facilities of nuclear research centres in Germany, China, France, and Switzerland.

Experimental and Methodological Investigations. ***Investigations of Neutron-Charged-Particle Reactions.*** 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 results of experiments on measuring the cross section of ^{56,54}Fe$(n,\alpha)^{53,51}$Cr [9] reactions were obtained. The cross sections were measured in the neutron energy range of 5–11 MeV using three accelerator-driven neutron sources, a twin Frisch-grid ionization chamber, and highly enriched ^{56}Fe and ^{54}Fe samples. Both measured cross sections show the same structure ("shoulder" in the neutron energy region of 8–11 MeV), which may be determined by the structure of the levels of daughter nuclei. These results are useful for obtaining excitation functions of ^{56,54}Fe$(n,\alpha)^{53,51}$Cr and for determining the deviations between the available experimental data and estimates.

In October–November 2019, measurements were performed for ^{14}N$(n,\alpha)^{11}$B at $E_n = 4.25-6.0$ MeV, ^{58}Ni(n,α) at 4.75, 5.0, 5.25, 5.5 MeV, and ^{60,61}Ni(n,α) at 5.0, 5.5 MeV. The data treatment is in progress.

Fission Physics Research. A position-sensitive twin ionization chamber for studying prompt fission neutrons with 32 scintillation detectors was developed and tested (Fig. 4). The setup opens up new prospects for studies of resonance-neutron-induced fission and thermal neutron subbarrier fission of such nuclei as ^{232}Th, ^{237}Np, and ^{238}U.

Activities within the Framework of TANGRA Project. A multidetector system "Romasha" includes 18 BGO detectors located around a target-sample at a distance of 750 mm from it at equal angular intervals, and one high-resolution germanium detector (HPGe). The neutron source is an ING-27 neutron generator operating in a continuous mode, with a built-in position-sensitive silicon alpha-particle detector. Neutrons are generated in the $D + T \rightarrow n + \alpha$ reaction. The maximum flux of monoenergetic neutrons with an energy of 14.1 MeV from the generator is $5 \cdot 10^7$ s^{-1}. The built-in alpha-particle detector allows implementing the tagged neutron method (TNM), when each detected alpha particle "marks" the direction of the associated neutron. TNM, in turn, makes it possible to realize the coincidence of events in the detector with the alpha-particle signal and suppress the background from various events that accompany the propagation of high-energy neutrons.

In 2019, systematic studies of the angular distributions of the yield and cross sections of gamma rays from the reactions of inelastic interaction of neutrons with various nuclei were continued. Measurements of the angular distributions of gamma rays with energies of 847 and 1238 keV from the ^{56}Fe(n,n') and ^{56}Fe$(n,2n')$ reactions were carried out. Similar measurements were performed for gamma rays with energies of 935.5, 1333.7, 1434.1, and 1530.7 keV from the ^{52}Cr(n,n') reaction [10]. In addition, for 12 gamma transitions from this reaction, cross sections were calculated and compared with the known literature data and calculation results using the TALYS 1.9 code. The angular distributions of gamma rays with energies of 844, 1015, 1809, 2212, and 3004 keV from the ^{27}Al(n,n') and ^{27}Al(n,d) reactions were measured as well [11]. For a ^{24}Mg target, the angular distributions were measured for gamma rays with energies of 1368.6, 3866.1, 4237.9, 2754, 4642.2, and 350.7 keV. For nine characteristic gamma lines from the ^{24}Mg$(n,\alpha)^{21}$Ne, ^{24}Mg$(n,p)^{24}$Na, ^{24}Mg$(n,d)^{20}$Na, and ^{24}Mg(n,n') reactions, cross sections were determined and compared with the known data and calculations by TALYS. Systematic measurements of the cross sections of gamma-ray production can be used to supplement the available nuclear databases, as well as in geological exploration for rapid analysis of samples.

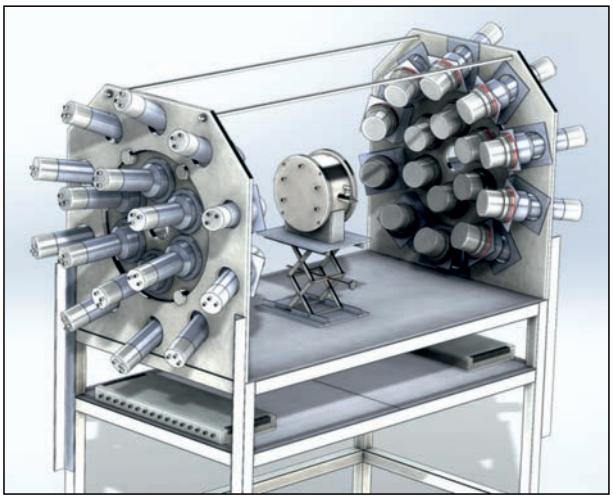

Fig. 4. New experimental setup comprising 32 liquid scintillators and a twin ionization chamber

Investigation of the $(n_{th}, 2\gamma)$ Reaction for Simultaneous Determination of Nuclear Physics Parameters of Gamma Decay. The empirical method for analyzing the cascade gamma decay of the neutron resonance in the compound nucleus was improved. The empirical method developed at JINR for analyzing the experimental intensities of two-quantum cascades makes it possible to simultaneously determine (from their approximation with percentage accuracy) the density of nuclear levels, ρ, and the partial widths, Γ, of the gamma-ray emission. In 2019, the cascade gamma decay of neutron resonances of ^{153}Sm [12] and ^{56}Mn [13] compound nuclei was investigated, experiments with which were carried out by teams of physicists from Hanoi and Belgrade (at reactors in Dalat (Vietnam) and Garching (Germany)). To date, the measured cascades of two successively emitted gamma rays have been analyzed in the capture of thermal neutrons by 44 nuclei in the mass range of $28 < A < 200$.

Activities within the n_TOF Collaboration, CERN. Precision measurements of the ^{235}U fission cross section for neutrons with energies from thermal to 170 keV [14], which are important for studying the dynamics of fast neutron reactors, were performed at the neutron time-of-flight (nTOF) CERN neutron source. To solve the key problems of nucleosynthesis, the cross sections of the ^{70,73}Ge(n, γ) [15, 16] and ^{155,157}Gd(n, α) [17] reactions were measured.

Temperature Dependence of the Probability of "Small Heating" and Total Losses of UCNs on the Surface of Hydrogen-Free Fomblin Oils of Different Molecular Weights. An experiment was conducted to measure the temperature dependence of the probability of small heating and total losses of ultracold neutrons (UCNs) on the surface of hydrogen-free Fomblin oils with various molecular weights, M_W (2800, 3300, 6500 amu) in the temperature range of 100–300 K. The probability of small heating decreases sharply with increasing molecular weight and decreasing temperature. The probability of the total loss decreases slightly with decreasing temperature in the entire measured range and takes the minimum value at $M_W = 3300$ amu. Since this oil provides a homogeneous surface with minimal probabilities of small heating and total losses of UCNs at a temperature of 270–250 K, it is the preferred candidate for experiments on measuring the neutron lifetime. The measurement was carried out at the Institut Laue–Langevin, France, using a Big Gravitational Spectrometer manufactured at FLNP. The performed measurements provide the necessary data for introducing corrections into the experiments on measuring the neutron lifetime and searching for new oil for neutron traps, which makes it possible to conduct experiments free from systematic corrections for small heating of UCNs, as well as free from the problem of instability of coating of UCN trap surfaces with Fomblin oils.

Neutron Diffraction by a Moving Diffraction Grating and the Possibility of Increasing the Efficiency of Energy Transfer. The study of nonstationary neutron diffraction by a moving diffraction grating was continued [18]. It was shown that by choosing the depth of the grating profile it is possible to significantly change the ratio of wave intensities of different diffraction orders, thereby changing the amount of energy transferred to the neutron. The possibility of increasing the intensity of higher orders allows one to think about using a time lens on a moving grating with second- and third-order diffraction to create an intense source of ultracold neutrons on a pulsed neutron source. The idea of the source with a time lens was expressed by A. I. Frank and R. Gähler as early as 1996.

Diffraction of Cold Neutrons by Surface Ultrasonic Waves. The study of nonstationary neutron diffraction by surface acoustic waves (SAW) was continued. A new theoretical approach was developed to describe the diffraction of neutron waves by travelling and standing surface acoustic waves. A systematic analysis of previously obtained experimental data on the diffraction of cold neurons by SAW was carried out. The experimental data are in good agreement with the theoretical predictions (Fig. 5).

Applied Research. ***Analytical Investigations on Charged Particle Beams of the EG-5 Accelerator.*** The main areas of scientific activity of the "EG-5 Accelerator" group were studies of the elemental composition and electrical properties of materials for power engineering, medicine, and electronics. In 2019, the EG-5 electrostatic accelerator operated for physics experiments for 500 h. The main research area is the elemental analysis of the surface layers of solids using nuclear-physical analytical techniques, including the Rutherford backscattering (RBS) and elastic recoil detection (ERD). The experiments were carried out in collaboration with a number of Russian and foreign research institutes, including: Maria Curie-Skłodowska University (Lublin, Poland), Institute of Electrical Engineering of the Slovak Academy of Sciences (Bratislava, Slovak Republic), Donetsk A. A. Galkin Institute for Physics and Engineering of the National Academy of Sciences of Ukraine (Ukraine), Vinča Institute of Nuclear Sciences, University of Belgrade (Belgrade, Serbia). In addition, on charged particle beams of the EG-5 accelerator, specialists from DLNP conducted experiments to study the characteristics of matrix gallium–arsenide detectors.

Analytical Investigations at the IBR-2 Reactor. ***Studies Using High-Resolution Gamma Spectrometry.*** Work was carried out to develop and construct a facility for analyzing the composition of samples using prompt gamma rays on IBR-2 beamline 11b. Test experiments were conducted to determine the hydrogen

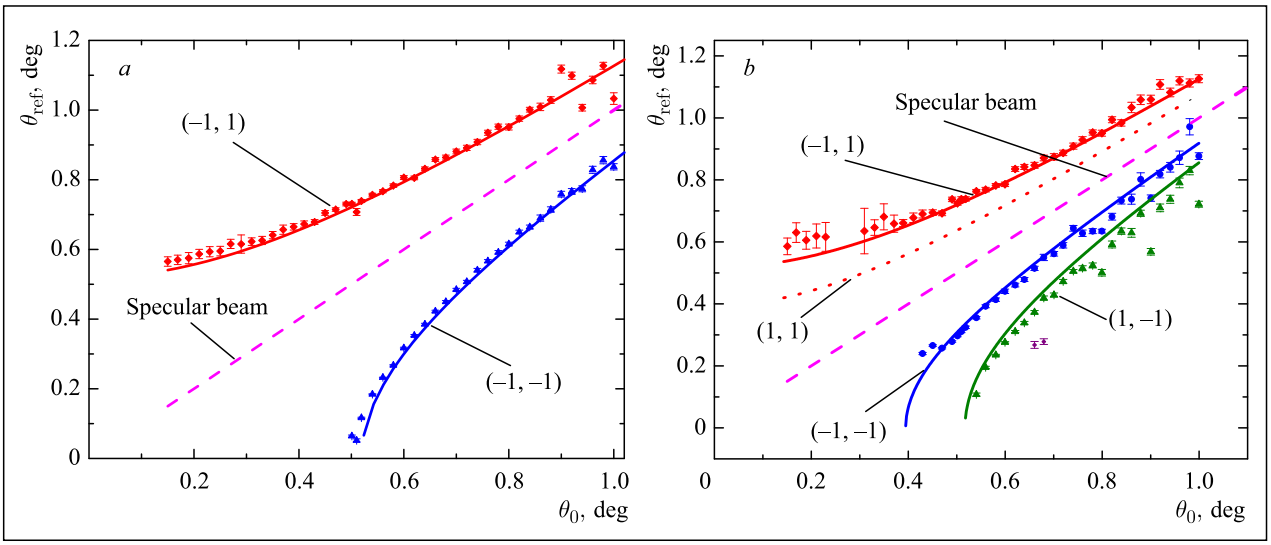

Fig. 5. Angular distributions of diffracted beams as a function of the glancing angle of the incident beam. Solid curves — calculation, points — experiment. *a*) Traveling wave, *b*) standing wave. The index of the direction of propagation of the ultrasonic wave s ($+1$ and -1 — along and opposite the velocity of neutrons) and the order of reflection n: (s, n) are indicated in brackets

content in nanodiamonds and the content of various elements in archaeological samples.

Activities of the Sector of Neutron Activation Analysis and Applied Research. In 2019, the REGATA facility was used for multi-element instrumental neutron activation analysis of about 2000 environmental samples (vegetation, soil, air filters), a number of technological, biological, and archaeological samples, as well as of samples of extraterrestrial origin within the framework of programmes and grants of the JINR Member States and Protocols on scientific and technical cooperation with the JINR Non-Member States. Investigations of test samples were conducted for an interlaboratory comparison of the results under the International Atomic Energy Agency (IAEA) programme. The elemental analysis of $\sim$ 1000 samples was performed using a Thermo Scientific iCE 3500 Atomic Absorption Spectrometer.

IBR-2 PULSED REACTOR AND COMPLEX OF CRYOGENIC NEUTRON MODERATORS

In 2019, the IBR-2 research nuclear facility was operated in a nominal on-power mode under Rostekhnadzor license valid until 30.09.2022. Statistical data on the IBR-2 operation are presented in the table.

In 2019, the activities on the construction and development of the complex of cryogenic moderators at the IBR-2 facility were carried out within the framework of theme 1105 and the work schedule for 2019 of group 2 of the FLNP Mechanical and Technological Department.

In accordance with the schedule of operation of the IBR-2 facility, the CM-202 moderator operated in a cryogenic mode in cycles III and VIII. The total time of its operation for physics experiments was 521 h.

For technical reasons and due to the need for additional research and work, the installation of CM-201 in the working position and its trial operation for physics experiments is scheduled for autumn 2020.

No. of cycle	Period	Moderator type	Reactor operation for physics experiments, h
1	14.01–27.01	Water	300
2	04.02–22.02	Water	415
3	11.03–22.03	Cryogenic	258
4	08.04–26.04	Water	433
5	13.05–28.05	Water	339
6	—	—	Cancelled
7	14.10–28.10	Water	336
8	11.11–22.11	Cryogenic	263
9	02.12–16.12	Water	336
		Total:	2680

NOVEL DEVELOPMENT AND CONSTRUCTION OF EQUIPMENT FOR THE SPECTROMETER COMPLEX OF THE IBR-2 FACILITY

Work continued on the project "Development of PTH Sample Environment System for the DN-12 Diffractometer at the IBR-2 Facility" aimed at developing a horizontal-vertical cryostat with a superconducting magnet and a variable temperature in the range of 4–300 K. The project is carried out in collaboration with the National Institute for Research and Development in Electrical Engineering ICPE-CA (Bucharest, Romania). In 2019, at ICPE-CA, in accordance with the requirements specification, the fabrication technique was upgraded and the HTSC-tape-based magnet was produced. In October, the magnet was delivered to JINR and installed in the cryostat. During the first tests, the achieved magnetic field strength of the superconducting magnet was 5 T. Characteristic turned out to be strictly linear, which indicates that there are no signs of degradation of the high-temperature superconductor (HTSC) tape. It should be noted that the magnet will be an autonomous and mobile device, which will require only power-supply sources.

EVENTS

1. The 32nd regular Task Force Meeting of the ICP Vegetation was held in Romania (Valahia University, Targoviste) on 18–21 February. At the meeting, there were 10 staff members of the Sector of Neutron Activation Analysis and Applied Research (FLNP JINR) representing the Russian Federation, Belarus, Bulgaria, the Czech Republic, Georgia, Moldova, Romania, and Tajikistan, as well as one staff member of the Department of External Communications and Distributed Informational Systems (LIT JINR). Such a composition of the delegation reflects cooperation of FLNP and LIT within the framework of the UN Programme for Long-Range Transboundary Air Pollution in Europe, and now in Asia as well.

2. FLNP Chief Scientific Adviser, Head of the Department of Neutron Diffraction of the MSU Faculty of Physics, Corresponding Member of RAS, Professor V. L. Aksenov was awarded the Order of Alexander Nevsky. The awarding ceremony took place in Moscow at the A. P. Alexandrov Scientists' Club of NRC "Kurchatov Institute" on 16 April.

3. On 28 May, a jubilee seminar dedicated to the 90th anniversary of Yu. A. Aleksandrov was held at the Museum of History of Science and Technology of JINR. The seminar was devoted to the major achievements of the scientist in the period from 1954 to 2019.

4. The annual International Seminar on Interaction of Neutrons with Nuclei ISINN-27 was held in Dubna on 10–14 June. The organizers of ISINN-27 were the Frank Laboratory of Neutron Physics of JINR, the State Key Laboratory of Intense Pulsed Radiation Simulation and Effect (SKLIPRSE) of the Northwest Institute of Nuclear Technology (NINT, China), the Shaanxi Key Laboratory of Advanced Nuclear Energy and Technology (SKLANT) of the Xi'an Jiaotong University (XJTU, China), the China Institute of Atomic Energy (CIAE), the China Spallation Neutron Source of the Institute of High Energy Physics, CAS (CSNS, IHEP).

5. The traditional European Conference on Neutron Scattering ECNS-2019 was held in St. Petersburg, Russia, from 30 June to 5 July. The organizers of the Conference were the European Neutron Scattering Association (ENSA) and the Russian National Research Center "Kurchatov Institute" (NRC KI). They placed particular emphasis on topics related to the development of the research programme for two high-flux neutron sources currently being constructed in Europe: the European Spallation Source ESS (Lund, Sweden) and the stationary reactor PIK (Gatchina, Russia).

During the Conference, the Medal of the Russian Neutron Scattering Society for "Outstanding Achievements in the Field of Neutron Scattering" was awarded to FLNP Chief Researcher, Prof., Doctor of Physics and Mathematics A. M. Balagurov.

6. On 6 November, a monument to I. M. Frank, Academician of the USSR Academy of Sciences, Nobel Prize winner in Physics, organizer and long-standing head of the Laboratory of Neutron Physics of JINR, was inaugurated in Dubna.

7. The International Workshop on the use of nuclear physics methods for cultural heritage research was held at the JINR Scientists' Club on 16–17 December.

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LABORATORY OF INFORMATION TECHNOLOGIES

In 2019, the studies on two topics of first priority, namely, "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 framework of the direction "Networks, Computing, Computational Physics". The LIT staff participated in research on 26 topics of the JINR Topical Plan within cooperation with 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 JINR and its Member States on the basis of the JINR Multifunctional Information and Computing Complex (MICC).

In 2019, employees of the Laboratory of Information Technologies published 220 scientific papers in refereed scientific journals and presented 135 reports at international and Russian conferences.

INFORMATION AND COMPUTING INFRASTRUCTURE OF JINR

In 2019, one of the major directions of the LIT activities was the development of the Multifunctional Information and Computing Complex (MICC) of JINR [1]. It comprises the following: the development and improvement of the JINR telecommunication and network infrastructure; the modernization of the MICC engineering infrastructure; the modernization, development and creation of new components of the MICC for data storage, processing and analysis, namely, the development of the IT infrastructure of the NICA megascience project, the extension of capacity and volume of data storage systems of the grid components, i.e., Tier-1 and Tier-2, the extension of the cloud component and creation of an integrated cloud environment for JINR experiments, the enlargement of the HybriLIT heterogeneous computing platform, including the "Govorun" supercomputer.

JINR Telecommunication Channels. In 2019, a significant modernization of the JINR network infrastructure was carried out.

The project of increasing the bandwidth of the Moscow–JINR telecommunication channel from 100 to 3×100 Gbit/s was implemented; the bandwidth of the backbone of the Institute local area network was increased to 2×100 Gbit/s, and a distributed computing cluster network between the DLNP and VBLHEP sites with a capacity of 400 Gbit/s with double redundancy to increase the reliability of the backbone network was built.

At present, the external distributed network of JINR (Fig. 1) is represented by the JINR–CERN direct channel and a backup channel passing through MMTS-9 in Moscow and Amsterdam, ensuring the operation of LHCOPN (JINR–CERN) for the connection between Tier-0 (CERN) and Tier-1 (JINR) and the LHCONE external superimposed network designed for the JINR Tier-2 center, as well as by direct channels for the connection with the collaboration of RUHEP research centers and networks RUNNet, RETN using the RU-VRF technology.

The distribution of incoming and outgoing traffics over the JINR subdivisions in 2019 (exceeding 25 TB by the incoming traffic) is shown in the table.

In 2019, the overall incoming traffic of JINR, including the general-purpose servers, Tier-1, Tier-2 and the computing complex, amounted to about 56 PB. The traffic with scientific and educational networks accounting for 96.4% of the total is the major one.

JINR Local Area Network (LAN). In 2019, the work on the development and improvement of the network components of the JINR IT infrastructure was continued. The Cisco ACI factory based on the equipment Cisco Nexus 9504 and Cisco Nexus C9336C-FX2, allowing one to connect the MICC components

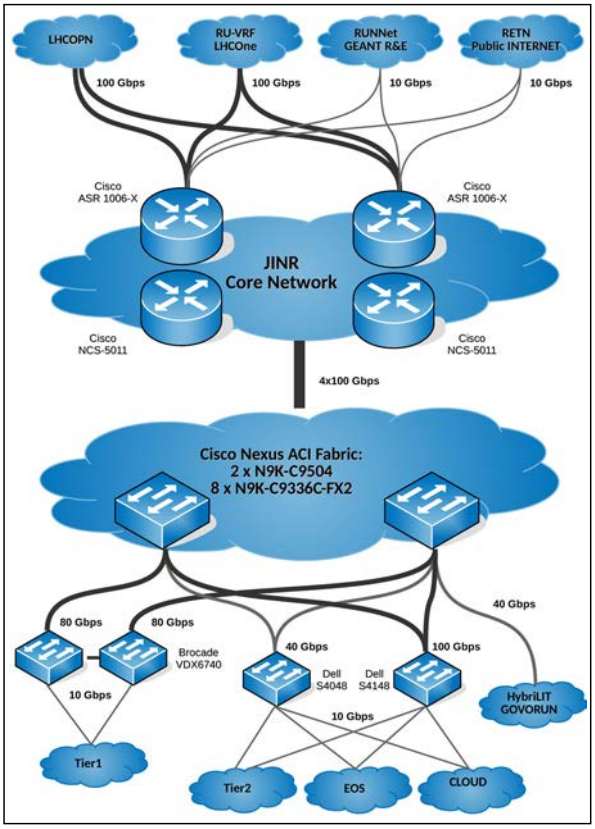

Fig. 1. Scheme of the external JINR distributed network

at speeds of up to 100 Gbit/s and more, was put into operation. To ensure the necessary bandwidth and the possibility of redundancy, the factory is connected to the JINR backbone network by 4 channels of 100 Gbit/s.

The Tier-1 network was transferred to the ACI factory and has the overall connection of 160 Gbit/s (4 channels of 40 Gbit/s). The EOS distributed file system, the HybriLIT heterogeneous platform, the "Govorun" supercomputer, WEB services, Tier-2 and the networks of "Cloud computing" were connected to the ACI factory.

The modernization of the network cluster of virtual services of the JINR network operations center (NOC) was in progress. The NOC virtualization cluster was created using the Proxmox open source software under the license with the open source code GNU AGPL v3, which enables the free use of the code in creating cluster solutions. The cluster serves virtual machines of network services of the JINR network, such as DNS, DHCP, RELAYs, different network databases, as well as a number of LIT and UC services.

The functionality of the system for the network traffic analysis was expanded with the help of new scripts, which 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, more than 150 services and conditions is monitored in the network monitoring system.

Subdivision	Incoming, TB	Outgoing, TB
VBLHEP	414.4	689
LIT	414.3	182
DLNP	369.6	500.5
Dubna State University	212.8	110.5
FLNP	173.6	266.5
FLNR	156.8	175.5
Hotel and Restaurant Complex	145.6	71.5
JINR Directorate	100.8	266.5
Remote access node	95.2	32.5
BLTP	61.6	58.5
University Centre	44.8	26
Medical-Sanitary Unit 9	39.2	13
Social Infrastructure Management Office	39.2	32.5
Telephone Communications Site (TCS)	28	13
LRB	28	19.5

Several types of notifications, namely, e-mail messages and SMS alerts, are used.

JINR LAN comprises 8169 network elements and 15 505 IP-addresses, 7512 network users, 2465 users of the mail.jinr.ru service, 1531 users of electronic libraries, and 358 users of the remote access service.

MICC Engineering Infrastructure. In 2019, the work on the improvement of the MICC engineering infrastructure, designed to ensure the reliable, uninterrupted and fault-tolerant operation of the information and computing system and the network infrastructure, was in progress. Using the integrated approach to building the MICC engineering infrastructure allowed one to elaborate algorithms of the equipment operation and interaction of separate systems both in a normal operation mode and in emergencies, which ensured the uninterrupted performance regardless of external factors. The system of uninterruptible power supplies provides guaranteed power to connected consumers, the automatic launch of diesel-generator units (DGU), the automatic load transfer from the main external power supply network to DGU and vice versa, and allows one to send messages to the dispatcher post in case of an emergency with DGU.

The MICC existing climate control system is a complex of the interconnected equipment with different air and liquid cooling schemes, with the help of which the corresponding temperature regime ensuring the MICC functioning in a 24×365 mode is created. At present, the MICC climate control system has the following components: free cooling of the server equipment of the machine hall with cooled air; raised floor supply of cold air with a forced exhaust of hot air by ventilation panels; cooling of the cold corridor of the Tier-1 module by inter-row conditioners; liquid cooling of the elements of the "Govorun" supercomputer. According to the type of heat removal, the MICC climate control system refers to the mixed type that combines systems with the evaporation of a coolant and systems with an intermediate coolant.

Additional opportunities and new requirements to the cooling system are associated with the commissioning of the "Govorun" supercomputer in 2018, which required the creation of a precision liquid cooling system balanced for constant work with a high-temperature coolant. In accordance with the equipment placement conditions, an optimum operation mode of the computing rack at a constant coolant temperature of $+45\,^{\circ}$C at the entrance to the computing nodes (with a peak value of up to $+57\,^{\circ}$C) was chosen. The work in a "hot water" mode for this solution allowed one to apply a year-round free cooling mode using only dry cooling towers, which cool liquid with the help of ambient air on any day of the year, and also to completely get rid of the freon circuit and chillers. As a result, the average annual PUE (Power Usage Effectiveness) indicator of the system, reflecting the level of energy efficiency, is less than 1.06.

JINR Grid Environment. The JINR grid infrastructure [2] is represented by the Tier-1 center for the CMS experiment at the LHC and the Tier-2 center, which provides processing of data from the experiments ALICE, ATLAS, CMS, LHCb, BES, BIOMED, MPD, NOνA, STAR, and others.

In 2019, the Tier-1 data processing system for CMS was increased to 10 688 cores, providing a performance of 151.97 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 10.4 PB; the IBM TS3500 tape robot is 11 PB. In terms of performance, Tier-1 (T1_JINR) is ranked second among other Tier-1 centers for the CMS experiment (Fig. 2, *a*). More than 301 493 million events were processed, which accounts for 20% of the total number of processed events (Fig. 2, *b*) and 18% of the total CPU load of all Tier-1 centers for the CMS experiment.

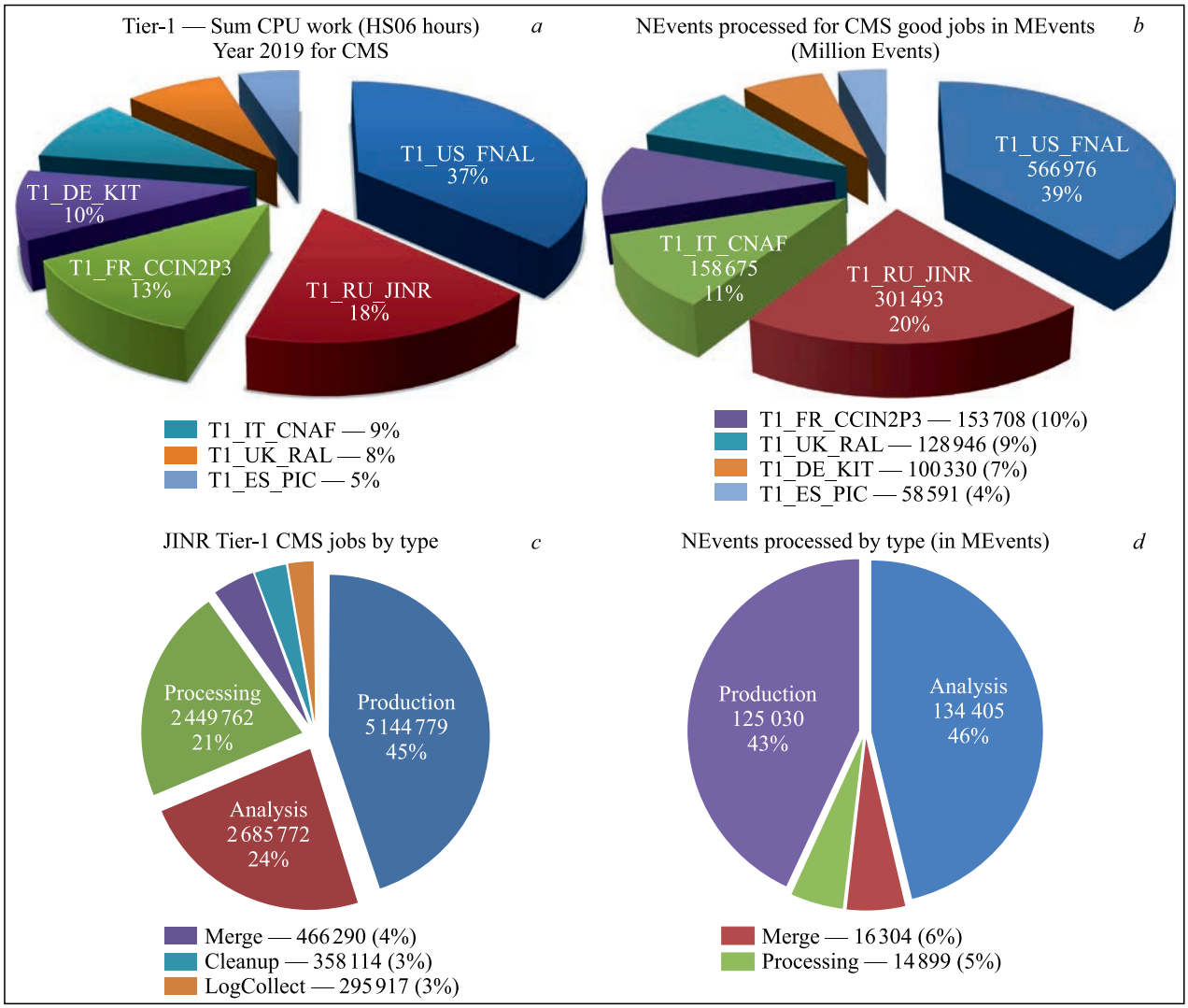

Fig. 2. Contribution of the world Tier-1 centers to the processing of CMS experimental data in 2019: *a*) distribution by the normalized CPU time in HS06 hours; *b*) number of processed events (in millions of events). Statistics on the use of the JINR Tier-1 center by the CMS experiment by different types of data stream processing in 2019: *c*) distribution of jobs; *d*) distribution of events by type of processing

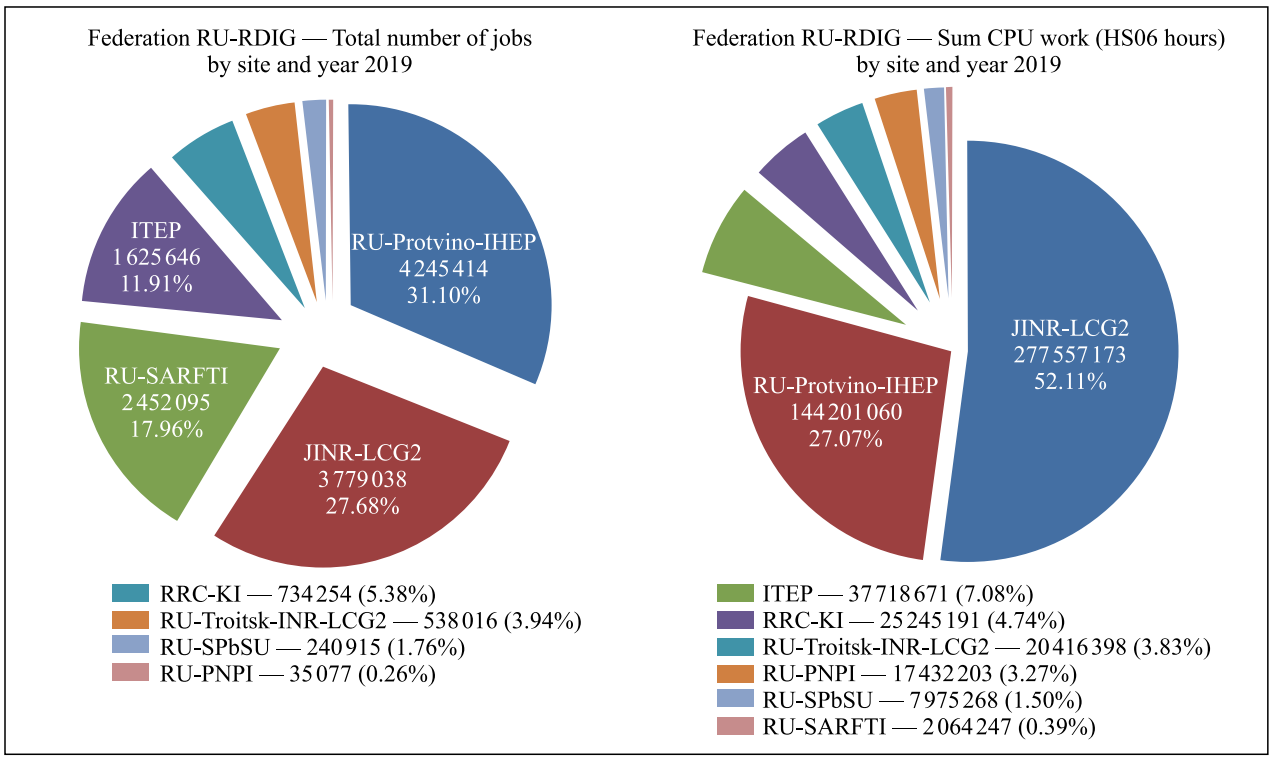

Fig. 3. Statistics of the work of Tier-2 sites of the organizations being part of the Russian Consortium RDIG

Figure 2, *c*, *d* shows the number of jobs and events processed at the JINR CMS Tier-1 center in 2019 by different types of data stream processing (reconstruction, modeling, reprocessing, analysis, etc.).

One of the main functions of Tier-1 centers is to provide data exchange with all world sites operating for the CMS experiment and storage of raw experimental and simulated data. In 2019, the overall volume of CMS data exchange with the tape robot was 9.6 PB, of which 2.1 PB of new files were recorded. The disk storage was used more actively: the total volume of CMS data and the results of their processing, taking into account the DCAP protocol, was 119.7 PB, of which the output stream was 33.4 PB.

In 2019, the computing resources of the Tier-2 center amounted to 4128 cores, which currently provides a performance of 55.489 kHS06. The total usable capacity of disk servers is 2789 TB for ATLAS, CMS, and ALICE and 140 TB for other virtual organizations. The JINR Tier-2 web site is the best one in the Russian Consortium RDIG (Russian Data Intensive Grid). In 2019, 3 779 038 jobs were processed, which accounts for 52.11% of the total performance of RDIG CPU (Fig. 3).

Figure 4 shows the data on using the JINR Tier-2 site by virtual organizations within grid projects in 2019.

The MICC allows users to perform calculations outside the grid environment. It is necessary for experiments, such as NOνA, BES, NICA/MPD, etc., as well as for local users of the JINR Laboratories. JINR and grid users have access to all computing facilities via

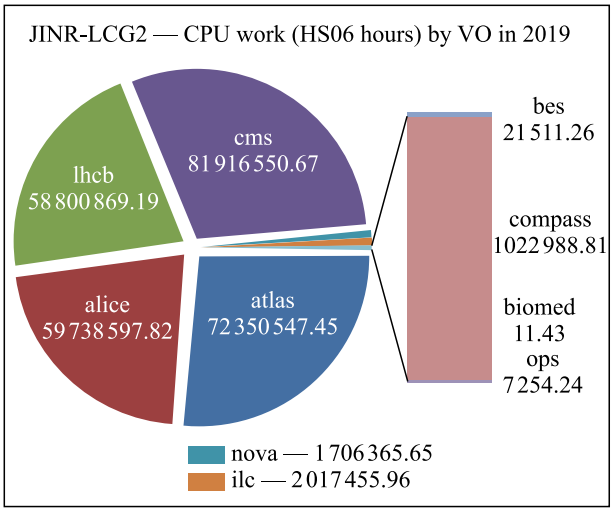

Fig. 4. The use of the Tier-2 grid site by virtual organizations (VO) of the global grid infrastructure: distribution by the normalized CPU time in HS06 hours

a unified batch processing system. The distribution by time and jobs performed on the computing cluster by the JINR subdivisions and user groups is shown in Fig. 5.

Systems of data storage and access, such as dCache, EOS, and XROOTD, ensure joint work with data for JINR local users, as well as WLCG (Worldwide LHC Computing Grid) users and other virtual organizations. JINR joined a group of research centers that develop a WLCG data lake prototype for HL-LHC. The data lake prototype was built as a distributed EOS storage system and is used for storing and accessing big arrays

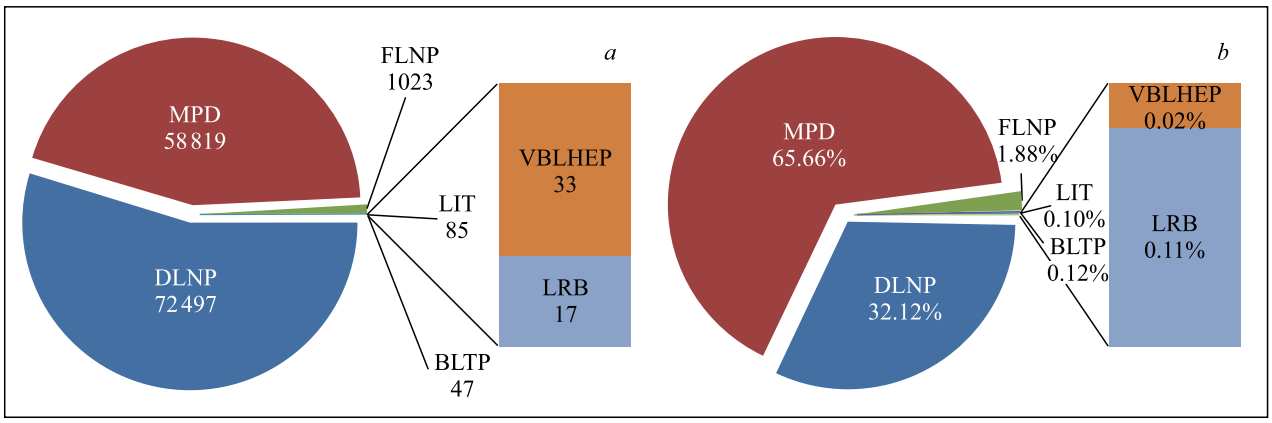

Fig. 5. Statistics of the use of the computing cluster: distribution by time (*a*) and jobs (*b*) performed on the computing cluster by the JINR subdivisions and user groups

of information. The EOS system was successfully integrated in the MICC structure. At present, 3740 TB of disk space is available for EOS. The NICA experiments have already been using EOS for data storage. EOS is visible as a local file system on the MICC working nodes and allows authorized users (by the kerberos5 protocol) to read out and write data.

Cloud Environment. In 2019, the work on expanding the JINR cloud environment [3] and combining computing powers of organizations of the Institute Member States into a unified information and computing environment was in progress. For efficient use of local computing resources, cloud infrastructures were or are created in each of the organizations participating in the unification, and clouds of each of the partner organizations of the JINR Member States are integrated into a distributed platform based on the DIRAC Interware (Distributed Infrastructure with Remote Agent Control) [4]. The distribution of jobs by clouds of the Member States's organizations is presented in Fig. 6.

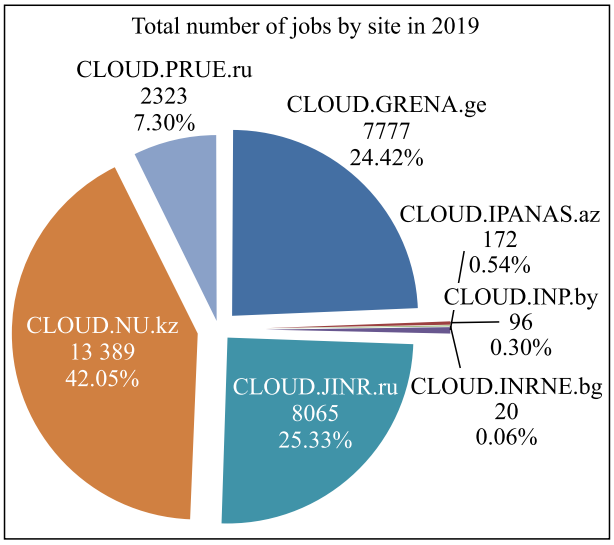

Fig. 6. Distribution of jobs by clouds of the Member States' organizations

The resources of the cloud infrastructure were enlarged to 1564 CPU cores and to 8.5 TB of the total RAM. Figure 7 shows the information on consuming the resources of the cloud infrastructure in 2019: DLNP, LIT, and the NOνA experiment are the major users of the cloud infrastructure.

The service that provides access to the MICC resources for carrying out a wide range of scientific calculations via a problem-oriented web interface [5], which ensures extended capabilities for launching jobs and notifying the user about the job status, was developed and improved in the JINR cloud. Access to the calculation results was changed: when the job is completed, the output is downloaded to an external file storage, where it becomes available at the automatically generated unique URL for user download, further analysis and/or visualization.

The studies, carried out in collaboration with FLNP within the international program "UNECE International Cooperative Program (ICP) Vegetation" for monitoring and predicting air pollution processes in Europe and Asia, were in progress [6]. In 2019, a mobile application, which allows automatically filling in information about places of moss samples in accordance with the standards of UNECE ICP Vegetation, was elaborated. The application is integrated with the system of managing data of the ICP Vegetation, so that all information about sampling locations can be imported into the system. Predictions of some heavy metals for Norway, Romania, and Serbia were made using deep neural networks. The methodology was worked out not only on a regional scale, but also in predicting pollution on a city scale.

Heterogeneous Infrastructure. The heterogeneous infrastructure of the JINR MICC consists of two elements, i.e., the "Govorun" supercomputer and the education and testing polygon, combined by a unified software and information environment into the HybriLIT heterogeneous platform (http://hlit.jinr.ru/). The resources of the platform are used to solve problems that require massively parallel calculations in different

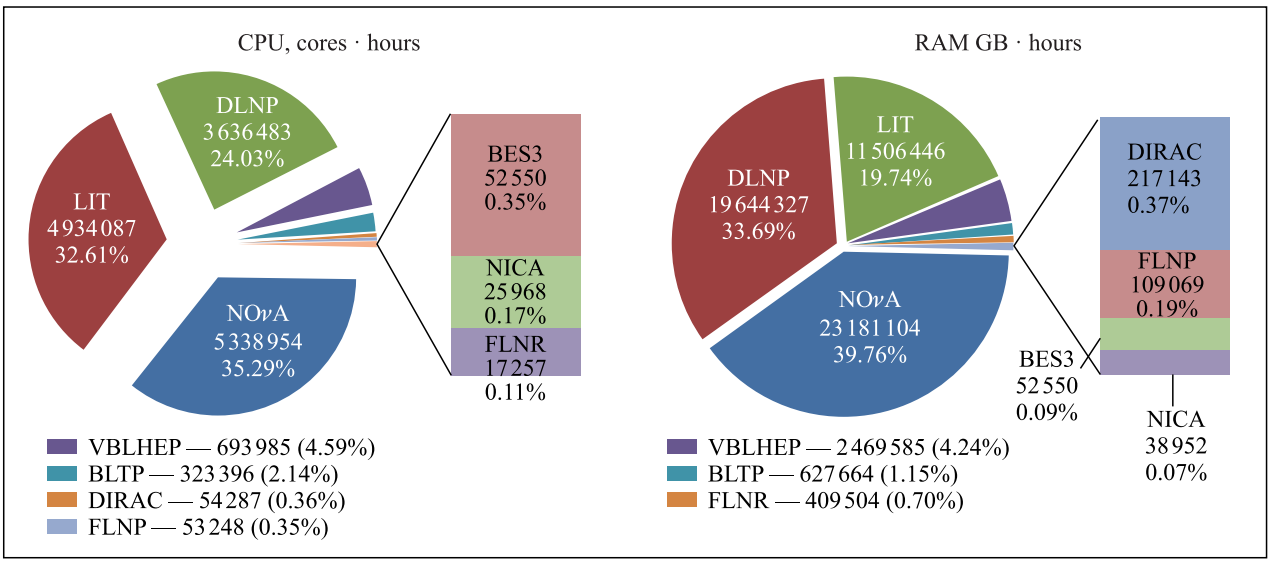

Fig. 7. Consumption of the resources of the cloud infrastructure in 2019

fields of nuclear physics and high-energy physics, condensed matter physics, radiobiology and others underway at JINR, including the development of computing for the NICA megaproject.

Based on the rapid development of IT technologies and user requests, the supercomputer was modernized, i.e., the transition to new processors Intel®Xeon®Scalable gen 2 (models Intel®Xeon®Platinum 8268) and novel high-speed solid-state disks Intel®SSD DC P4511 with the NVMe interface and a capacity of 2 TB was carried out. As a result of the modernization, the performance of the CPU component increased three times, and the total peak performance of the supercomputer reached 860 TFlops for double-precision operations and 1.7 PFlops for single-precision operations, which in turn allowed the CPU component of the "Govorun" supercomputer to take the 10th place in the TOP50 list of the most powerful supercomputers in Russia and the CIS.

The CPU component of the supercomputer is implemented on the high-density architecture "RSC Tornado" with direct liquid cooling, which ensures a high density of computing nodes, i.e., 150 nodes per computing rack, and high-energy efficiency of about 10 GFlop/W.

The "Govorun" supercomputer is a hyperconverged software-defined system and has unique properties for flexibility of customizing the user's job, ensuring the most efficient use of the computing resources of the supercomputer. To speed up the work with data, an ultrafast data storage system (UDSS) was implemented on the "Govorun" supercomputer under the Lustre file system. The total capacity of UDSS is currently 256 TB, and the data input/output rate is 300 GB/s.

The operation of the first version of the "Govorun" supercomputer made it possible to carry out a number of resource-intensive calculations in the field of lattice quantum chromodynamics, to qualitatively increase the efficiency of modeling the dynamics of collisions of relativistic heavy ions, to accelerate the process of generation and reconstruction of events for the experiments of the NICA megascience project, to calculate radiation safety of JINR experimental facilities, and to significantly speed up studies in the field of radiation biology and other scientific and applied tasks. The results of the given scientific studies were published in more than 50 leading world scientific journals (http://hlit.jinr.ru/users_publications/). In 2019, more than 260 000 jobs were performed on all computing components by all groups making calculations on the supercomputer. The distribution of the computing resources usage by user groups is shown in Fig. 8.

As seen from the given diagrams, the main users of the supercomputer are users from BLTP, LIT, and VBLHEP. At the same time, it should be noted that 85% of the resources of the supercomputer are used for the NICA megaproject, both for theoretical calculations and for event generation and reconstruction [7] using the DIRAC Interware (Fig. 9).

In 2019, the average load on the computing components was the following: Skylake — 95.61%, KNL — 57.12%, DGX — 84.59%.

An offline computer complex for data modeling, processing, analysis, and storage within the NICA project, which consists of territorially distributed online and three offline clusters connected by the high-speed computer network with a bandwidth 4×100 Gbit/s, was created. The NICA computing and information offline cluster at LIT was organized on the basis of the JINR MICC as a distributed scalable hybrid cluster, which allows organizing computing for the NICA project efficiently and without additional labor costs at the request of a different class of jobs and users. The main objective of the LIT offline cluster is to create a two-level (disk-tape) storage system for the NICA experiments, as after the first stage of these experiments, significant storage volumes will be required (from 2.5 to 70 PB per year).

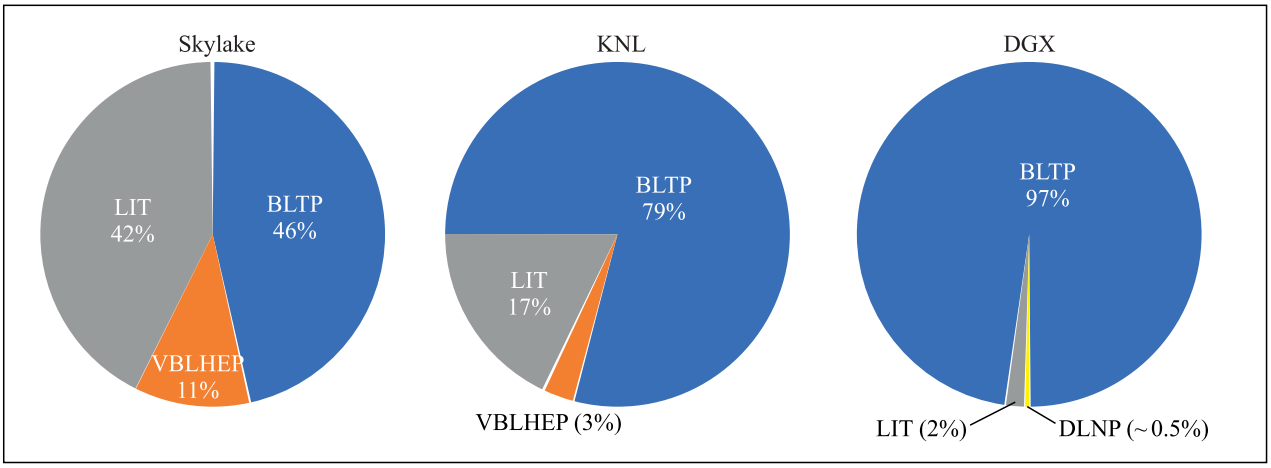

Fig. 8. Distribution of resources among user groups by the computing components of the supercomputer, while the Skylake component contained 40 computing nodes with two CPUs Intel®Xeon 6145, the KNL component contained 21 computing nodes with the processor Intel®Xeon Phi™ 7290, and the DGX component was implemented on the basis of 5 servers NVIDIA DGX-1 with 8 GPUs NVIDIA Tesla V100 in each

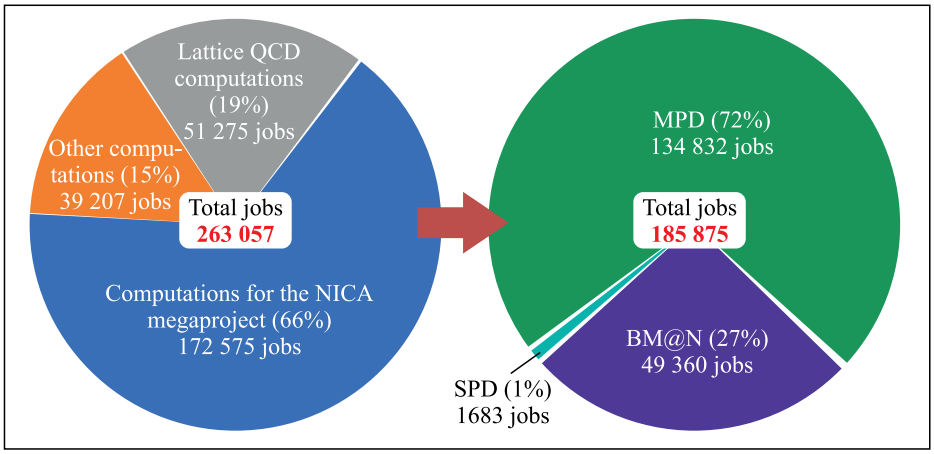

Fig. 9. Number of jobs performed for the NICA megaproject: the share of jobs related to theoretical studies within lattice quantum chromodynamics was 19%, the event generation and reconstruction for all NICA experiments amounted to 66%. At the same time, the share of MPD, out of these 66% of jobs, was 72%

At present, the following computing resources of the JINR MICC were combined using the DIRAC Interware: Tier-1/Tier-2, the "Govorun" supercomputer, the JINR cloud and storage resources, such as UDSS Lustre, dCache, and EOS [7]. More than 120 000 jobs were performed on the MICC components using the DIRAC platform within the framework of data generation by the Monte Carlo method for the MPD experiment. The distribution of simulation jobs by the MICC components via DIRAC is illustrated in Fig. 10.

Monitoring System. To ensure a reliable performance of the MICC, a multilevel monitoring system was created and expanded; it operates in a 24×365 mode and allows monitoring climate control and power supply systems, the local network equipment, telecommunication channels and computing nodes, jobs, disk and tape storage systems. It is based on different technologies, such as Nagios, Icinga2, Grafana, and systems that are developed at LIT. At present, the monitoring system controls all types of the MICC equipment. The

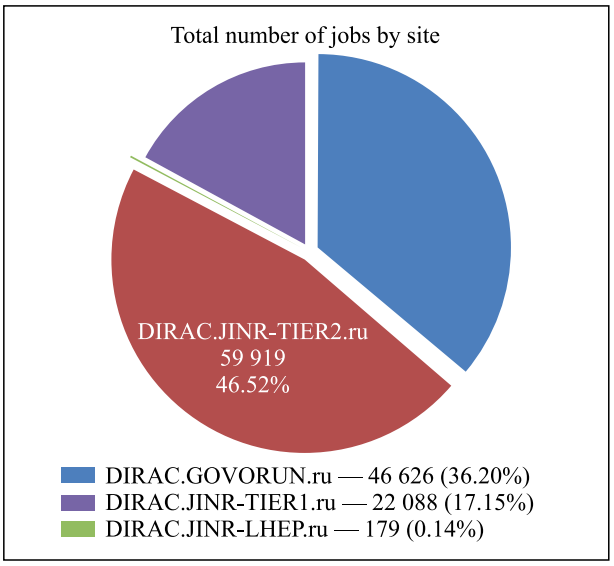

Fig. 10. Statistics on simulation jobs for MPD on the MICC components

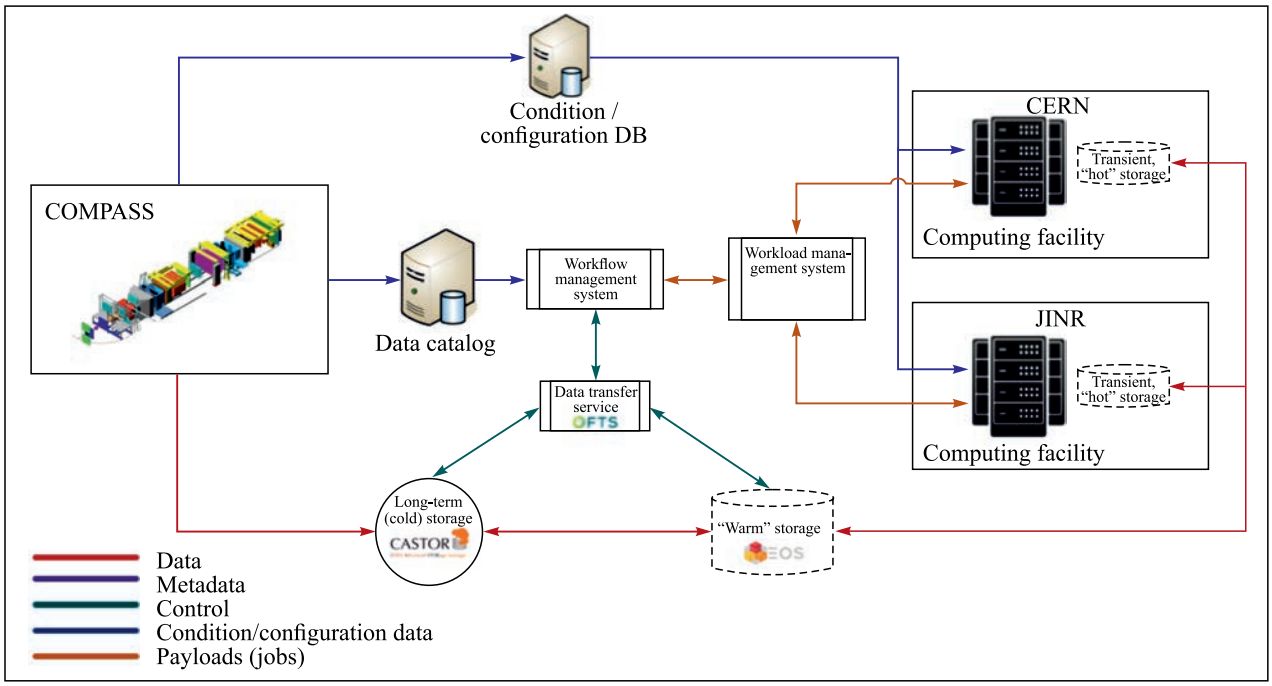

Fig. 11. System architecture and data workflows for data processing of the COMPASS experiment

number of nodes included in monitoring amounts to more than 2000.

In 2019, the work on finalizing the software package [8] for processing data from the COMPASS experiment, which has been operating in a production mode since August 2017, was in progress. The following data processing chains were implemented: reconstruction of real data, filtering of events. In 2019, a chain of job processing for the Monte Carlo modeling and reconstruction was implemented. Two grid nodes, namely, CERN and JINR, take part in data processing on a regular basis. In 2019, the Stampede 2 and Frontera supercomputers from the Texas Advanced Computing Centre (USA) were also connected to this system. The current architecture of the system and the workflow of processing are shown in Fig. 11.

One of the important subjects of analysis in different fields is streaming data, i.e., continuously incoming new information, on which it is necessary to carry out a historical analysis and to make operational decisions. At present, using Big Data technologies seems to be the most effective for studying streaming data. A prototype of the analytical platform was created at LIT for these purposes. The following services are deployed: 1) Apache Spark for analyzing incoming data in memory; 2) streaming data processing and storage system Apache Kafka for uninterrupted data transfer and intermediate storage; 3) Mesos for managing the resources of the computing cluster; 4) Elasticsearch for primary profiling and analysis, as well as incoming data storage; 5) Docker server for deploying supporting services.

The work on the further development of the APT EVM project management system for NICA was in progress. An English version of the system, required for presenting information to the Supervisory Council, was elaborated. A summary report, necessary for the timely coordination of planned expenses with the Russian Federation agreement on additional financing of the NICA project, was formed. The ongoing support and development of the system were carried out.

A number of works on the extension and current maintenance of the "Dubna" electronic document system (EDS) were completed: new documents were worked out and put into operation; a module for gathering statistics was developed; modules of the subsystem for electronic archive storage and search for contracts of capital construction and repair and construction works were elaborated.

The development upon users' requests and the ongoing maintenance of the following systems: Personal Information System (PIN), Information Search System (ISS), JINR Document Base and others, were carried out.

In 2019, the ongoing maintenance of 1C programs, training and support of users, the elaboration of new modules were carried out. A conference management module, which enables full financial accounting of JINR events, was developed and put into operation; in addition, to simplify the payment of participation, a specialized web site of accepting Internet payments (acquiring) was created.

A system of additional analytics of the Topical Plan, which allows taking into account expenses in frames of individual projects within one theme, was created as part of the development of management accounting. The given system was successfully tested in three Laboratories.

In 2019, a new version of the LIT portal (http://lit.jinr.ru) was created in the CMS Drupal environment. The JINR Information System of Scientific Certification (ISSC) was elaborated and put into operation (https://dissertations.jinr.ru/); it is designed to submit documents by applicants of scientific degrees to JINR Dissertation Councils, as well as for further work with these documents by scientific secretaries and Council members. The maintenance of the "Visit Center" portal (https://visitcentre.jinr.ru/) and the web site of "Physics of Elementary Particles and Atomic Nuclei" (PEPAN) and "Letters to PEPAN" journals (http://pepan.jinr.ru/) was performed. The traditional development, creation and maintenance of web sites of conferences, symposia at the request of the Laboratories and other JINR subdivisions were carried out.

A review devoted to the analysis of information acquisition and processing devices used in high-energy experiments, as well as of the classification and the need of information systems and databases in the NICA project experiments, was published together with VBLHEP [9]. The study singled out systems and components, the implementation or adaptation of which is vitally necessary to the NICA experiments.

In 2019, the work related to the development of an interface for the interaction of the jAliEn middleware and central services of the ALICE experiment was performed. The code integrated into the jAliEn environment and enabling to identify users, create working sessions, as well as send jobs to central services, by using Java Websocket, was developed [10].

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 studies conducted at JINR. A summary of some of the results is presented below.

When processing Big Data, the problem of finding sets of identical records in the whole volume of the information array often arises. As a new approach to connecting records, a study on the application of locality-sensitive hashing methods to search for the nearest lines in terms of the edit distance was carried out. A method to speed up the connection of records in Big Data was developed. A high performance of the given approach to reducing the dimension and searching for the nearest neighbors in the multidimensional vector space was shown [11].

Within the framework of the JINR NICA project, the three-dimensional modeling of the collider multipole corrector and the vertical output magnet was carried out. The magnet parameter influence on the field distributions in the magnet working areas was studied [12].

A workable prototype of the Geometry Database for the BM@N experiment was developed on the basis of the experience of the Geometry Database design for the CBM experiment [13]. The developed information system includes a database, intuitive and compact GUI tools and API tools as a set of ROOT macros. The Geometry Database is being prepared for production.

Research related to the study of the main characteristics of the MPD detector of the NICA accelerator complex, using data on proton–proton interactions obtained by simulating this detector with the help of the Monte Carlo method, was carried out [14]. The obtained results can be used to justify the necessity to build this detector and develop a high-level trigger system including machine learning techniques.

New effective tracking methods based on the graph neural network (GNN) are actively developed and tested for the GEM detector of the BM@N experiment at NICA. This approach was well adapted for solving the known fake hit problem inherent to strip detectors like GEM with the help of minimum branching tree algorithms [15].

A peak experimentally detected in the ratio of the number of strange kaons to nonstrange pions in the energy region $\sqrt{s_{NN}} = 8{-}10$ GeV was considered within the Nambu–Jona-Lasinio model with the Polyakov loop [16]. As a result of the study, it was shown that the splitting in the mass spectrum of kaons of different signs was observed at low energies of ion collision (at high densities), which might cause a difference in the behavior of the ratio of kaons to pions of different signs; the peak value of the K^+/π^+ ratio in the model depends on the properties of the substance (strange and baryonic chemical potentials and temperature); the peak position significantly depends on the curvature of the position of the phase diagram.

A set of parameters of the HIJING model (Heavy Ion Jet INteraction Generator) widely used for simulations of nucleus–nucleus collisions was found, and some improvements, which allow one to describe the NA49 and NA61/SHINE collaboration data on proton–proton interactions at momenta of projectile protons in the rest frame of target protons from 20 up to 158 GeV/c, were proposed. The modified model was applied to analyze nucleus–nucleus collisions at high energies, and it was shown that the model could describe the main characteristics of those interactions [17].

Parameters of the reactions p, d, He, C + C, Ta, and C + Ne, Cu at momenta of 4.2, 4.5, and 10 GeV/c per nucleon were calculated using the UrQMD model sup-

plemented by the Statistical Multifragmentation Model (SMM). Azimuthal correlations of pions and protons produced in the listed reactions were calculated and compared with the experimental data obtained at VBLHEP on the SKM-200-GIBS and Propane Bubble Chamber installations. A good agreement between the calculations using UrQMD + SMM and the experimental data was achieved [18].

A Monte Carlo study was performed for modeling experimental results on the elastic scattering of ^{15}N ions from ^{11}B, as well as for the analysis of systematic errors arising from the derivation of the elastic scattering cross section from experimental data within the EXPERTroot framework [19]. The developed software will be used for planning and analyzing similar experiments in the future.

Multiple improvements for the reconstruction algorithm of the particle trajectory on a single layer of the cathode strip chambers (CSC) detectors of the CMS experiment were developed [20]. The wavelet-based approach was adopted for overlapping signals delimitation. The tuning of the reconstruction for the special geometry ME1/1 chamber was performed, and as a result, the inefficiencies in the problematic regions were almost eliminated.

The development of discontinuous hp-adaptive schemes with parallel algorithms of two-level domain decomposition methods enabled highly precise three-dimensional projection-grid solutions with proved convergence. The advantage of the proposed method over the other known high-order approximation methods was demonstrated numerically [21]. Three-dimensional computations for finding an optimal configuration of the magnetic device with highly uniform magnetic fields for experiments with neutrons were continued as part of the collaboration with co-workers from FLNP.

Algorithms based on the basic element method were developed for the separation of neutron noise from slow power changes of IBR-2M. It was applied to both static and dynamic states of the reactor in the 0–2 MW power range. The algorithm speed is adequate for real-time monitoring [22].

In collaboration with FLNP, on the basis of the method of separated form factors (SFF), the analysis of SANS/SAXS experimental data for samples of various polydispersed vesicular systems, including the phospholipid transport nanosystem, was carried out. To increase the computational performance, the procedure of fitting the parameters of the SFF model to the experimental data of SANS and SAXS was implemented on the HybriLIT cluster using MPI techniques [23].

The φ_0-Josephson junction model in the "superconductor–ferromagnet–superconductor" system was investigated [24]. For numerical simulation in a wide range of parameters, which requires the significant computer time, a parallel MPI/C++ computer code was developed and implemented on the HybriLIT cluster and the "Govorun" supercomputer.

Numerical studies were performed for implementations of three different types of algorithms for solving band matrix systems of linear algebraic equations (SLAEs) obtained from the discretization of parabolic nonlinear partial differential equations. The results of the performance analysis of the implementations were obtained on the HybriLIT and Avitohol clusters [25].

Molecular dynamic simulations of long-range effects in metal targets irradiated with nanoclusters unveiled in depth the occurrence of fusion of high-temperature moving regions [26]. The temperature in the fusion region rises sharply, exceeding the melting temperature of the target. As a result, structural changes can occur in the crystal lattice at the target depth exceeding the penetration depth of the nanoclusters.

Methods and algorithms were developed for building finite difference schemes for systems of partial differential equations that possess the property of strong consistence [27].

To study constructive models of composite quantum systems, an efficient algorithm was developed [28] and implemented for decomposing the representations of the wreath products of finite groups into irreducible subrepresentations.

A method for reducing the Feynman integrals, depending on several kinematic variables and masses, to a combination of integrals with fewer variables was proposed. The method is based on the iterative application of functional equations proposed by the author [29].

The global indicator for quantization of the "classicality–quantumness" correspondence was introduced [30] and defined as a relative volume of the subspace with the positive Wigner function of the state space of an N-dimensional quantum system, and it was exemplified for the Hilbert–Schmidt ensemble of qubits and qutrits.

Computational experiments on quantum teleportation of the two-qubit Bell states done on the five-qubit quantum computer IBM Q were conducted. The comparison with such teleportation performed on the Feynman classical quantum simulator written in Maple was carried out [31].

APPLIED RESEARCH

To continue the work on the RFBR project, a mobile application for detecting plant diseases, which uses the modern cloud infrastructure and technologies of deep learning to provide a new level of service to the farmers' community, was developed [32]. The application allows users to send photos and text descriptions of

sick plants and get the cause of the illness and treatment.

The programs for calculating the dynamics of the beam of the SC230 superconducting cyclotron for proton therapy, developed at JINR DLNP with information and computing support of LIT in collaboration with the Institute of Plasma Physics (Hefei, China), were improved [33]. New algorithms, in which the components of the magnetic field outside the medium plane are calculated to the fourth order, were proposed. An algorithm for finding an equilibrium orbit for a large number of particles with different energies with a good calculation speed was implemented.

Some approaches to the intellectual analysis of the text as applied to the automated monitoring of the labor market were considered. A scheme for building an analytical system based on Big Data technologies was proposed. A system for monitoring the Russian labor market was created on the basis of the given methods [34].

INTERNATIONAL COOPERATION

The creation of the second segment of the grid infrastructure within the AZ-IFAN grid site is a result of collaboration between LIT and the Institute of Physics of the National Academy of Sciences of Azerbaijan in the field of information technologies in 2019. The grid and cloud infrastructures work in a production mode [35].

In collaboration with colleagues from Bulgaria, microscopic optical potentials and differential cross sections for the quasielastic scattering of exotic nuclei ^{12,14}Be on ^{12}C nuclei at 56 MeV/nucleon and on protons at 700 MeV were calculated using different density models [36]. A good agreement of the theoretical results with the available experimental data of both quasielastic scattering and breakup processes was obtained.

Within the framework of the cooperation agreement between JINR and IKF (Frankfurt, Germany), the work, which presents ultrahigh resolution data on fully differential cross sections for single ionization of helium induced by the 1-MeV proton impact, was performed [37]. A reasonable agreement between the first Born approximation (FBA) and the experiment was obtained in the kinematic regime close to the Bethe ridge. Far from this region, the calculated binary peak was shifted with respect to the experiment. To solve this problem, several theoretical mechanisms beyond the customary FBA theory were analyzed. These mechanisms include a 3C model (three Coulomb functions), effective charges, off-shell pair T matrices instead of pair potentials, and semiclassical postcollision interaction. The given combination can explain the observed discrepancy.

MEETINGS, CONFERENCES

In 2019, the 10th International Conference "Mathematical Modeling and Computational Physics" (MMCP'2019) and the XXVII International Symposium on Nuclear Electronics and Computing (NEC'2019) were organized with the participation of LIT.

The International Conference MMCP'2019 was held in the High Tatras (Slovakia) on 1–5 July. Organizers of the conference were JINR LIT, Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH) (Bucharest, Romania), the Institute of Experimental Physics of the Slovak Academy of Sciences (Košice, Slovakia), the Technical University of Košice (Slovakia), and Pavol Jozef Šafárik University (Košice, Slovakia).

More than 100 scientists and specialists from JINR and 15 countries (Armenia, Belarus, Bulgaria, the United Kingdom, Germany, Egypt, India, Canada, Moldova, Russia, Romania, Slovakia, the USA, Finland, and the Czech Republic) participated in the conference.

The International Computer School "Machine Learning, Parallel and Hybrid Computations & Big Data Analytics" was held in frames of the conference. In total, 26 students and postgraduate students from Slovakia, Romania, and Russia took part in the school.

The proceedings of the conference (revised selected papers) were published (Math. Modeling and Comput. Phys. (MMCP'2019) // Eur. Phys. J. Web Conf. 2020. V. 226).

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LABORATORY OF RADIATION BIOLOGY

In 2019, the Laboratory of Radiation Biology continued research within Theme 04-9-1077-2009/2020 "Research on the Biological Effect of Heavy Charged Particles with Different Energies" in the following fields: fundamental radiobiological and radiation genetics research; research on the action of accelerated charged particles on the central nervous system; mathematical modeling of radiation-induced effects; and radiation research at JINR's basic facilities and in the environment. Work was continued within Theme 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".

RADIATION GENETICS AND RADIOBIOLOGY

Research on the Structure of Clustered DNA Double-Strand Breaks Induced by Ionizing Radiation of Different Quality. Research was continued on the structure of clustered DNA double-strand breaks (DSBs) induced by ionizing radiation of different quality. With this purpose, an analysis was done of the formation patterns and structure of the 53BP1/OGG1 foci in clusters after exposure to spread-out Bragg peak protons, accelerated nitrogen ions (LET 181 keV/μm), and ^{60}Co γ rays. Irradiation was carried out at the Phasotron (DLNP JINR), Rocus-M γ-ray facility at the DLNP Medical Technical Complex, and U-400M cyclotron (FLNR JINR).

Using specific fluorescent antibodies allows visualization of the marker proteins of DNA DSB repair (53BP1) and proteins participating in damaged base re-

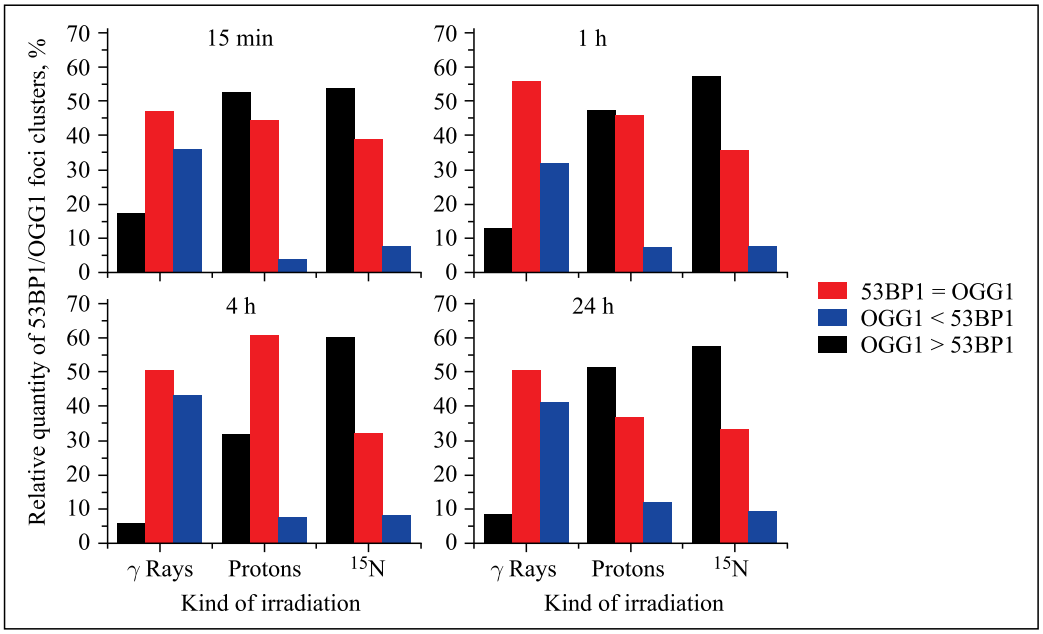

Fig. 1. The relative number of 53BP1/OGG1 foci clusters in nuclei of human normal skin fibroblasts 15 min, 1, 4, and 24 h after exposure to ^{60}Co γ rays, spread-out Bragg peak protons, and 13 MeV/nucleon ^{15}N ions at a dose of 1.25 Gy

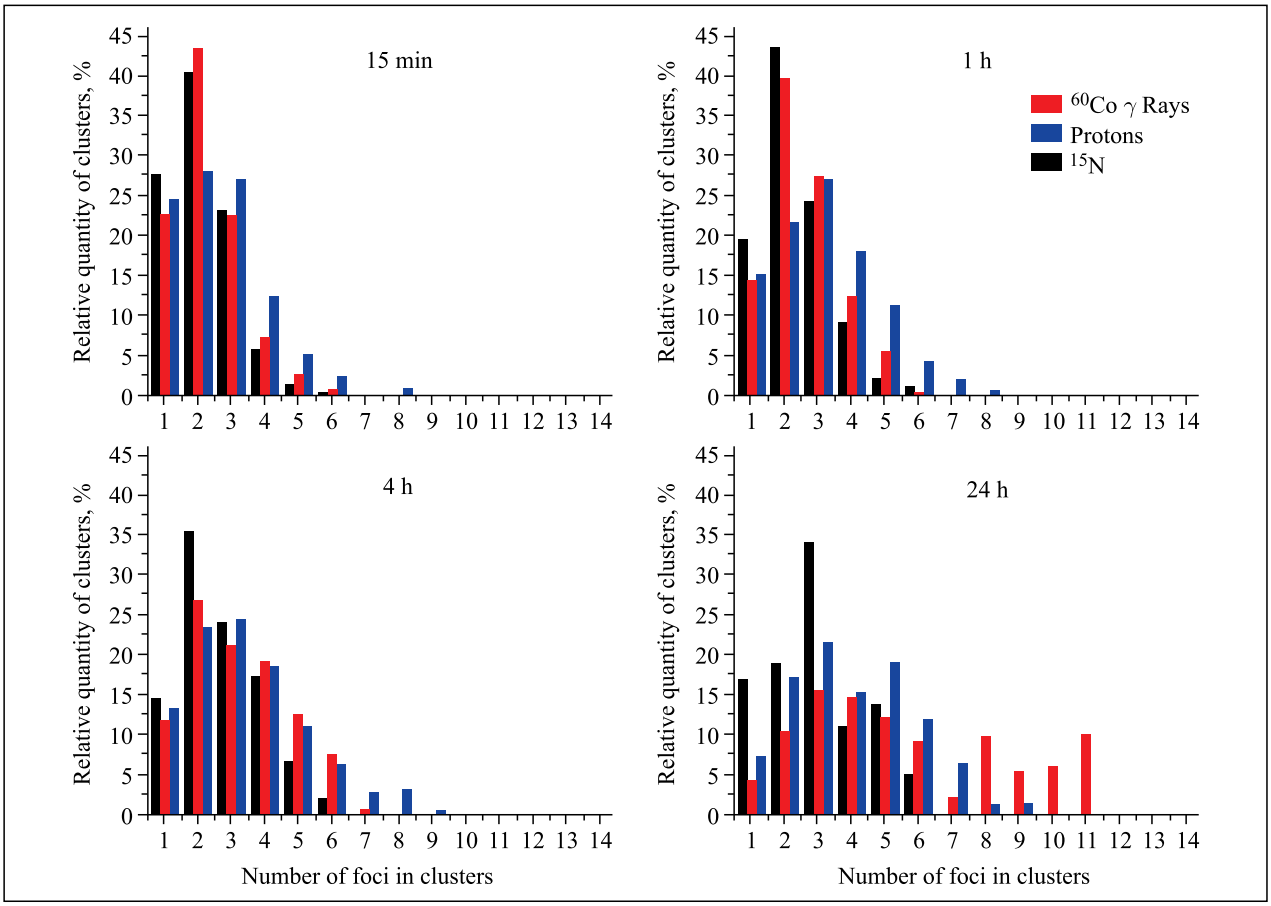

Fig. 2. Formation of 53BP1 foci clusters of different composition in nuclei of human normal skin fibroblasts 15 min, 1, 4, and 24 h after exposure to ^{60}Co γ rays, spread-out Bragg peak protons, and 13 MeV/nucleon ^{15}N ions at a dose of 1.25 Gy

pair (OGG1). The colocalization places of these marker proteins are the sites of clustered DNA DSB formation. Three cluster groups were identified, with the number of OGG1 foci (1) greater than, (2) the same as, and (3) less than that of 53BP1 foci. The data obtained show that low- and high-LET (linear energy transfer) radiations induce clustered DNA DSBs of different composition. As can be seen (Figs. 1 and 2), in fibroblast nuclei, accelerated protons and nitrogen ions induce much more clusters of the first group than γ rays throughout the postirradiation period. It can indicate that most of the clusters induced by accelerated nitrogen ions and protons have more complex structure, one clustered DNA DSB containing several damaged bases. In the case of γ rays, on average, there is less than one damaged base per DNA DSB in a cluster. With increasing LET, the character of the formed clusters becomes more complex. It was observed that for nitrogen ion exposure, while the average number of foci per cell in the postirradiation period decreases, the composition of the clusters that formed after exposure practically does not change. The analysis of the cluster structure showed that a complex cluster structure consisting of 2–3 and more individual 53BP1 foci is characteristic of all the ionizing radiation types used in the experiments. With increasing LET, cluster complexity increases. In particular, 4 h after nitrogen ion exposure, clusters of the most complex composition were formed, a single 53BP1 foci cluster containing up to 9 individual foci. Protons and γ rays induced a lower number of individual lesions in a cluster (5–6 individual foci). In the postirradiation period, cluster complexity increased, peaking at 24 h. A similar picture is observed for OGG1 foci clusters. For accelerated proton and nitrogen ion exposure, however, complication of the clusters is observed: by 4 h after proton exposure, the number of individual foci in OGG1 clusters increased to 7; for nitrogen ion exposure, to 11.

Kinetics of DNA DSB Formation in Rat Dentate Gyrus Cells after Accelerated Proton Exposure under the Modifying Influence of Cytosine Arabinoside (AraC). Ten-week old male Sprague Dawley rats were cranially exposed to 150-MeV protons at a dose of 3 Gy. 1–1.5 h before irradiation, the irradiated and control animals had 500 μl of an isotonic solution of AraC (cytosine β-D-arabinofuranoside, Sigma, M1738) at a concentration of 0.4 g/ml injected into their caudal vein.

A quantitative analysis of γH2AX/53BP1 foci formation and elimination kinetics in dentate gyrus cells

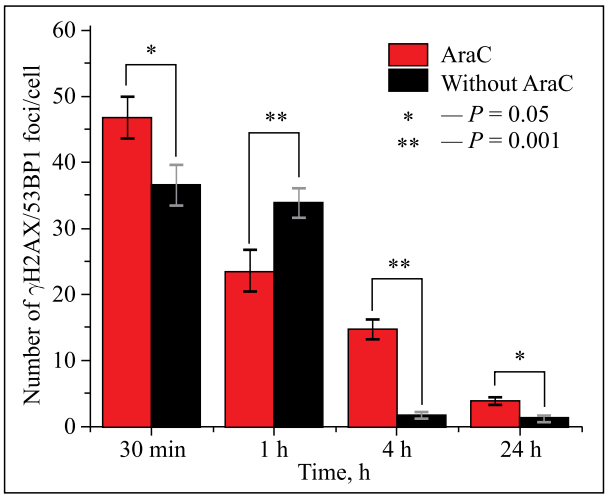

Fig. 3. γH2AX/53BP1 foci formation and elimination kinetics in dentate gyrus cells of the rat hippocampal formation after accelerated proton exposure at a dose of 3 Gy in the presence and without AraC. The mean value ± the standard error of the mean is shown

shows (Fig. 3) that the highest DNA DSB yield in the AraC-treated animals is observed 30 min after exposure. In 30 min, 4 and 24 h during the postirradiation period, a significant increase is observed in the γH2AX/53BP1 foci yield in the AraC-treated animals compared with the control animals irradiated without AraC introduction (the Mann–Whitney test, $P = 0.05$ and 0.001). The greatest difference in the γH2AX/53BP1 foci yield was observed 4 h after exposure, when the number of foci was six times higher in the presence of AraC than without it.

DNA DSB Formation and Elimination in Cultures of Human Normal Skin Fibroblasts and Glioblastoma Cells after Accelerated Proton Exposure under the Modifying Influence of AraC. The action of AraC on the frequency of DNA DSB formation in human normal (fibroblasts) and tumor (glioblastoma U87) cells was studied for spread-out Bragg peak proton exposure at a dose of 1.25 Gy. By immunocytochemical staining and fluorescent microscopy, foci of the DNA DSB repair proteins γH2AX and 53BP1 were visualized. An analysis of the colocalized γH2AX/53BP1 foci showed that in the absence of AraC the number of foci per cell decreases in both cell culture types during the postirradiation period, which points to the successful DNA DSB repair. In the presence of the DNA synthesis inhibitor, however, no decrease in the number of γH2AX/53BP1 foci is observed. It was established that in the presence of AraC the number of foci in fibroblast nuclei 24 h after exposure is six times higher than without introducing AraC; in glioblastoma cells, three times (Fig. 4).

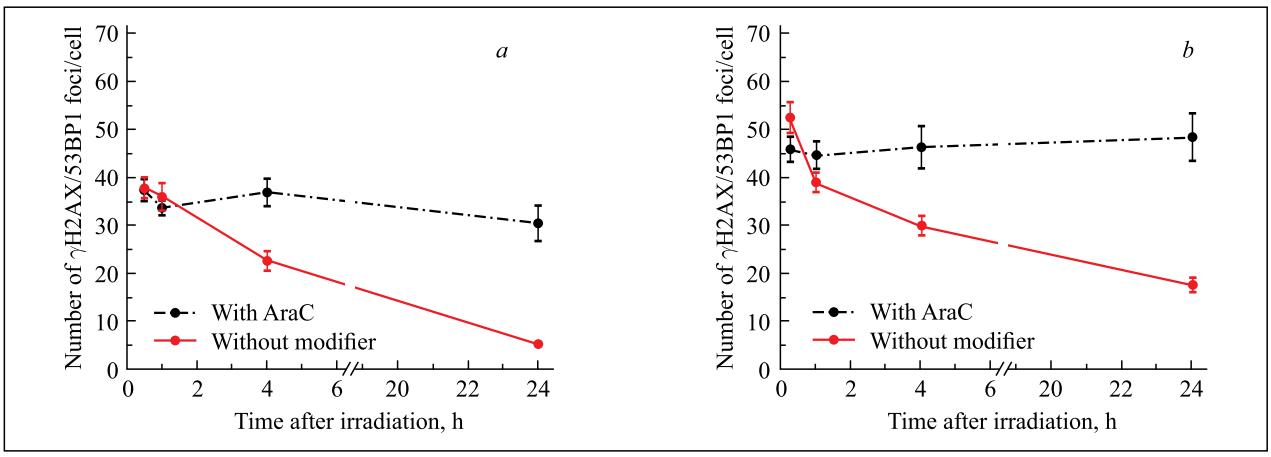

Fig. 4. γH2AX/53BP1 foci formation and elimination kinetics in nuclei of fibroblast (*a*) and glioblastoma (*b*) cell cultures after irradiation with spread-out Bragg peak protons at a dose of 1.25 Gy in the presence of AraC and in an intact culture (without modifiers)

Research on DNA DSB Formation and Elimination in a Primary Culture of Rat Hippocampal Cells after ^{60}Co γ-Ray and Accelerated Proton Exposure. To study *in vitro* DNA DSB formation kinetics in a primary culture of rat hippocampal cells after ^{60}Co γ-ray and accelerated proton exposure, two experimental models were designed: a neural cell culture, which was obtained using the antimitotic agent 1-β-D-arabinofuranosylcytosine; and a primary culture of intact hippocampal cells, which was not influenced by AraC and consisted of both neural and glial elements [1]. It was found that AraC introduction into a primary culture of rat hippocampal cells results in the death of a significant part of the dividing — non-neural — cells (over 90%), which was determined by the staining of GFAP — an astrocyte marker. DNA DSB formation and elimination kinetics in a neural cell culture was evaluated by the colocalized DNA repair marker proteins γH2AX and 53BP1 using indirect immunocytochemical staining. In an intact culture, pro-

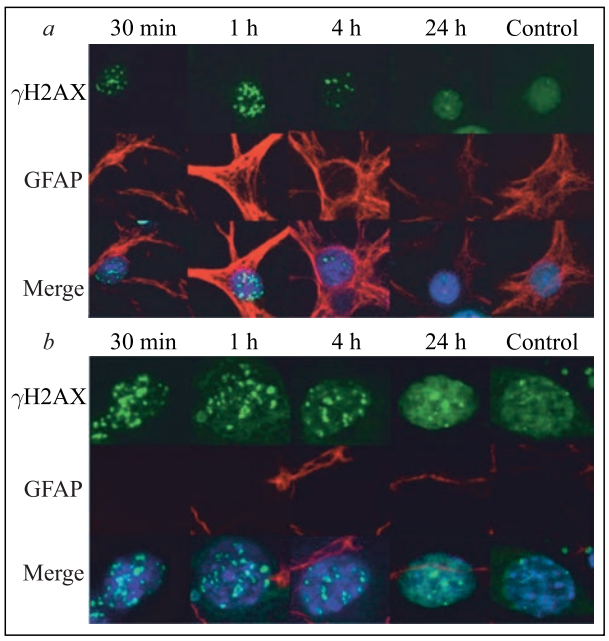

Fig. 5. γH2AX foci formation kinetics in astrocytes (*a*) and in neurons (*b*) of an intact primary rat hippocampal culture after exposure to ^{60}Co γ rays at a dose of 3 Gy (1000× magnification)

teins were analyzed one by one in combination with cell type marker proteins: the astrocyte marker GFAP and the mature neuron marker MAP2, which belong to the cytoskeleton proteins. It was established that for ^{60}Co γ rays, the yield of radiation-induced foci (RIF) γH2AX and 53BP1 in a neuron culture peaks at 1 h after exposure and then decreases. However, 24 h after exposure, the RIF yield remains high and statistically different from the control level (the Mann–Whitney test, $P = 0.05$). In a study of γH2AX foci formation kinetics in astrocytes, the highest foci yield was observed 1 h after exposure. A qualitative analysis of mature hippocampal neuron images obtained after accelerated proton exposure shows that RIF are produced in a significant amount already in the first minutes, but their yield peaks at 30 min – 1 h after exposure. Then, gradually decreasing, the RIF yield remains significant even 48 h after exposure (Figs. 5 and 6).

Research on the Action of Accelerated Protons in the Presence of AraC on the Formation Kinetics of a Melanoma Tumor Implanted in Animals. *In vivo* research was continued to develop a new method of increasing the biological effectiveness of accelerated protons in the treatment of tumors [2, 3]. A group of animals (mice) were inoculated with a melanoma tumor. The tumors were exposed to Bragg peak protons — with and without pretreatment of mice with cytosine arabinoside (AraC). The control (non-exposed) animals died of tumor development on the 30th day after exposure (Fig. 7). On the 40th day, both irradiated groups were alive. The tumor size strongly differed between the animals that were and were not pretreated with AraC: the tumor was smaller by a factor of ∼3 in the group exposed in the presence of AraC.

Research on DNA DSB Formation and Elimination in Normal and Tumor Cells in the Presence of AraC after Accelerated Proton and Nitrogen Ion Exposure. Using the DNA comet assay, DNA DSB formation was studied in cultures of human normal fibroblasts and glioblastoma U87 cells under the modifying influence of DNA repair inhibitors cytosine arabinoside (AraC) and hydroxyurea (HU) after exposure to Bragg peak protons and accelerated ^{15}N ions

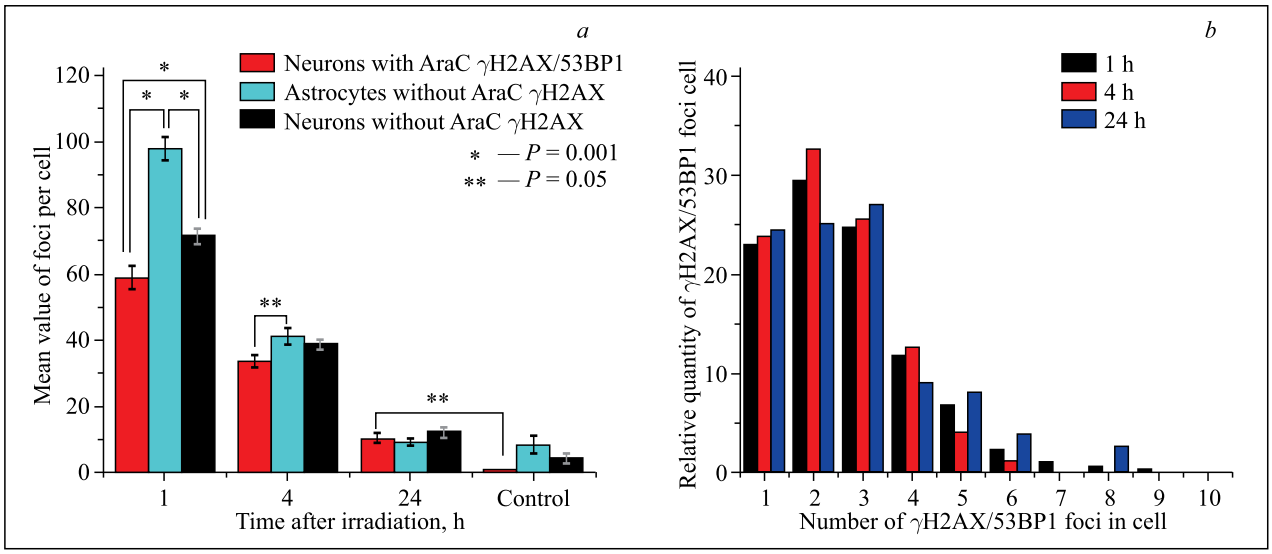

Fig. 6. *a*) Comparative analysis of the formation kinetics of γH2AX/53BP1 foci in a neural cell culture and γH2AX foci in neurons and astrocytes of an intact primary rat hippocampal culture. *b*) γH2AX/53BP1 foci cluster formation in a neural cell culture after exposure to ^{60}Co γ rays at a dose of 3 Gy

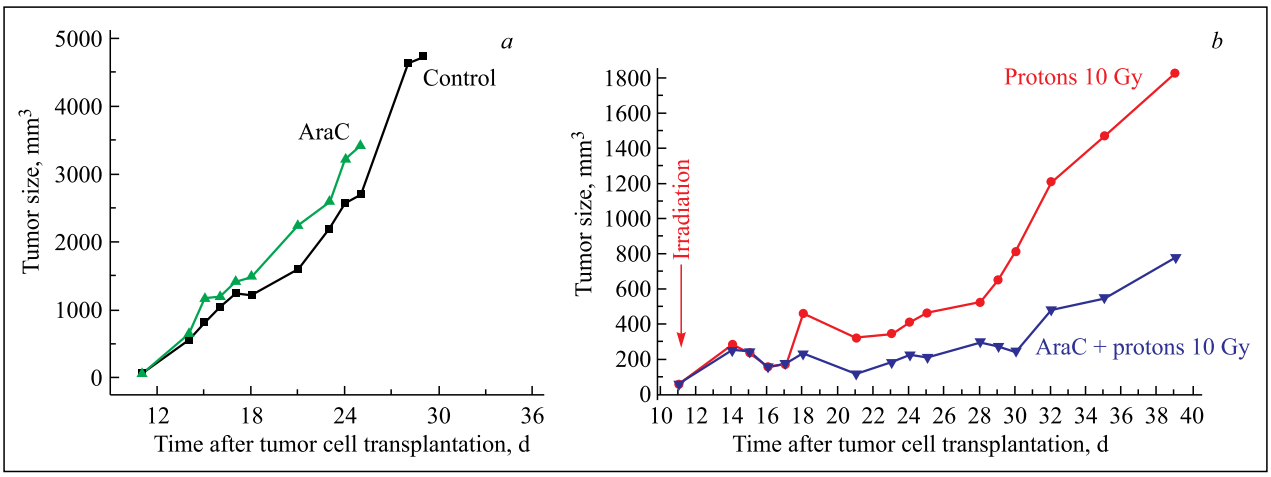

Fig. 7. Melanoma tumor growth kinetics in mice: *a*) non-irradiated control animals, *b*) Bragg peak proton exposure at a dose of 10 Gy

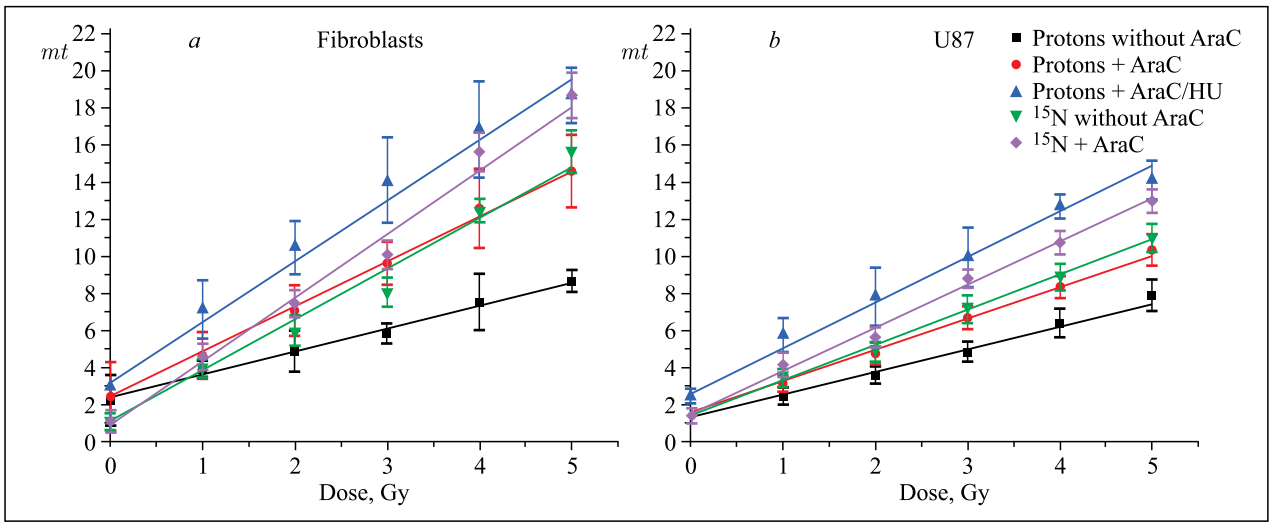

Fig. 8. A dose dependence of the mt parameter value for exposure to accelerated protons and ^{15}N ions — under normal conditions (*a*) and in the presence of AraC and AraC + HU (*b*)

(LET = 85 keV/μm). Figure 8 shows dose dependences of DNA DSB induction. As can be seen, the character of the DNA damage yield is linear for all the radiations used. With increasing LET, an increase was observed in the efficiency of DNA DSB induction. It was shown that in the presence of AraC, the number of DNA DSBs induced by all the radiations used significantly increases. In the presence of a combination of AraC and HU, the DNA DSB yield increases. In the case of accelerated nitrogen ion exposure, the modifying effect of the repair inhibitors is weaker for both fibroblasts and glioblastoma U87 cells.

The DNA DSB repair kinetics in the presence of radiomodifiers was studied (Fig. 9). It was shown that under normal conditions, damage elimination follows exponential kinetics and practically ends by 6 h. In the presence of inhibitors, repair kinetics depends on the type of radiation. In particular, for proton exposure, a significant increase, not a decrease, in the DNA DSB yield is observed up to 6 h of postirradiation incubation; some decrease takes place only by 24 h. For irradiation with accelerated nitrogen ions (LET = 85 keV/μm), the DNA DSB yield slightly decreases, but even by 24 h, the amount of unrepaired damage remains practically 3–4 times higher than under normal conditions. Like in the case with the dose dependence, the additional use of HU increases the damage yield in fibroblasts and glioblastoma U87 cells.

Cytogenetic Analysis of Chromosomal Damage in Human and Mammalian Cells. A new efficient method of the analysis of human and animal chromosomes, multicolor fluorescent *in situ* hybridization (mFISH), which was introduced at the LRB in 2018, allows identification of each pair of chromosomes of humans (22, X, Y), mice (20, X, Y), rats, etc., and evaluation of all types of chromosome rearrangements, including symmetric inherited aberrations (translocations) and complex chromosomal aberrations [4]. The primary task

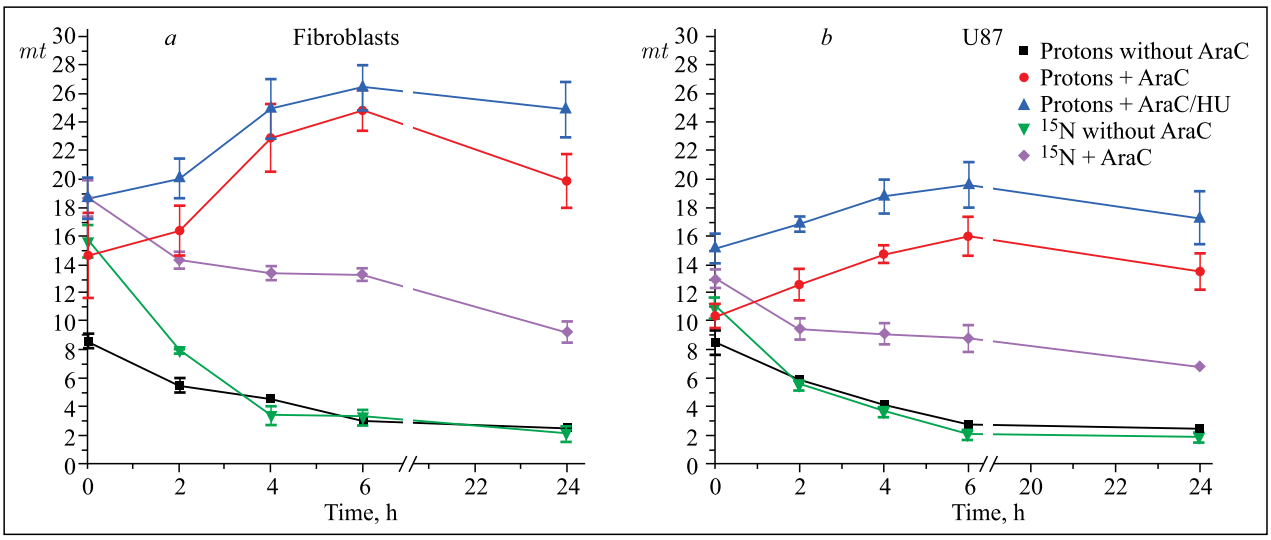

Fig. 9. DNA DSB formation and elimination kinetics in fibroblasts and U87 cells for exposure to accelerated protons and ^{15}N ions — under normal conditions (*a*) and in the presence of AraC and AraC + HU (*b*)

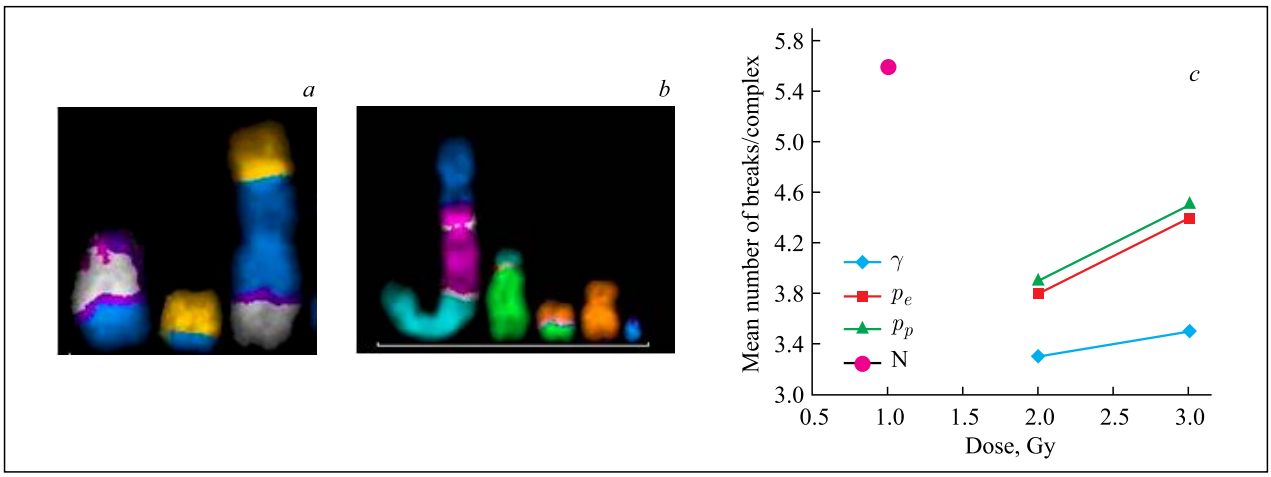

Fig. 10. *a*) A typical complex aberration induced by 3 Gy of γ rays: 3 breaks/complex. *b*) A typical complex aberration induced by 3 Gy of protons: 4–5 breaks/complex. *c*) The mean number of breaks per complex aberration induced by p_e and p_p proton beams and γ rays at a dose of 3 Gy and by accelerated nitrogen ions at a dose of 1 Gy

was to perform an mFISH evaluation of the relative biological effectiveness (RBE) of 150-MeV and spread-out Bragg peak (SOBP) protons of the tumor therapy beam at the DLNP Medical Technical Complex. New advanced techniques of evaluating radiation-induced damage can reduce uncertainties in the LET–RBE dependence for protons.

An analysis of chromosomal aberrations induced in human blood lymphocytes by ^{60}Co γ rays, 150-MeV protons (p_e) and SOBP protons (p_p) at doses of 2–3 Gy (earlier, the same samples were analyzed by the standard metaphase method, in which p_e RBE did not significantly differ from 1 [5, 6] and accelerated nitrogen ions at a dose of 1 Gy (LET = 71 keV/μm; the MC-400 cyclotron at FLNR)) showed higher efficiency of particle radiations as regards the induction of complex chromosomal aberrations compared with photon radiation. In particular, the proportion of the breaks that are part of complex aberrations in the total break yield was 27, 37, 42, and 70% for 3 Gy of γ, p_e, and p_p and 1 Gy of ^{14}N exposure, respectively. The relative dose effect (RDE) was 1.40 ± 0.16, 1.58 ± 0.17, and 9.68 ± 4.10 for 3 Gy of p_e and p_p and 1 Gy of ^{14}N exposure, respectively.

An important indicator of the clustered character of DNA damage induced by accelerated particles is not only the yield, but also the complexity of aberrations, which is characterized, for example, by the mean number of breaks per complex (Fig. 10). This value is close for both p_e and p_p beams (4.4 and 4.5, respectively), which is notably higher than for γ rays (3.5). For 3 Gy, the RDE is 1.25 ± 0.11 and 1.28 ± 0.11 for p_e and p_p, respectively.

In summary, the data obtained with mFISH show that particle radiations have higher biological effectiveness than photon radiation due to higher complexity of

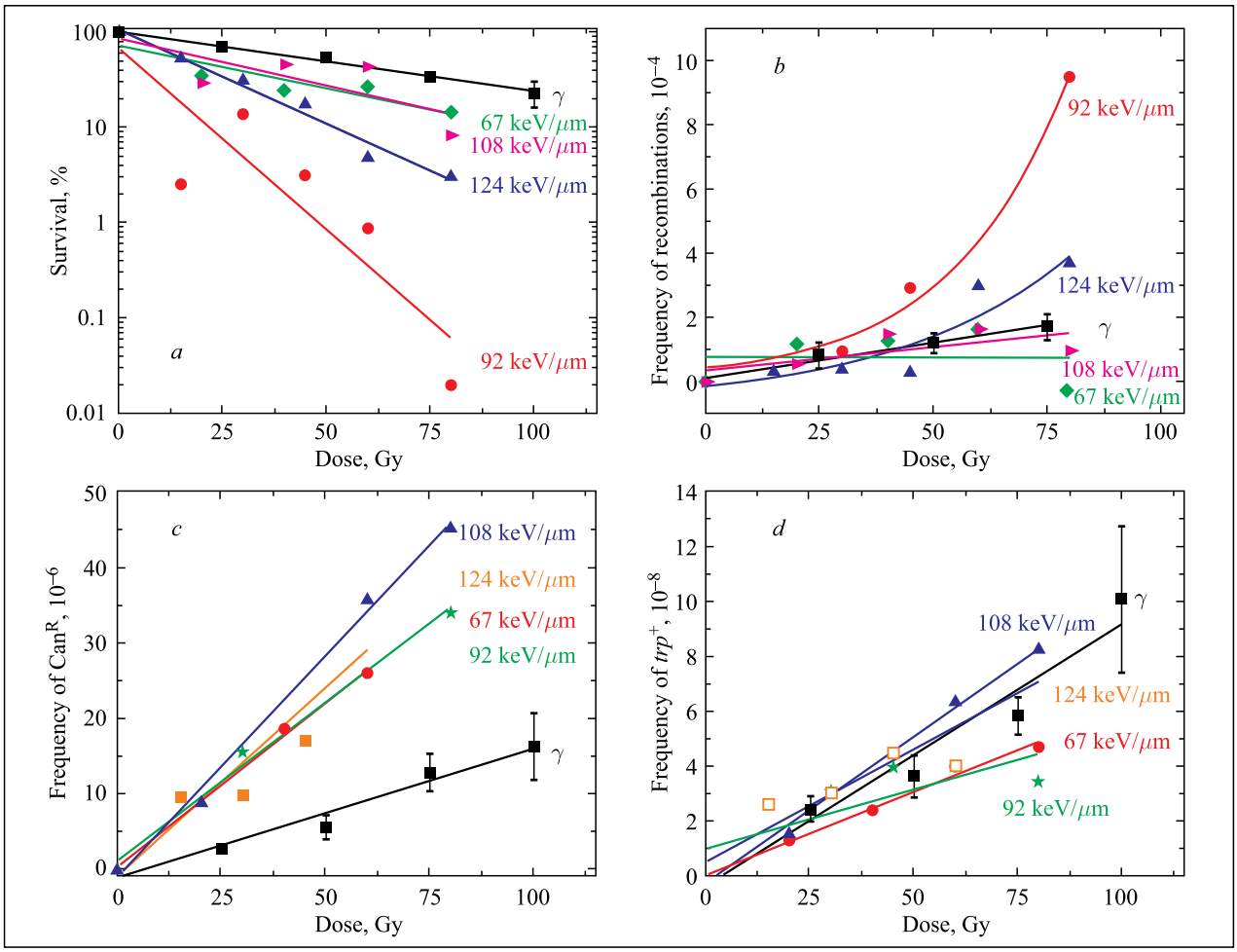

Fig. 11. Survival (*a*) and the frequency of recombinations (*b*) and mutations (*c*, *d*) in haploid yeast cells irradiated by accelerated nitrogen ions of different LET

the induced chromosomal damage. The proton RDE was thus found to be significantly greater than 1, which was obtained earlier by the standard metaphase technique.

Genetic Effects Induced by Ionizing Radiation in a Model Unicellular Eukaryotic Organism (the Yeast *Saccharomyces cerevisiae*). Research was continued on radiation-induced mutation events of different molecular nature in unicellular eukaryotes as a model organism [7]. Cells of several test strains were irradiated with nitrogen ions of linear energy transfer (LET) of 67, 92, 108, and 124 keV/μm. The strongest lethal effect was observed at LET values of 92–108 keV/μm (Fig. 11, *a*). The highest recombination frequency was also observed in this LET range (Fig. 11, *b*). As these two events are connected with the induction of DNA double-strand breaks, the peaks coincide. It was shown that the dose dependences of the frequencies of direct mutations in the *can1* gene and base pair changes (the GC–AT transitions) are described by linear functions. It was also found that accelerated ions induce direct gene mutations more efficiently than sparsely ionizing γ radiation. At the same time, no LET dependence was observed for the frequency of base pair change mutations. As the direct mutations can originate from any mutations damaging the *can1* gene (base pair changes, missing nucleotide(s), or multiple mutations), the analysis of the nucleotide sequence of the gene's mutant alleles is underway. Preliminary data were obtained showing that in the non-irradiated cultures mainly base pair change mutations emerge, while after accelerated nitrogen ion exposure the proportion of multiple mutations sharply increases [8].

The analysis was continued of human phosphatase, which participates in purine metabolism and genetic stability control. A molecular dynamics simulation was performed of the Pro32Thr-hITPA phosphatase — namely, of four dimer types: wild-type P32/P32 and mutant T32/T32 homodimers and two heterodimers, P32/T32 and T32/P32. A comparison of 20-ns structure dynamics revealed neither any critical displacement of the mutation loop between α2 and β2, where the mutation is localized, nor the protrusion of the neighboring Phe31 hydrophobic residue. A hypothesis of the signal hydrophobic residue followed by protein degradation was not thus confirmed. It was found, however, that the displacement of the mutant dimer is greater than that of single subunits [9].

Research on Morphofunctional Indicators and Behavioral Reactions in Animals after Exposure to Ionizing Radiation of Different Quality. Research was continued on the morphofunctional indicators of the action of accelerated protons on laboratory animals' central nervous system. In experiments on ICR CD-1 mice, 1–8 d after 70-MeV proton exposure (protons leaving the moderator) at nonlethal doses (0.5–5.0 Gy), a dose-independent decrease took place in the main indicators of rodents' spontaneous motor activity (Fig. 12). At the same time, in experiments on Sprague Dawley rats, after exposure to 170-MeV protons at a dose of 1 Gy, normalization of the orienting response (OR) and emotional status (ES) indicators was observed in all groups of the exposed animals compared with the control group (see the table). The disorder of motor activity in proton-irradiated rodents in the early period after exposure and its relative normalization in the long-term period happened against the background of the increased number of morphologically changed and dystrophic neurons in the hippocampus and Purkinje cell sparseness in the cerebellum (Fig. 13). This points to the necessity of complex physiological, morphological, and neurochemical approaches for the analysis of the radiobiological action of particle radiation, taking into account the irregularity of the dose distribution [10].

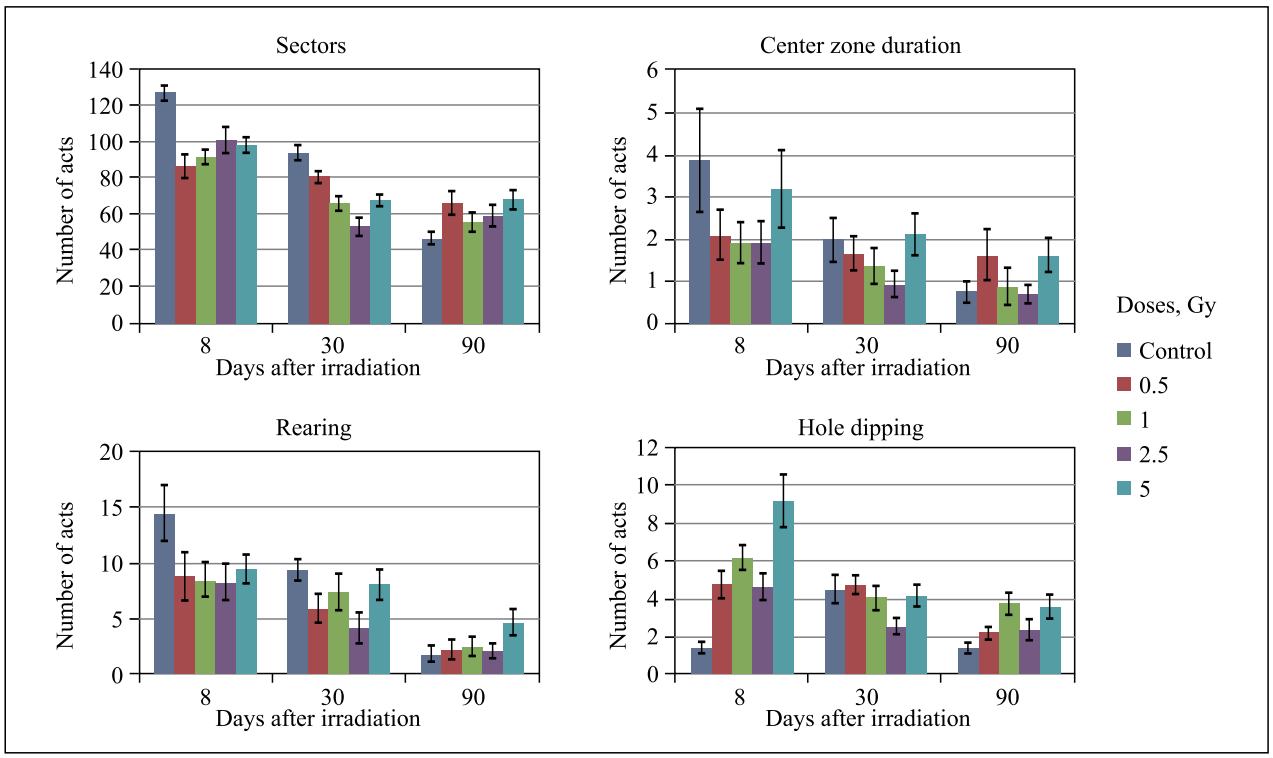

Fig. 12. The orienting response index (the number of acts per 3 min) in ICR CD-1 female mice after irradiation with 70-MeV protons at doses of 0.5–5 Gy

Neurological status indicators in male Sprague Dawley rats on the 90th day after 170-MeV proton irradiation at a dose of 1 Gy (the number of events for 1–3 and 4–6 min)

Group	Number of animals	Behavioral testing time, min	OR	ES
Irradiation 1 Gy	10	1–3	57.7 ± 6.1	2.7 ± 0.7
Control	10		35.3 ± 7.5	2.0 ± 0.3
Irradiation 1 Gy	10	4–6	41.3 ± 5.3	3.4 ± 0.5
Control	10		18.8 ± 2.7	3.1 ± 0.4

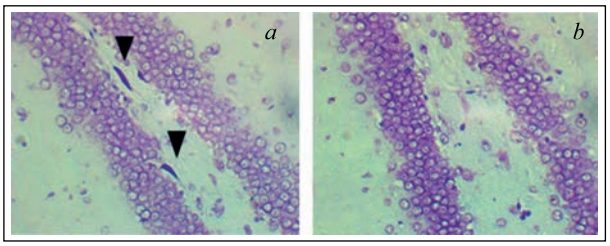

Fig. 13. Morphological changes in neurons of the hippocampal polymorphic hilum in rats exposed at a dose of 1 Gy (*a*) and in non-irradiated rats (*b*). The black arrows indicate neurons with dystrophic changes (400× magnification)

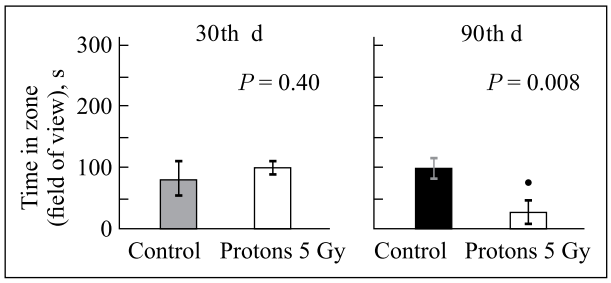

Fig. 14. Mean total time of the animal's head being in the monitored area after cranial proton irradiation at a dose of 5 Gy for a low-contrast visual stimulus (the contrast ratio $k = 0.5$). • — Statistically significant data (the Mann–Whitney test, $P < 0.05$)

An evaluation was made of the optomotor reflex and visual behavior in rats after their head exposure to 170-MeV protons at a dose of 5 Gy. A cranial proton exposure caused no statistically significant decrease in the optomotor response (the proportion of the correct and incorrect head turns) in the rats on the 30th and 90th days after irradiation. However, in the long-term postirradiation period, statistically significant changes were observed in the exposed animals' visual behavior [11]. It was found that on the 90th day the total time of the head being kept in the area where the animal is able to focus its attention on the visual stimulus is shorter in the irradiated rats (Fig. 14).

Research on the Inflammatory Reaction in a Culture of Microglial SIM-A9 Cells of the Mouse Brain after Exposure to Ionizing Radiation of Different Quality. The activation of brain microglial cells is considered to be one of the main causes of the development of cognitive disorders in mammals exposed to ionizing radiation. Microglia activation is accompanied by an inflammatory reaction induced by the secretion of a number of proinflammatory cytokines, chemokines, and reactive oxygen species by these cells, which results in oxidative stress, neurogenic signaling violation, and neurogenesis inhibition.

An inflammatory reaction was studied in a culture of SIM-A9 microglial cells of the mouse brain after exposure to ionizing radiation of different quality: γ rays, spread-out Bragg peak (SOBP) protons, and accelerated ^{15}N ions (LET ~ 180 keV/μm) at doses of 1–10 Gy. As markers of inflammatory processes, the concentration values of the inflammatory cytokines IL-1β, IL-6, and MCP-1 in supernatants were used. Measurements were made at different times after irradiation. It was found that in a microglial cell culture, radiation exposure stimulates the production of the cytokines IL-6 and MCP-1. No IL-1β production was observed.

The concentrations of IL-6 and MCP-1 increased with increasing of the radiation exposure dose and postirradiation cell cultivation time (Fig. 15). For the highest dose used, 10 Gy, the concentration of cytokines increased 3–6-fold relative to the control level depend-

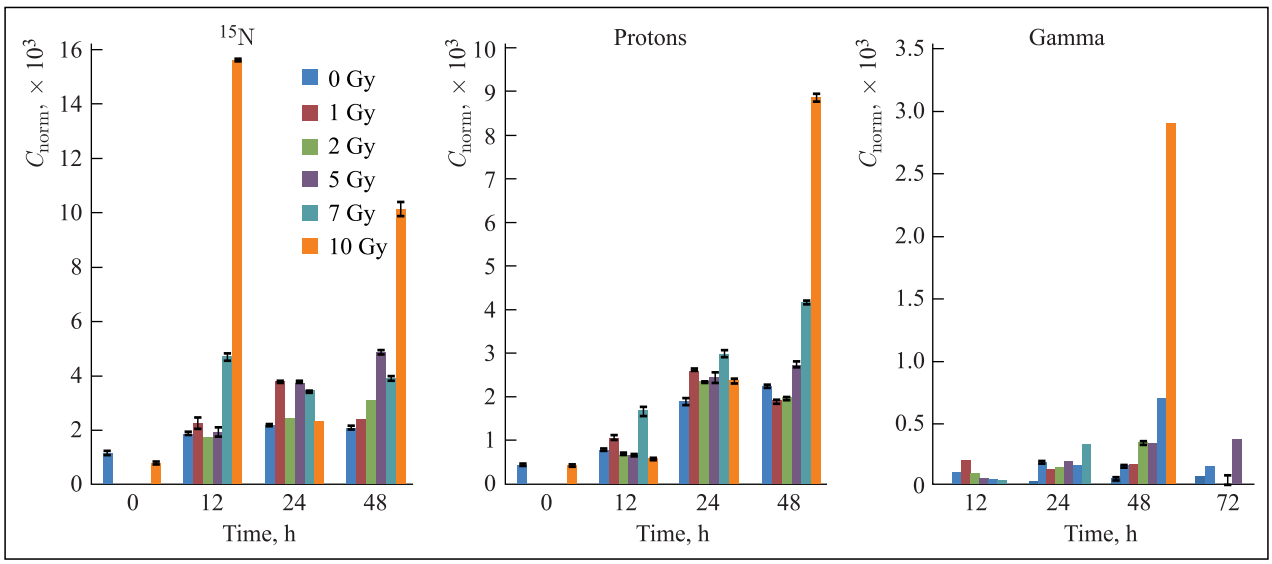

Fig. 15. A dependence of MCP-1 production on the postirradiation cultivation time for different radiation types. C_{norm} is the cytokine concentration normalized by a fixed cell number

ing on the type of radiation. A statistically significant increase in the MCP-1 concentration compared with the control level was observed at the doses of 2, 5, and 10 Gy of ion, proton, and γ-ray exposure, respectively. For IL-6, these values were 1 Gy of ion and 5 Gy of SOBP proton exposure; γ-ray exposure had no observable effect on the IL-6 yield. These data indicate that pathological changes in cerebral microglia can be induced by relatively low doses of heavy charged particle exposure, while the same doses of γ-ray and proton exposure have no observable effect on microglia.

MATHEMATICAL MODELING OF RADIATION-INDUCED EFFECTS

Mathematical modeling was continued of the structure of tracks of accelerated charged particles with different characteristics and processes of the induction of primary molecular damage. Simplified models of individual neurons and neural networks were developed as part of the simulation of the structure of particle tracks for studying changes in the activity of neural networks of different parts of the brain — mainly the hippocampus and prefrontal cortex — caused by exposure to accelerated heavy charged particles. Based on both simplified and complex (realistic) neuron models, a full model of the rat hippocampus exposed to radiation was constructed. In each neuron model, the cell body (soma) containing nuclear DNA, axon, and dendrites with spines and synapses distributed over them were determined. For exposure to accelerated charged particles with different physical characteristics, by the Monte Carlo modeling using the Geant4 package, a distribution was obtained of energy deposition events, the absorbed dose, and water radiolysis products in hippocampal neurons of different morphology (pyramidal neurons, mature and immature granular cells, mossy cells, and nerve stem cells) and in neural networks that they form. Modeling was performed of the formation and clustering of DNA molecular damage in nerve cells of different morphology, taking into account the radiolysis processes after the radiation injury (Fig. 16). The simulated data on the yield of the clustered DNA damage induced by heavy charged particles passing through the cell were used to calculate the relative biological effectiveness (RBE) of heavy charged particles with increasing their LET. The RBE was evaluated by the induction of DNA double-strand breaks and clustered double-strand breaks per cell per unit absorbed dose (Fig. 16, *b*). The modeling results were found to be in acceptable agreement with the known experimental data [12–17].

A mathematical model was developed describing radiation-induced changes in cell populations participating in neurogenesis and how these changes influence information processing by the hippocampus (Fig. 17, *a*). Modeling results show that accelerated heavy ions can irreversibly suppress neurogenesis, which causes errors in information encoding and retrieval by hippocampal neural networks (Fig. 17, *b*). Complex modeling methods thus allow interpreting radiation exposure effects on neural networks' functioning [18].

Research was continued to develop a model of the CA3 region of the hippocampus. With the NEURON simulation environment, a mathematical and computer model was constructed, containing a total of 1200 nerve cells. Based on this model, a calculation was performed of the generation of synchronous neural oscillations, which contribute to the formation of the γ and θ rhythms. Using the NAMD software and, as an example, the NMDA ionotropic glutamate receptor, which plays the key role in the regulation of synaptic plasticity, learning, and formation of different types of memory, a molecular dynamics modeling was performed of the

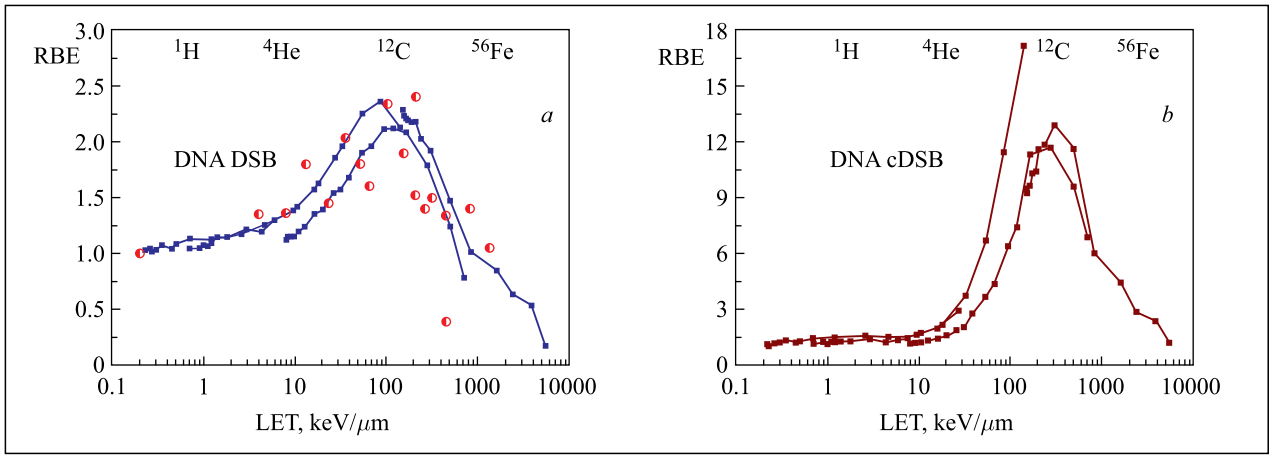

Fig. 16. A dependence of charged particles' RBE on their LET by the criterion of DNA DSB (*a*) and clustered DSB (cDSB) (*b*) induction: a comparison of simulation results (curves with symbols) and experimental data (large points)

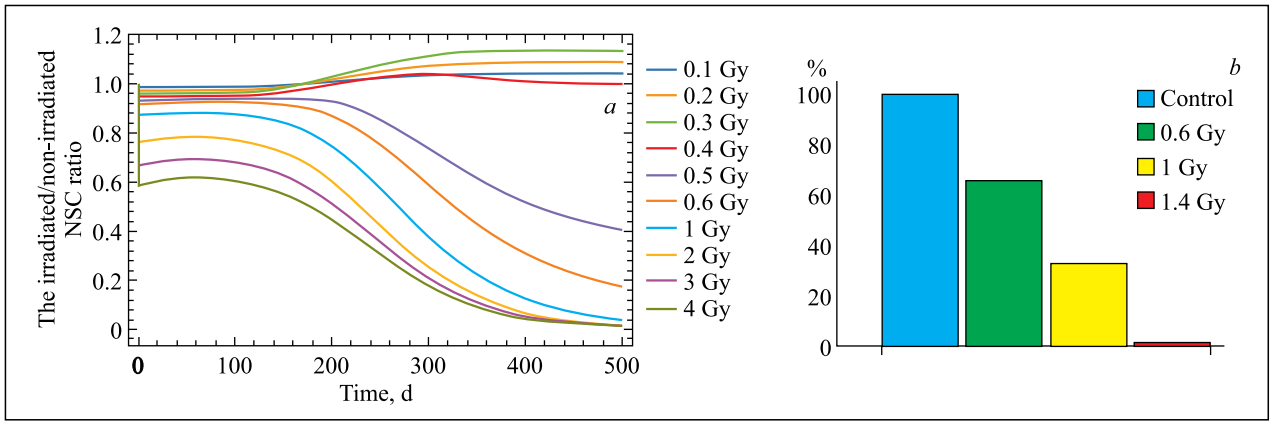

Fig. 17. Simulation of hippocampal neurogenesis after acute exposure to different doses of 600-MeV/nucleon iron ions: neural stem cell (NSC) population dynamics (*a*) and percentage of pattern retrieval success calculated from neural network activity after irradiation (*b*)

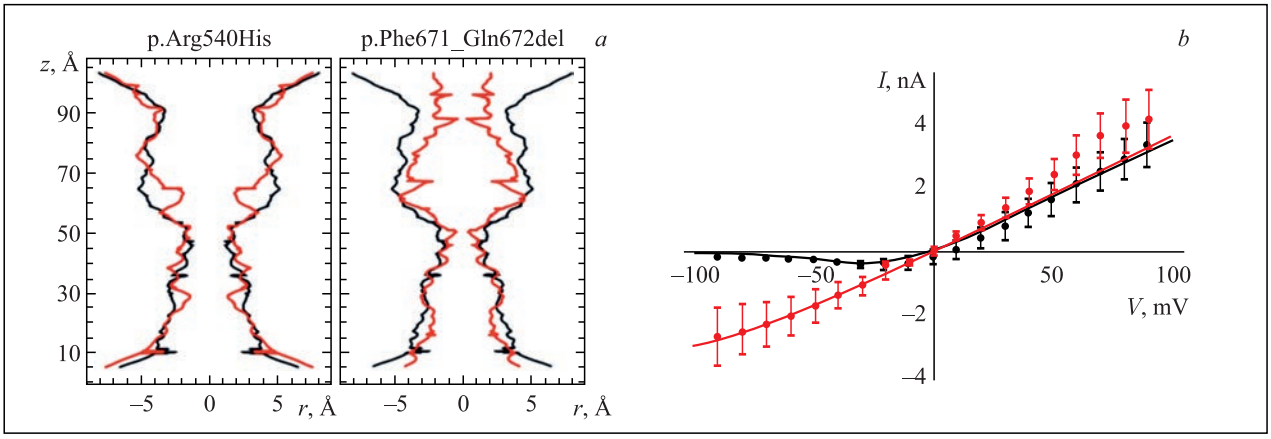

Fig. 18. Mutation effects in the *GRIN2* gene, which encodes the NMDA synaptic receptor's subunits: (*a*) ion channel geometry for the point mutation p.Arg540His and deletion p.Phe671_Gln672del (red) relative to the native form (black); (*b*) a comparison of calculated (curves) and experimental (points, according to *Fedele L. et al.* // Nat. Commun. 2018. V. 9. P. 957) voltage–current characteristics of the NMDA receptor for the native form (black) and the point mutation p.Asn615Leu (red)

activation of the NMDA receptor's full-atom structure (Fig. 18, *a*).

The influence was studied of single- and double-point mutations and a structure mutation (deletion) on the ion channel structure and functioning of the neural network as a whole. The highest ion conductance of a fully activated channel changes insignificantly between the native form and the examined forms with point mutations, but decreases sharply in the case of a deletion. This result agrees with the electrophysiological measurements made by L. Fedele et al. (Nat. Commun. 2018. V. 9. P. 957) (Fig. 18, *b*). A decrease in the activation time of the p.Arg540His and p.Asn615Leu forms can also affect the receptor's kinetics. An estimation of the macroscopic time of the NMDA receptor's opening/closure is beyond the applied molecular dynamics method and requires expansion of the model. The proposed model approach allows evaluation of the influence of mutations in hippocampal neuron genes on the synaptic receptors' condition.

The approach was tested on the experimentally known effects of the mutations in the transmembrane domain which lead to epileptic disorders. Based on the character of neural network activity and the corresponding electroencephalogram, it is possible to assess the macroscopic effect of a specific mutation type [19–24].

RADIATION PROTECTION PHYSICS AND RADIATION RESEARCH

In 2019, two experiments were conducted at the U-400M cyclotron (FLNR JINR) with ^{15}N ion beams of the initial energy of 46 MeV/nucleon. The Genom facility was partially upgraded: the electric motor was replaced with a stepper, and the software interface was changed. Numerous irradiations of cell culture samples and laboratory animals were performed: with 150–170-MeV and Bragg peak protons at the Pha-

sotron's medical beam (DLNP JINR) and ^{60}Co γ rays at the Rocus-M radiation facility.

A multisphere neutron spectrometer (with a 3″, 5″, 8″, 10″, 12″, and a heterogeneous 10″ + Pb spheres) was calibrated with a ^{252}Cf source in the open geometry. To this end, a calibration instrument was assembled at the height of 2.32 m above the ground at the DAN (dynamic albedo of neutrons) test bench, and a heterogeneous shadow cone was made. The experience of neutron spectrometry in a wide energy range in scattered fields at JINR's facilities was summarized [25].

An estimation was completed of the effective dose of galactic cosmic radiation that would be received by crew members within the habitable module on Mars missions [26]. The doses were estimated based on the detailed calculations of the mixed radiation field within the module [27] and proposed fluence-to-effective dose conversion coefficients for an astronaut-like cohort [28].

The work carried out over many years on the evaluation of the radiation conditions in the environment near the NICA accelerator complex was completed. The calculations take into account all possible radiation sources (the injection unit, booster, Nuclotron, collider, and MPD, SPD, and BM@N facilities in Building 205) and were performed for the specified beam losses and schedules of accelerator complex operation [29]. The calculations were done using universal Monte Carlo radiation transport codes GEANT4, MCNPX, and FLUKA. It was shown that for the specified design conditions the radiation situation around the accelerator complex will meet the regulatory radiation safety requirements.

A design was proposed, and energy sensitivity was calculated of a 10^4-MeV–1-GeV neutron dosimeter for zone radiation monitoring at the NICA accelerator complex [30].

As part of cooperation with the Space Research Institute (RAS, Moscow), the instruments FREND (fine-resolution epithermal neutron detector) for the ExoMars mission and ADRON (active detector of γ rays and neutrons) for the Luna-Glob and Luna-Resurs missions were tested with radionuclide neutron sources and neutron generators at the DAN test bench. A layout was proposed of an experiment at the Phasotron's medical beam (DLNP JINR) to verify the labeled proton method. A facility was prepared, and experiments were conducted to study the efficiency of the measurement of the characteristic γ radiation from planetary soil by landing modules with high radiation background [31, 32].

STUDYING COSMIC MATTER ON THE EARTH AND IN NEARBY SPACE

Research was continued on the formation of complex prebiotic compounds from the simpler ones. A number of experiments were conducted on the abiotic phosphorylation of DNA and RNA components [33]. A possibility was studied of the formation of prebiotic compounds as a result of serpentinization processes which took place during the Archean. The results indicate a probability of the geochemical origin of complex organic molecules. After 150-MeV proton irradiation of a mixed saturated alkaline solution of silica and formamide, a high catalytic activity of minerals forming in this mixture was revealed. Formation of different organic molecules, including nucleic bases, was observed.

New micropaleontological scanning electron microscopy studies of carbonaceous chondrite meteorites (Orgueil, Murchison, Polonnaruwa, etc.) were performed. In the Orgueil meteorite, fossilized rod-shaped and coccoid bacteria, diatoms, prasinophytes, pollen-like forms, spherical forms with appendices (presumably, acritarchs), testate amoebas, and filament forms resembling actinomycetes were found. Also, extended titanium-rich objects similar to sponges' spicules were found in this meteorite (Fig. 19). A number of findings were not interpreted strictly, but their shape undoubtedly indicates their biological origin.

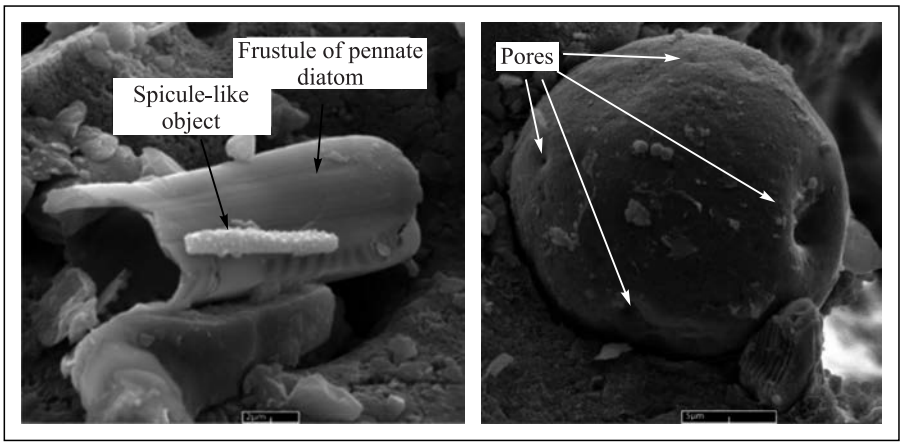

Fig. 19. A pennate diatom's shell, a sponge's spicule (presumably), and a fossilized prasinophyte in the Orgueil meteorite

The meteorite sample repository was extended to include a number of new samples: Murray (the USA), Aguas Zarcas (Costa Rica), Mukundpura (India), Tataouine (Tunisia), and Migei (Ukraine). The first studies of new samples were performed. In the Polonnaruwa meteorite, many diatom shells were found, as well as filament forms. In the Aguas Zarcas meteorite, filament forms were found resembling actinomycetes and cyanobacteria. Prasinophytes were found in the Murchison meteorite [34, 35].

CONFERENCES AND EDUCATION

In 2019, the Laboratory's researchers participated in ten scientific conferences in Russia and five conferences worldwide.

Jointly with the Council on Radiobiology of the Russian Academy of Sciences, the following two conferences were held: "Current Problems in Radiation Genetics" and "Radiobiological Basis of Radiation Therapy". The conferences were participated by more than 180 scientists representing research institutes and scientific organizations of the Czech Republic, Italy, Mongolia, Slovakia, Russia, and the USA.

The education process continued at the Department of Biophysics of Dubna University. The Department's current total enrolment includes 35 students and eight postgraduates. Six students successfully completed education and received their Master's diplomas in physics. One Doctoral dissertation was successfully defended in 2019.

Patent No. 2699670 was obtained in 2019 for a new method of enhancing the radiation effect on living cells: "A Method of Increasing the Formation Frequency of Ionizing Radiation-Induced DNA Double-Strand Breaks in Human Cells in the Presence of Radiomodifiers" (E. A. Krasavin, A. V. Boreyko, T. S. Bulanova, V. N. Chausov, E. A. Kulikova, G. N. Timoshenko). The method largely increases the biological effectiveness of therapeutic proton beams and gamma-ray facilities and brings the areas of the therapeutic use of proton and carbon ion accelerators much closer to each other.

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UNIVERSITY CENTRE

For almost 30 years, since its establishment in 1991, the JINR University Centre has been organizing, supporting, and developing the training programme for the scientific and engineering personnel of the Institute and its partner research centres in the JINR Member States. JINR UC organizes training of students from the JINR-based departments of the Russian universities and makes it possible for students and postgraduates from the Member States universities to write their theses on the basis of the Institute. The UC also runs international student programmes, practices, and schools. Great attention is paid to interaction with school students and teachers. The system of skill improvement and advanced training courses for JINR technical and engineering personnel has been actively developing and is in great demand.

JINR-Based Education. In 2019, about 500 students of the JINR-based departments of Moscow State University, Moscow Institute of Physics and Technology, Moscow Engineering Physics Institute, St. Petersburg State University, Kazan Federal University, Dubna State University, and the universities of the Member States were trained at the UC. Summer training courses and internships were organized for almost 500 university students from Armenia, Belarus, Cuba, Kazakhstan, Russia, Serbia, and Ukraine.

In 2019, 27 degree-seekers from Belarus, Kazakhstan, Mongolia, Russia, Ukraine, and Vietnam were assigned to JINR to prepare their PhD theses without studying academic programmes at PhD courses.

In 2019/2020, 153 lecture courses were developed for students from the JINR-based departments of Moscow Institute of Physics and Technology, Moscow State University, and Dubna State University. Their programmes are available at uc.jinr.ru.

International Student Practice. Over 15 years of running the International Student Practices (ISP) in JINR Fields of Research, more than 1700 representatives of the JINR Member States, Associate Members, and other states have taken part in the event. In 2019, ISP was held in four stages for 134 representatives of Azerbaijan, Belarus, Bulgaria, Chile, Cuba, the Czech Republic, Egypt, Poland, Romania, Serbia, Slovakia, and South Africa.

Stage 1 started on 3 June and was attended by 22 students from South Africa. Sixty-six students from Azerbaijan, Bulgaria, the Czech Republic, Poland, Romania, and Slovakia took part in Stage 2 that began on 8 July. Twenty-two students from Belarus, Chile, Cuba, Serbia, and South Africa participated in Stage 3 launched on 9 September. The final Stage 4 of the International Student Practice was held starting from 8 December 2019. To participate in this Stage of the Practice, 24 students from the Arab Republic of Egypt had an interview and went through a competitive selection at the Academy of Scientific Research and Technology of Egypt.

The participants listened to introductory lectures on the activities of JINR Laboratories and went on excursions to the basic facilities. Most of the Practice three-week period was devoted to working on research projects under supervision of JINR specialists.

JINR Summer Student Programme. Fifty-eight students and postgraduates from Azerbaijan, Belarus, Bulgaria, Cuba, Egypt, Italy, Kazakhstan, Mexico, the Netherlands, Poland, Romania, Russia, Serbia, Slovakia, Ukraine, and Uzbekistan took part in the Summer Student Programme 2019. Russian participants represented Moscow State University, Moscow Engineering Physics Institute, Dubna State University, universities of Belgorod, Irkutsk, Ivanovo, Kazan, Novosibirsk, Samara, St. Petersburg, Tomsk, Tula, and Yaroslavl. For 4–8 weeks, SSP participants have been working on research projects in the scientific departments of the Institute.

International Scientific Schools for Physics Teachers at JINR and CERN. For 10 years, the JINR University Centre, together with the European Organization for Nuclear Research (CERN), has been organizing international scientific schools for Physics teachers from the JINR Member States. In 2019, over 400 teachers from Armenia, Azerbaijan, Belarus, Kazakhstan, Moldova, Russia, and Ukraine took part in the event.

Twenty-three teachers and almost 100 school students from Belarus, Kazakhstan, Russia, and Ukraine became participants of the Summer School "Physics. Mathematics. Informatics". In 2019, the traditional School for teachers at JINR was held jointly with Dubna State University. The selection of Physics, Mathematics, and Informatics teachers was carried out on the basis of application forms submitted through teachers.jinr.ru. School students were selected by Dubna State University.

The updated and extended programme for teachers included popular-science lectures by JINR specialists, visits to JINR experimental facilities and laboratories, discussions and round tables on school education issues, and exchange of teaching experience. The school students attended a workshop in physics and masterclasses in programming, solved olympiad-level tasks, and worked on research projects. Their programme also included lectures and excursions to JINR Laboratories.

The organizers and partners of the Summer School were JINR, CERN, Dubna State University, Aerospace Systems Design Bureau, JSC "PKK Milander", JSC "NPK Dedal", JSC "PROMTECH-Dubna". The General Partner of the School was Yandex, the official media partner was Television Channel 360°.

On 3–10 November, the XII Scientific School for Physics Teachers from the JINR Member States was held at the European Organization for Nuclear Research (CERN). Twenty-four teachers from Belarus, Russia, and Ukraine participated in the programme that included popular-science lectures introducing them to the world of elementary particles, design of accelerators and detectors, gravitational waves, and experimental data processing technologies. At one of the lectures, the textbook "Nuclear Physics" for schools developed by the JINR staff members was presented. The participants also attended thematic exhibitions and operating facilities at CERN.

Lectorium. As part of the popularization of modern scientific knowledge and achievements, the JINR University Centre organizes social educational events including popular-science lectures for secondary- and high-school students (7–11 grades). These lectures help to expand knowledge about the most recent discoveries and achievements in science and technology using the research conducted at JINR as an example. The staff members of the Institute give lectures on the crucial issues of physics, informatics, and biology. At the beginning of 2019, the Lectorium project was launched at the educational institutions of Dubna, Moscow Region. Over 10 months, the 22 organized events have been attended by about 1080 students from Dubna and Moscow schools.

Outreach Events. To promote its outreach programme, JINR took part in the following science festivals:

— "Science Night" at Kazan Federal University;

— "Geek Picnic" Festival of Modern Technology, Science, and Arts in St. Petersburg ("Habitat" and "Outer Space" sites);

— All-Russia Science Festival NAUKA 0+ in Moscow and Dubna State University. The following activities were offered to the Festival visitors:

- public popular-science lectures;
- video conference MSU – JINR FLNR;
- entertaining demonstrations of physics and chemistry experiments;
- interactive exhibitions;
- demonstration of the models of JINR setups;
- demonstration of popular-science videos promoting JINR, its fields of research and basic facilities;

— World Dark Matter Day in Dubna.

Over 2019, 36 popular-science lectures were given to more than 2200 listeners.

In 2019, the JINR exhibition stand presented at five outreach events by the JINR UC Social Communications Group was attended by about 10 000 visitors.

Live Streams — Online Excursions. In 2019, test runs of online tours of the JINR Laboratories (FLNR, VBLHEP) were live streamed for the first time. During these streams, researchers of the Institute answered real-time questions from the audience. Such tours are intended for school students, university undergraduate and postgraduate students, and Science teachers.

JINR UC in Social Networks. JINR news are available on Vkontakte, Facebook, Instagram, Twitter. In addition, in 2019, the UC youth information channel "Dubnium" was created on the following sites: Vkontakte, Facebook, Instagram, and YouTube. The main goal is to stimulate interest in science and increase the awareness of the target audience on the possibilities of building a scientific career at JINR. Over the past year, 30 videos have been produced and uploaded to the Dubnium site on YouTube.

Copywriting and Designing of Information Materials. To popularize fundamental and applied research, as well as achievements and discoveries of JINR, information materials for school students were developed and published.

Activities for School Students. In the 2019/20 academic year, the Interschool Physics and Maths Open Classroom for secondary- and high-school students (6–11 grades) organized classes in Physics, Mathematics, and preparation for the Unified State Examination. Yandex.Lyceum started Programming classes.

Students of the Interschool Physics and Maths Open Classroom became the winners and prize-winners in the traditional 27th Open City Physics and Mathematics Olympiad, the First Olympiad named after P. Kapitsa in Experimental Physics in Dolgoprudny, the First Moscow Regional Tournament for Young Mathematicians organized by PhysTech Lyceum in Dolgoprudny.

Physics Days. On 13–14 April, the 6th science festival for children and adults "Physics Days" was held in Dubna. The Festival was dedicated to the 150th anniversary of the Periodic Table. The event programme included demonstrations of physics and chemistry experiments, master classes, quests, and quizzes. Besides participants from Dubna, school students from Bryansk, Glazov, Istra, Moscow, St. Petersburg, and Volgograd took part in the Festival.

Tournament "CyberDubna-2019". On 9–10 February, the Culture Centre "Mir" hosted the VIII Open Robotics Tournament of the Upper-Volga Educational Cyber Network "CyberDubna-2019". The Tournament organizers were JINR, International Computer School named after V. Volokitin and E. Shirkova, and the Center for Information Technologies and Analytics "Remote Electronic Laboratory". The participants were school students aged 8–17 from Dubna, Dmitrov, Yakhroma, Moscow, Protvino, and Eldigino village (Pushkino district). They built automated models, participated in competitions "Races along the Line" and master classes on the basics of designing and programming microcontrollers.

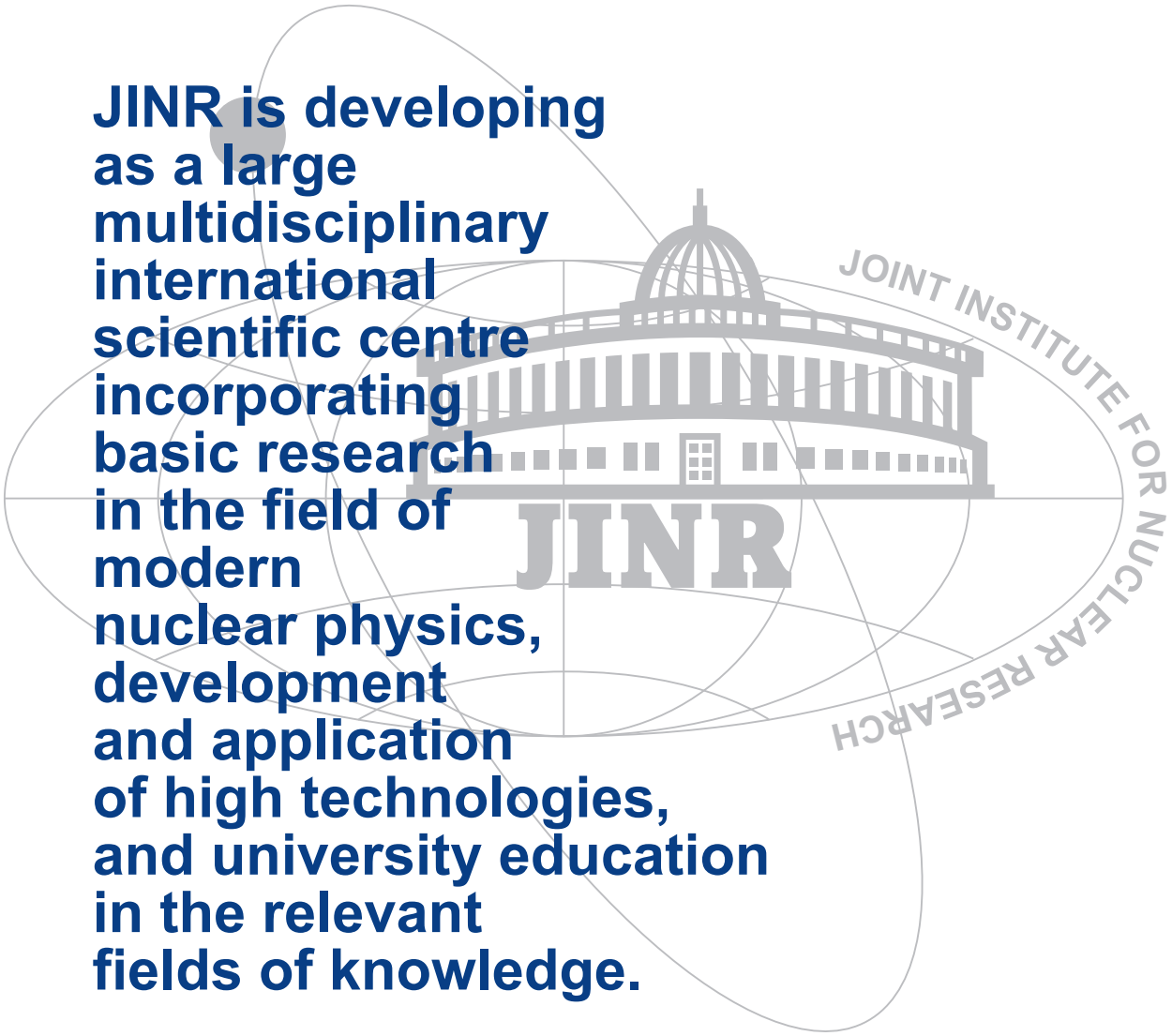
International Computer School 2019. On 3–17 August, JINR UC took part in the organization and running of the 31st International Computer School named after V. Volokitin and E. Shirkova (ICS-2019). The school students worked on research projects and listened to popular-science lectures. The event programme also included intellectual competitions, while the free time was devoted to films, board games, etc. In 2019, 45 students aged 7–16 from Russia, the USA, and Montenegro participated in the School.

Visits. In 2019, introductory visits to JINR were organized for 23 groups from Germany, Israel, France, and the Czech Republic. Six hundred and nineteen school students and teachers got acquainted with the scientific activities of JINR and the current research conducted by the Laboratories, visited the basic facilities, as well as the Museum of Science and Technology of JINR.

Skill Improvement. Two hundred and twenty JINR staff members, including top executives, engineers, technicians, and specialists, were trained in the normative legal acts and normative-technical documents stating requirements for industrial safety in various industries of supervision and certified by the Central Attestation Commission of the Institute and the Territorial Attestation Commission of the Central Department of Rostekhnadzor. One hundred and ten JINR staff members were trained at the courses intended for the personnel maintaining the facilities subordinate to Rostekhnadzor. The training in the basics of fire safety was organized for 123 JINR staff members. Thirty students of Dubna State University College and Moscow Region Agrotechnology College were trained at JINR.

In 2019/2020, 160 JINR staff members signed up for the language courses organized by JINR UC: English — 115 people, French — 18 people, German — 18 people, Russian — 9 foreign specialists.

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.



Moscow–Dubna, 9–13 September. The international Bogoliubov conference “Problems of Theoretical and Mathematical Physics”

Dubna, 19 June. The seminar dedicated to the memory of Professor G. Efimov (1934–2015)

Dubna, 17 September. The jubilee seminar dedicated to the 70th anniversary
of Chief Researcher of the JINR Bogoliubov Laboratory of Theoretical Physics Professor V. Burov

Dubna, 22 July – 2 August. Organizers and participants of the Helmholtz international school “Quantum Field Theory at the Limits: From Strong Fields to Heavy Quarks”

Dubna, 5 August. The Helmholtz international school “Cosmology, Strings and New Physics”

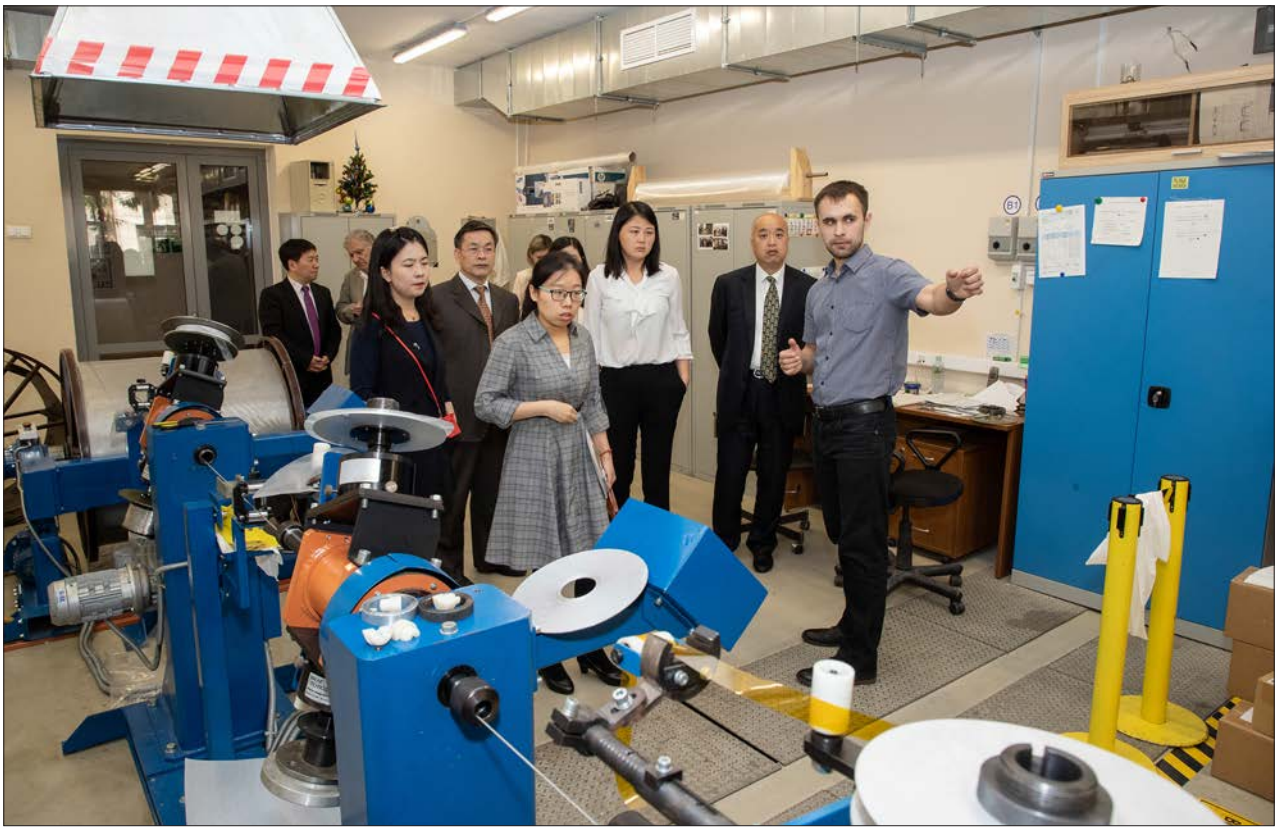
Dubna, 16–19 September. The participants of the 2nd international workshop “Theory of Hadronic Matter under Extreme Conditions”

Dubna, 14–15 March. Participants of the meeting of the Section of Nuclear Physics of the RAS Physical Sciences Department on an excursion at the Veksler and Baldin Laboratory of High Energy Physics

Dubna, 18–19 April. The interdepartmental delegation of the Socialist Republic of Vietnam on an excursion at the Veksler and Baldin Laboratory of High Energy Physics

Dubna, 3 April. The meeting of the working group on participation of China in the NICA megascience project

The Veksler and Baldin Laboratory of High Energy Physics, 31 May.
The delegation from the Hefei city of the People's Republic of China on a working visit at the Joint Institute



The Veksler and Baldin Laboratory of High Energy Physics, 17 May. The President of the Asia Pacific Centre for Theoretical Physics Yunkyu Bang at the factory of superconducting magnets

The Veksler and Baldin Laboratory of High Energy Physics, 19 June.
The meeting of the leaders of the CMS collaboration with a group of CMS project participants from JINR

Dubna, 12 July. Representatives of the RF Ministry of Science and Higher Education, the Bauman MSTU and MIPT on a visit to JINR

Dubna, 29 August. A delegation from the Federal Republic of Germany on an excursion to the Veksler and Baldin Laboratory of High Energy Physics

The Veksler and Baldin Laboratory of High Energy Physics, 27 June. At the final meeting of the Laboratory Dissertation Council

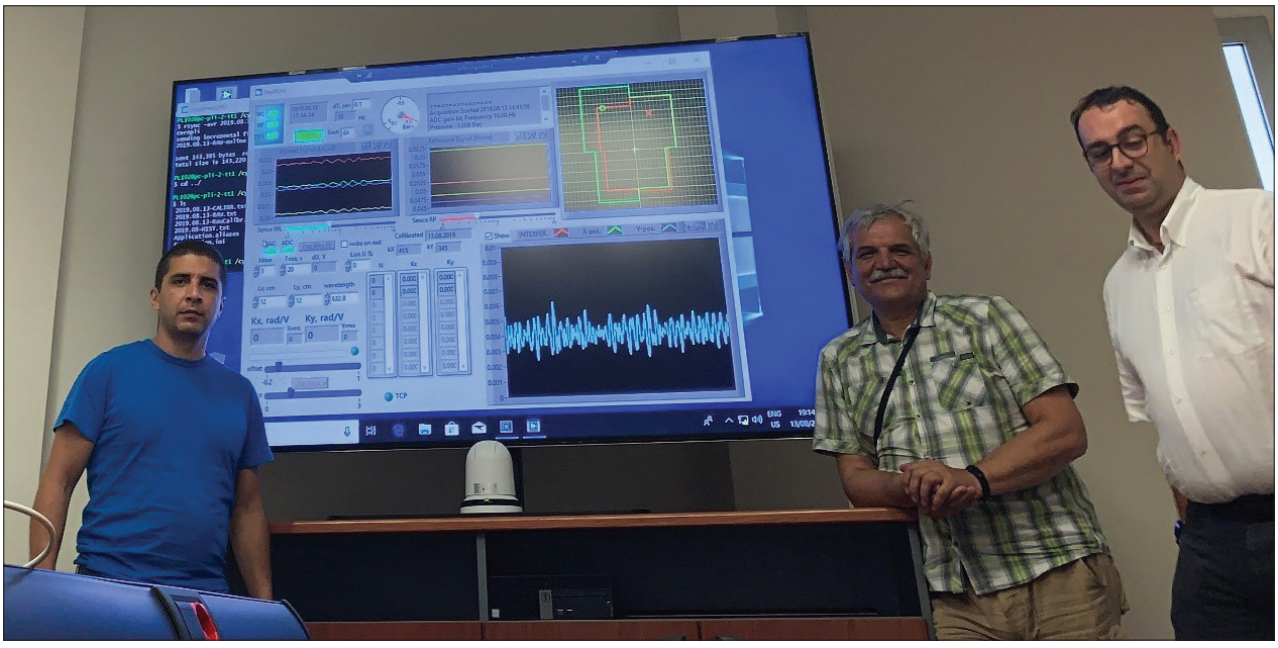
The Veksler and Baldin Laboratory of High Energy Physics, 14–15 October.
Participants of the 4th Collaboration Meeting of the BM@N Experiment

The Veksler and Baldin Laboratory of High Energy Physics, 19 September. The participants of the SC session at the inauguration of the NICA Computing Centre

The Veksler and Baldin Laboratory of High Energy Physics, 23 December. Launching of technological testing of the Booster for the NICA accelerator complex

Dubna, 22 February. The V. Dzhelepov Prize is presented to Chief Researcher of DLNP V. Komarov.
Left to right: V. Bednyakov, V. Komarov, and V. Matveev

Visualization of angular microseismic oscillations registered by the precision
laser inclinometer in the VIRGO conference hall. Left to right: N. Azaryan, M. Lyablin, and B. Di Girolamo



Dubna, 1–5 July. The 69th international conference on nuclear spectroscopy and nuclear structure “Nucleus-2019”

On the slopes of Mount Elbrus, 10–18 April.
The participants of the 16th Baksan international school “Particles and Cosmology” (*photo by A. Yudin, G. Rubtsov*)

Baikal, April. Deep-underwater assembly of a garland of the neutrino telescope Baikal-GVD

One more optical module of the telescope is prepared for immersion

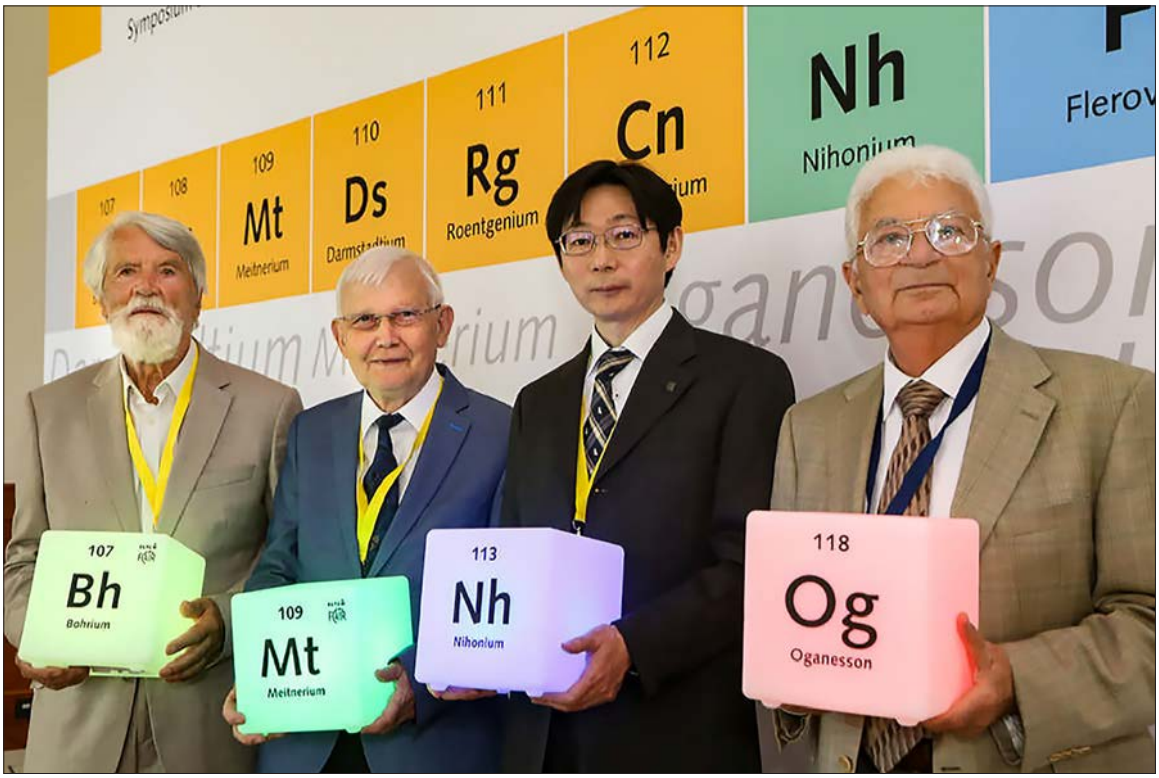
The last photo before leaving the ice. The Baikal expedition-2019 is completed!

Dubna, 25 March. The ceremonial launch of the DC-280 cyclotron of the SHE Factory and the inauguration of the alley named after A. Hrynkiewicz

Dubna, 30–31 May. The international symposium “The Present and the Future of the Periodic Table of Chemical Elements”

The FLNR Scientific Leader Academician Yu. Oganessian and the laureates of the Flerov Prize — Corresponding Member of the Russian Academy of Sciences N. Tarasova, Professor of the University of Nottingham Sir M. Poliakoff, and graduates of the Flerov Lyceum No. 6 A. Surkova and G. Adamyan


Colliding Neutron Stars
Origin of Gold



Wilhelmshaven (Germany), 25–30 August. The four element discoverers (left to right): Professor P. Armbruster and Professor G. Münzenberg (GSI, Germany), Dr. K. Morimoto (RIKEN Nishina Center for Accelerator-Based Science, Japan), and Professor Yu. Oganessian (JINR, Dubna) (*photo by Björn Lübbe, Wilhelmshavener Zeitung*)

Sejong (South Korea), 2 April. The Protocol on cooperation between JINR and the Korea University is signed

The Flerov Laboratory of Nuclear Reactions, 4 April. The meeting of Minister of Education and Science of the Republic of Armenia A. Harutyunyan and Minister of Transport, Communication and Information Technologies of RA H. Arshakyan with FLNR Scientific Leader Academician Yu. Oganessian during a reconnaissance visit to JINR

The Flerov Laboratory of Nuclear Reactions, 18 April. The excursion to the Superheavy Element Factory for the delegation of the Ministry of Science, Technology and Environment of the Republic of Cuba and the Embassy of Cuba in the Russian Federation

Dubna, 5 June. The delegation from the China Institute of Atomic Energy, headed by CIAE Director Wan Gang, on an excursion to the Frank Laboratory of Neutron Physics

Dubna, 10–14 June. The participants of the 27th International Seminar on Interaction of Neutrons with Nuclei (ISINN-27)

A monument to Academician I. Frank was unveiled in Dubna on 6 November

The Laboratory of Information Technologies, 14 May. The representatives of the JINR Directorate, the leaders of management departments visited the Laboratory to get acquainted with the opportunities of the supercomputer “Govorun”

Stará Lesná (Slovakia), 1–5 July.
Participants of the international conference “Mathematical Modelling and Computational Physics” (MMCP’2019)

Budva (Republic of Montenegro), 30 September – 4 October. Participants of the 27th International Symposium on Nuclear Electronics and Computing and the international student school in the framework of the symposium NEC'2019

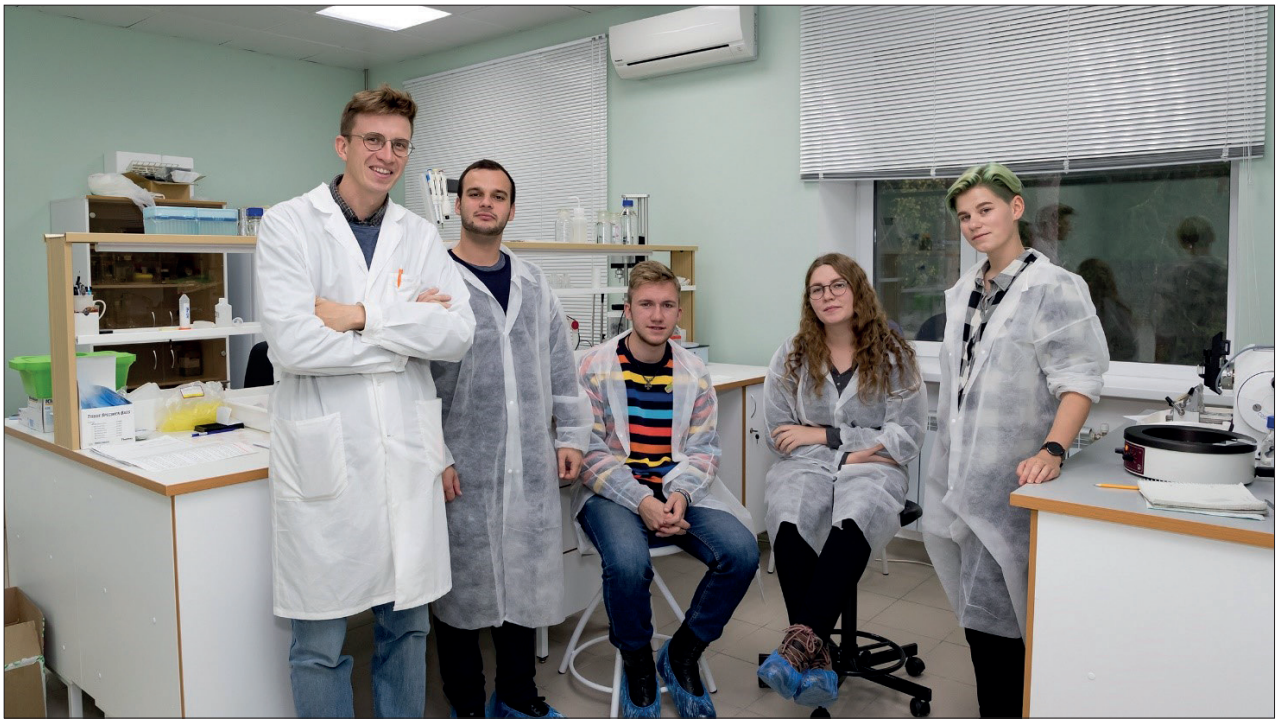
The Laboratory of Information Technologies, 15 November. The participants of the training seminar "Intel Architectures and Technologies for High-Performance Computing and Machine/Deep Learning (ML/DL) Tasks"

The Laboratory of Information Technologies, 14 November. The demonstration of the second modification of the JINR “Govorun” supercomputer in the LIT computer room

Dubna, 17–18 October. The 3rd Russian scientific conference
with international participation “Radiobiological Basis of Radiation Therapy”

Dubna, 27–28 June. The participants of the conference “Current Problems in Radiation Genetics”

The Laboratory of Radiation Biology, 24 September. Practice class for students

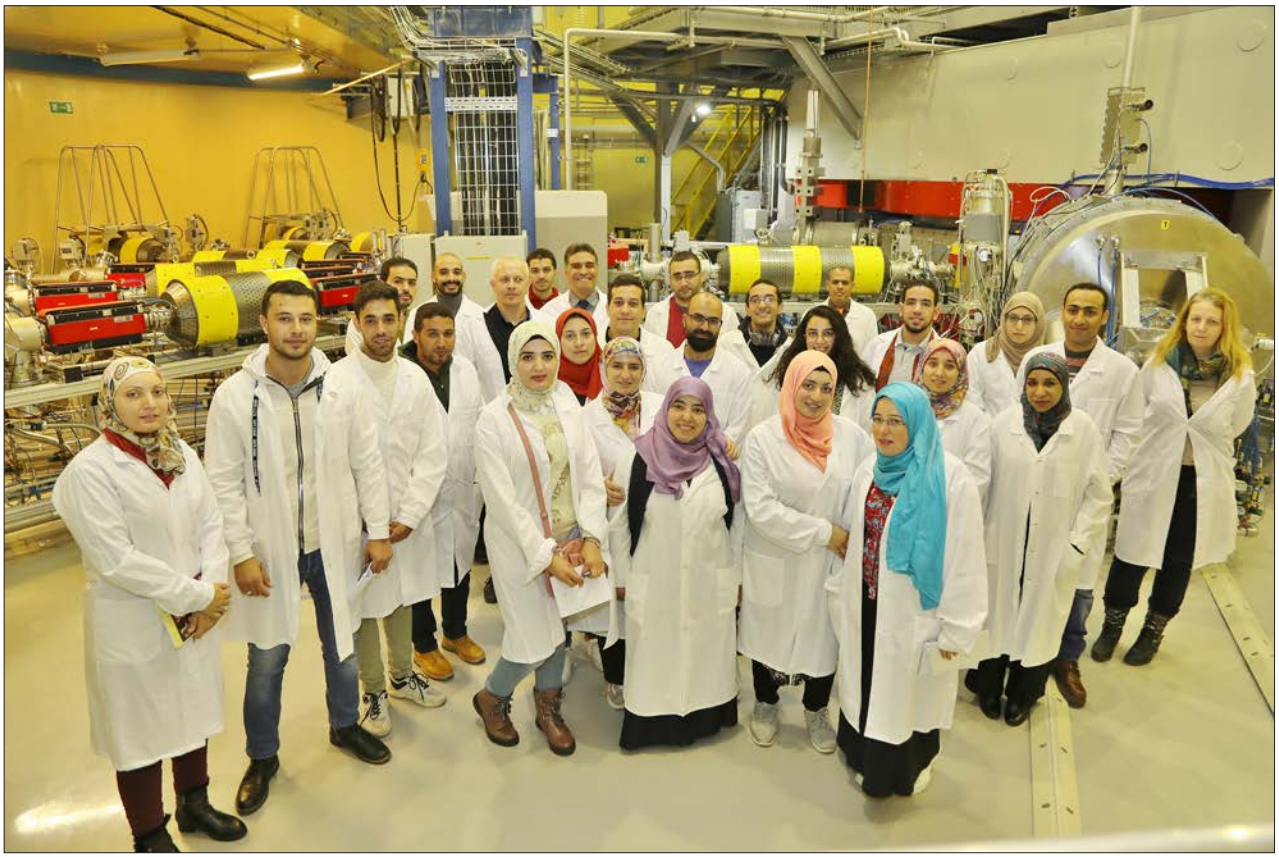


South Africa, 10–29 January. JINR staff members and RSA students participating in the Physics School at iThemba LABS

Dubna, 17 September. The “International Morning” is an informal event held as part of student practices of the JINR University Centre

CERN (Geneva), 3–10 November. XII Scientific School for Physics Teachers from the JINR Member States

Dubna, December. The participants of the 4th stage of the International Student Practice 2019,
students from the Arab Republic of Egypt, on an excursion at the Flerov Laboratory of Nuclear Reactions



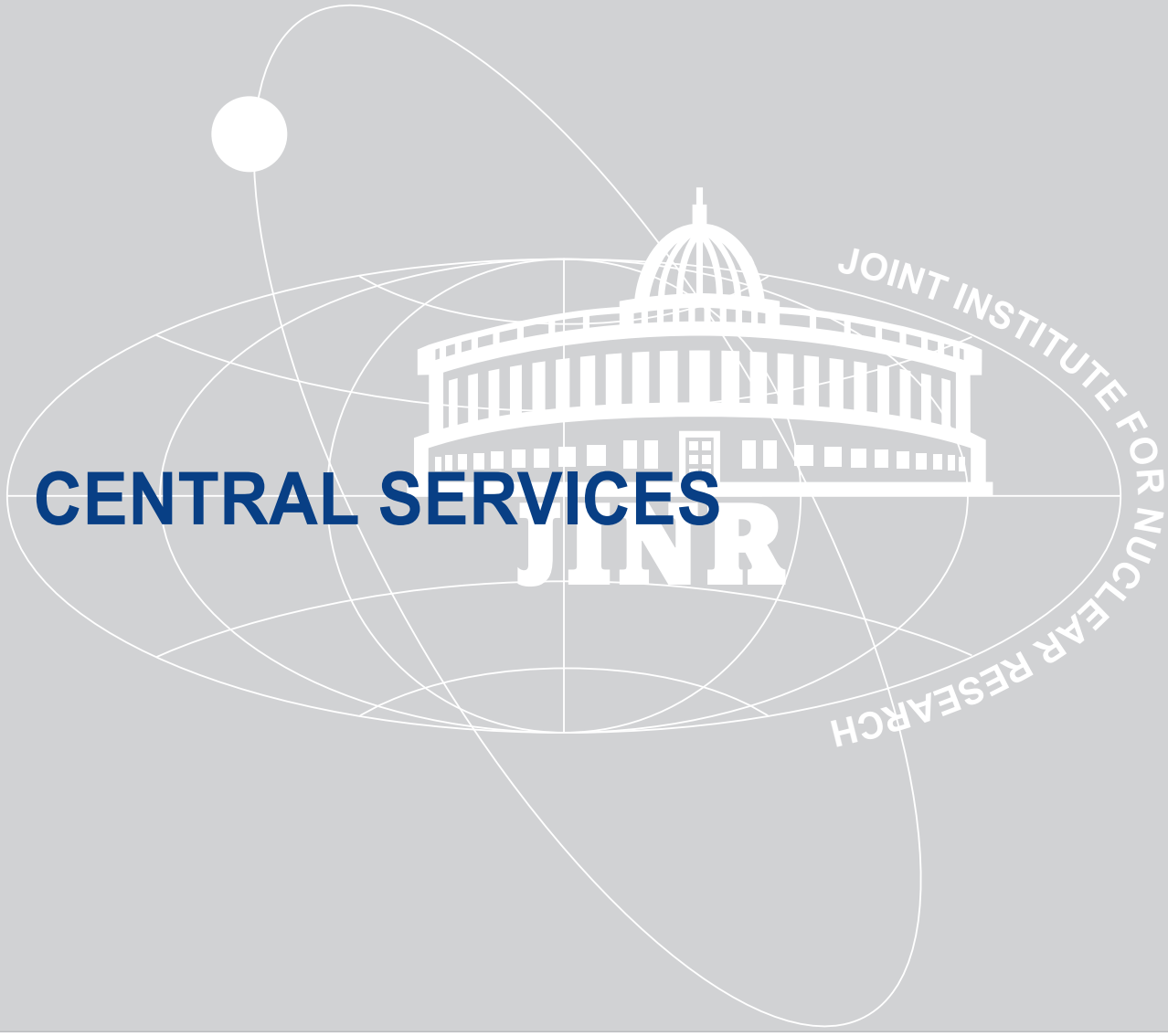
Sinaia (Romania), 1–10 September. Participants of the VIII International Pontecorvo Neutrino Physics School. Professor S. Bilenky gives a lecture

Dubna, 29 October – 6 November. The joint CERN–Japan–Russia international accelerator school “Ion Collider Physics”

Dubna, 15–19 April. The 23rd International Scientific Conference of Young Scientists and Specialists of JINR (AYSS-2019)

Lipnya, 26–28 July. The 23rd Summer School for Young Scientists and Specialists (Lipnya-2019)

2019



CENTRAL SERVICES

PUBLISHING DEPARTMENT

In 2019, the Publishing Department issued 61 titles of publications and 43 titles of official documents.

Among the books of abstracts and proceedings of various conferences, schools and workshops organized by JINR that appeared in 2019 are the following ones: the Proceedings of the conference "New Trends in High-Energy Physics" (Budva, Montenegro, 24–30 September 2018), the Proceedings of the XXVI International Seminar on Interaction of Neutrons with Nuclei (ISINN-26) (Xi'an, China, 28 May – 1 June 2018), the Proceedings of the Russian conference with international participation "Current Problems in Radiation Genetics" (Dubna, 27–28 June 2019), the Book of Abstracts of the LXIX international conference on nuclear spectroscopy and nuclear structure "Nucleus-2019" (Dubna, 1–5 July 2019), the Proceedings of the 14th international workshop "Relativistic Nuclear Physics: from Hundreds of MeV to TeV" (Stará Lesná, Slovak Republic, 26 May – 1 June 2019).

The JINR Annual Report for the year 2018 (Russian and English versions) was published.

Among the publications issued in 2019 are the two volumes of the book "The Nanoradian Precision Laser Inclinometer" by J. Budagov, B. Di Girolamo, and M. Lyablin (in English), a book by A. P. Isaev and V. A. Rubakov "Theory of Groups and Symmetries. Representations of Lie Groups and Algebras. Applications", a collection "The Blokhintsev Universal Public Library of JINR" dedicated to the 70th anniversary of the Library, and a monograph "Integral Assessment of Environment Condition on the Territory of Dubna, Moscow Region" by I. Z. Kamanina, S. P. Kaplina, O. A. Makarov, and N. A. Klikodueva.

In 2019, six issues of the journal "Physics of Elementary Particles and Atomic Nuclei" that included 49 papers came out. Six issues of the journal "Physics of Elementary Particles and Atomic Nuclei, Letters" that included 133 papers were published.

The information bulletin "JINR News" was continued to be published in Russian and English.

Fifty-one issues of the JINR weekly newspaper "Dubna: Science, Cooperation, Progress" were published in 2019.

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 over 176 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", "Theoretical and Mathematical Physics", "Bulletin of the Russian Academy of Sciences: Physics", "Instruments and Experimental Techniques", "Nuclear Physics and Engineering", "Radiochemistry", "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 2018" was issued. Publication of express bulletins of the Licensing and Intellectual Property Department was continued.

The Publishing Department fulfilled numerous orders of JINR Laboratories to produce poster presentations of the Institute's staff members for submission to conferences and workshops.

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 123 thousand various forms were printed.

The Publishing Department started 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.

SCIENCE AND TECHNOLOGY LIBRARY

In 2019, the JINR Science and Technology Library (STL) rendered services to 2000 readers. An electronic loan system has been implemented. 6600 copies of publications were given out. As of 1 January 2020, the library stock amounted to 429 965 copies, 194 072 of them being in foreign languages. 172 publications ordered by readers were received via the interlibrary loan system, 61 requests from other libraries were completed. On the whole, the library received 2116 copies of books, periodicals, preprints and theses from all acquisition sources including 746 publications in foreign languages. All the new publications were registered in the central catalogues, branch catalogues and in the information system "Absotheque".

The weekly express bulletins "Books", "Articles", "Preprints" (156 issues) were published with information including 8308 titles. Electronic versions of the bulletins are distributed among 100 addresses via e-mail. Subscription is available via the STL website 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 weekly. 1593 publications were displayed on them. Six topical exhibitions were organized.

The electronic catalogues of books, journals, articles, preprints, theses and author's abstracts are accessible in Internet at the address: http://lib.jinr.ru:80http://lib.jinr.ru:8080/OpacUnicode/80/OpacUnicode. The total number of requests to the electronic catalogues was 15 000. In the electronic catalogue in the personal account the readers can order requested literature and look through their reader's register forms (the Library website, the section "Electronic catalogue").

"The Bibliographic Index of Papers Published by JINR Staff Members in 2018" (1465 titles) was prepared. The Index is available on the Library website, in the section "Services": http://lib.jinr.ru/buk/2016/bibl_uk.php. Three bibliographic indexes have been prepared.

2496 JINR preprints and communications have been scanned and added to the electronic catalogue. The database of papers of JINR scientists is Internet accessible.

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 our 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 Library's participation in the Ministry of Science and High Education Consortiums and the RFBR, JINR scientists are provided with the electronic access to the full-text versions of journals of the following publishing houses: Elsevier, Wiley, American Physical Society, American Institute of Physics, Springer, IEEE Digital Library, as well as journals "Nature", "Science", and world information retrieval databases Web of Science, MathSciNet and Scopus.

Under the project "History of JINR and Dubna in Books, Journals and Central Newspapers", 72 new bibliographic records have been introduced. The information system "Literature about JINR Scientists" is available on the page of the site of JINR STL "Publications about JINR": http://who-is-who.jinr.ru/catalog3/main.html.

In 2019, in exchange for JINR publications printed by the JINR Publishing Department, the Library received 438 publications from 10 countries. Among them 54 issues were from Russia, 22 from Romania, 18 from Ukraine, 214 from Germany, 9 from France, 16 from Japan, and 15 from CERN.

In 2019, within the framework of the information system "Absotheque", the input of documents to electronic catalogue was for: books — 793 titles, journals — 1526 numbers, preprints — 2836 titles, theses and author's abstracts — 515 titles, book articles — 417 titles, and journal articles — 7316 titles.

As of 1 January 2020, the total number of records in the information system "Absotheque" was 312 424.

Bibliometric Factors of Publication Activity of JINR Staff Members (by Web of Science Database on 31.01.2020)

JINR publication statistics in 2019 was as follows:

- Total number of publications — 1 316;
- Total number of citations — 1 388;
- Excluding self-citations — 1 120;
- Average citations per article — 1.05;
- 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	314
Azerbaijan	210
Belarus	271
Bulgaria	193
Cuba	78
Czech Republic	419
Georgia	221
Kazakhstan	41
Moldova	10
Mongolia	72
Poland	447
Romania	253
Slovakia	245
Ukraine	259
Uzbekistan	41
Vietnam	24

* In alphabetical order.

Table 2. Joint publications with authors from Associate Members

State *	Number of publications
Egypt	140
Germany	597
Hungary	360
Italy	470
Serbia	244
South Africa	208

* 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	510	Estonia	119
China	452	Ecuador	116
France	438	New Zealand	116
England	382	Latvia	115
Switzerland	379	Lithuania	115
Turkey	370	Chile	111
Brazil	357	Argentina	110
India	333	Qatar	106
Austria	320	Slovenia	103
Greece	310	Morocco	100
South Korea	287	U Arab Emirates	98
Japan	285	Saudi Arabia	97
Spain	277	Sri Lanka	81
Sweden	271	Indonesia	78
Pakistan	269	Peru	78
Taiwan	264	Palestine	27
Netherlands	261	Montenegro	18
Portugal	254	Tajikistan	9
Australia	233	Venezuela	9
Croatia	232	Uruguay	5
Finland	223	Malta	4
Colombia	220	Uganda	4
Mexico	209	Wales	4
Norway	202	Lebanon	3
Thailand	198	Nigeria	2
Denmark	189	Oman	2
Belgium	149	Sudan	2
Scotland	136	Albania	1
Canada	135	Algeria	1
Cyprus	128	Bosnia and Herzegovina	1
Israel	126	Costa Rica	1
Iran	124	Jordan	1
Malaysia	123	Macedonia	1
Ireland	122	Tunisia	1

* In order of decreasing number of publications.

LICENSING AND INTELLECTUAL PROPERTY DEPARTMENT

In 2019, the activities of the Licensing and Intellectual Property Department (LIPD) were conducted in the following areas:

Industrial Intellectual Property Protection. In this area, work was done on applications for JINR patents that had undergone the formal Federal Institute of Industrial Property (FIIP) expertise in 2018–2019. Arrangements were done; changes, alterations and clarifications were agreed upon and included into the application documents according to the comments rendered by FIIP experts. Expert evaluation was conducted of 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; for five elaborations, in collaboration with the authors, packages of submission documents were prepared and forwarded to RF Rospatent for patents on inventions:

— "Superconducting compact isochronous cyclotron";

— "A method of forming balanced trajectories in cyclic accelerator with constant orbit radius";

— "Magnetic system of inductive synchrotron with magnetic field constant in time";

— "A method of forecasting of the risk of disease development related to the level of immunoglobulin E(IgE) in human blood serum";

— "Nano-ion condenser based on nano-powders".

In 2019, work was finished on applications submitted earlier and seven RF patents were obtained for the inventions:

— "A device for extraction of charged particles from the cyclic accelerator" by G. Dolbilov;

— "A method of analysis of atomic composition of organic substances and a device to apply it" by S. Tyutyunnikov and V. Shalyapin;

— "A device to watch solar corona" by A. Borodin;

— "A device to study properties of straw-tube of coordinate particle detector" by A. Volkov, M. Kravchenko and A. Pavlov;

— "A method of simulation of chemical behaviour of superheavy elements' atoms" by V. Domanov;

— "A method to increase the frequency of formation of DNA double-strand breaks in human cells at the action of ionizing radiation in conditions of the radiomodifiers' influence" by E. Krasavin, A. Boreiko, E. Kulikova, T. Bulanova, G. Timoshenko and V. Chausov;

— "Superconducting compact isochronous cyclotron" by K. Bunyatov, G. Shirkov, S. Shirkov, G. Karamysheva, O. Karamyshev, V. Malinin, S. Gursky and D. Popov.

Three computer programs were registered in Rospatent: "Program of visualization of spectrometric data spectra viewer" by A. Kirilov, L. Truntova and I. Gapon; "Program complex Sonix+" by A. Kirilov, I. Morkovnikov, S. Murashkevich, T. Petukhova and L. Truntova; "Program of adjusting neutron reflectometers ICE" by A. Kirilov and I. Gapon.

As of 1 January 2020, JINR possesses 73 RF patents for invention in force.

Patents and Information. In 2019, 36 issues of the federal state institution "Federal Institute of Industrial Property" of the bulletin "Inventions. Utility Models" 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". The LIPD stock is 3379 Rospatent bulletins.

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 (https://oliis.jinr.ru/).

Standardization. Standard library was supplemented: 20 new intergovernmental and state RF standard documents, 12 GOST directories and standard information directories for 2019; directories of national

standards and technical conditions, guidelines, recommendations and regulations issued in 2019. 187 alterations were introduced into relevant documents of the standard library files and subscribers' copies on the basis of these norm documents (NDs). Fifteen 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 "The Catalogue of Normative Legal Acts and Norm Documentation Used at the Joint Institute for Nuclear Research" is kept. As of the end of 2019, it contains about 10 000 standards and norm documents with hyper references to documents on sites of the Federal Agency on Technical Regulation and Metrology (Rosstandart) and the legal reference system "Consultant Plus".

Work was done on classification of documents included into DB according to the All-Russian classificatory of standards ОК (МК (ИСО/ИНФКО МКС) 001-96. "The Catalogue of Normative Legal Acts and Norm Documentation Used at the Joint Institute for Nuclear Research" is placed on the internet page of LIPD. The norm-technical documentation on JINR activities is updated.

2019

ADMINISTRATIVE ACTIVITIES

STAFF

As of 1 January 2020, the total number of the staff members at the Joint Institute for Nuclear Research was 5176.

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; 234 Doctors of Science, 621 Candidates of Science, 52 Professors and 27 Assistant Professors.

In 2019, 592 people were employed and 481 people were discharged because of engagement period expiry and for other reasons.

AWARDS

For the services for JINR and international cooperation the ***Anniversary Medal "90 years of the Moscow Region"*** was awarded to 1 staff member; the ***Honorary Mention of the Governor of the Moscow Region*** was awarded to 1 staff member; the ***Honorary Diploma of the Mayor of the Dubna city*** was awarded to 3 staff members; the ***Honorary Mention of the Mayor of the Dubna city*** was awarded to 1 staff member; the ***JINR Honorary Service Medal*** was awarded to 2 staff members; the title ***"Honorary JINR Staff Member"*** was conferred to 10 staff members. A number of staff members of the Institute received other departmental, city and Institute awards.

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Joint Institute for Nuclear Research. 2019

Annual Report

2020-9

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