I. Preamble

The Chair of the PAC for Nuclear Physics, V. Nesvizhevsky, presented an overview on implementing the recommendations taken at the previous meeting.

JINR Vice-Director S. Dmitriev informed the PAC about the resolution of the 133rd session of the JINR Scientific Council (February 2023) and the decisions of the JINR Committee of Plenipotentiaries (March 2023).

The PAC is pleased to note that the recommendations of the previous PAC meeting concerning JINR research in the area of nuclear physics were accepted by the JINR Scientific Council and the JINR Directorate.

II. Opening of new projects within the framework of the extended theme "Theory of Nuclear Systems"

The PAC took note of the report by N. Antonenko on the structure of the extended theme "Theory of Nuclear Systems" (01-3-1136-2019), which includes four projects. The PAC heard proposals to open new projects "Low-energy nuclear dynamics and properties of nuclear systems", "Microscopic models for exotic nuclei and nuclear astrophysics", "Quantum few-body systems", and "Relativistic nuclear dynamics and nonlinear quantum processes" presented by heads of the projects N. Antonenko, A. Dzhioev, A. Motovilov, and S. Bondarenko, respectively.

The PAC highly appreciates the current state of research on the theme and the scientific programmes of the four projects proposed for implementation in 2024–2028: structural features of nuclei far from the stability line, structure of superheavy nuclei, interaction of nuclei at low energies, fusion and fission dynamics, astrophysical reactions, low-energy particle systems, nuclear dynamics at relativistic energies, properties of hot and dense nuclear matter, nonlinear quantum processes in strong polarized electromagnetic fields. The PAC also highly appreciates the connection between theoretical research and the experimental programme of JINR.

Recommendation. The PAC recommends opening four new projects: "Low-energy nuclear dynamics and properties of nuclear systems", "Microscopic models for exotic nuclei and nuclear astrophysics", "Quantum few-body systems", and "Relativistic nuclear dynamics and nonlinear quantum processes" until the end of 2028. The PAC supports the proposed structure of the extended theme "Theory of Nuclear Systems".

III. Proposal for extending the theme "Synthesis and Properties of Superheavy Elements, the Structure of Nuclei at the Limits of Nucleon Stability" and opening new projects in this theme

The PAC heard with interest a proposal to extend the theme "Synthesis and Properties of Superheavy Elements, the Structure of Nuclei at the Limits of Nucleon Stability" (03-5-1130-2017) presented by S. Sidorchuk. The main directions of scientific research for the period 2024–2030 within the framework of the theme are related to the study of the heavy and superheavy nuclei and atoms as well as light nuclei far from the β-stability line. Research in the field of superheavy nuclei will be aimed at the synthesis of new elements of the periodic table and their isotopes, study of the properties of radioactive decay by nuclear spectroscopy (α-, β-, γ-spectroscopy), study of the chemical properties of new elements as well as the study of the mechanisms of nuclear reactions leading to the formation of new, still unknown nuclei. The scientific programme also includes studies of the structure of light nuclei at the nuclear stability boundary and the mechanisms of their formation.

Within the framework of this theme, two projects are being opened with implementation dates of 2024–2028: "Investigation of heavy and superheavy elements" and "Light exotic nuclei at the borders of nuclear stability".

The PAC heard with interest a report on the project "Investigation of heavy and superheavy elements" presented by A. Karpov. The main tasks of the project are the synthesis and study of the nuclear and atomic (chemical) properties of the heaviest elements as well as the study of the mechanisms of nuclear reactions leading to the formation of such elements. Research will be mainly carried out at the SHE Factory.

The PAC heard with interest a report on the project "Light exotic nuclei at the borders of nuclear stability" presented by G. Kaminski. The project will be aimed at producing, as well as studying the structure and decay properties of isotopes of light elements located near the borders of nucleon stability. Research in this direction will be carried out on the modernized U-400M accelerator and ACCULINNA-2 fragment separator.

Recommendation. The PAC highly appreciates the proposals of FLNR for the development of research in the field of heavy-ion physics and recommends opening two new projects "Investigation of heavy and superheavy elements" and "Light exotic nuclei at the borders of nuclear stability" until the end of 2028. In order to be able to open and implement two new projects, as well as to conduct other experiments in the field of heavy-ion physics, the PAC recommends extending the theme "Synthesis and Properties of Superheavy Elements, the Structure of Nuclei at the Limits of Nucleon Stability" for a period of 7 years

until the end of 2030. The target preparation and the recycling of the target material are urgent issues.

IV. Large research infrastructure project “Development of the FLNR Accelerator Complex and Experimental Setups (DRIBs-III)” and proposals for opening new projects in this LRIP

The PAC heard a report on the theme “Development of the FLNR Accelerator Complex and Experimental Setups (DRIBs-III)” and proposals for its reformation into a large research infrastructure project (LRIP) presented by I. Kalagin. Within the framework of this LRIP, it is planned to open two projects: “Construction of the U-400R accelerator complex” and “Development of the experimental setups to study the chemical and physical properties of superheavy elements”. In addition, under this project, it is planned to complete the construction, to commission and develop the DC-140 accelerator complex for applied research. The project also includes support for experiments performed at the FLNR accelerator complex, in particular ensuring the required operating parameters for existing accelerators, improving the reliability of accelerators, and developing experimental facilities.

The PAC heard the proposal to open a new project “Construction of the U-400R accelerator complex” presented by A. Eremin. The project includes the modernization of the existing U-400 accelerator into U-400R, construction of a new experimental building, development of new experimental setups of the complex.

The PAC heard a proposal to open a new project “Development of the experimental setups to study the chemical and physical properties of superheavy elements” presented by A. Eremin. The project is aimed at implementing the tasks of developing new experimental facilities of the SHE Factory, namely: a separator for studying the chemical properties of superheavy elements GASSOL based on a gas-filled superconducting solenoid, and a multi-reflection time-of-flight mass spectrometer for precision measurement of SHE masses.

Recommendation. The PAC recommends that the theme “Development of the FLNR Accelerator Complex and Experimental Facility (DRIBs-III)” be reformed into a large research infrastructure project with the same title for the period 2024–2030. The PAC recommends opening two new projects “Construction of the U-400R accelerator complex” and “Development of the experimental setups to study the chemical and physical properties of superheavy elements” until the end of 2028.

V. Report on the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron" and on the projects "TANGRA", "ENGRIN", and "Modernization of EG-5". Proposals for extending the projects "TANGRA" and "Modernization of EG-5"

The PAC heard a report on the main results obtained over the past year within the framework of the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron" and the projects "Tagged neutrons and gamma rays (TANGRA)", "Investigation of prompt fission neutron emission in fission (ENGRIN)" and "Modernization of EG-5", as well as proposals to extend the projects "TANGRA" and "Modernization of the accelerator EG-5 and its experimental infrastructure" presented by Yu. Kopatch. Scientific research was focused in three areas: 1) the study of violations of fundamental symmetries in the interactions of neutrons with nuclei and collection of nuclear data; 2) the study of the fundamental properties of the neutron, physics of ultracold and very cold neutrons; 3) applied and methodological research.

The PAC notes the high quality of the results obtained and the prospects of the proposed scientific programme and takes note of the report on the completion of work under the ENGRIN project and the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron".

Recommendation. The PAC recommends the completion of the project "ENGRIN" and closing the theme "Investigations of Neutron Nuclear Interactions and Properties of the Neutron".

VI. Proposals for opening a new project "Investigations of neutron nuclear interactions and properties of the neutron" and a new theme "Nuclear Physics with Neutrons"

The PAC heard proposals to open a new project "Investigations of neutron nuclear interactions and properties of the neutron" and a new theme "Nuclear Physics with Neutrons" presented by V. Shvetsov.

The PAC notes the promising outlook of the proposed scientific programme of the new project "Investigations of neutron nuclear interactions and properties of the neutron" and the programme included in the project "TANGRA".

The main efforts of the Laboratory should be focused on research into nuclear reactions with neutrons, the properties of the neutron as an elementary particle, experiments with ultracold and very cold neutrons, and applied research using the FLNP neutron sources, such as IREN, IBR-2, EG-5, as well as external neutron sources.

The PAC draws the attention of the Directorates of FLNP and JINR to the importance of bringing the EG-5 accelerator up to design parameters and putting it into operation. The PAC supports the opening of an activity in the framework of this theme aimed at developing the concept of a UCN source at the IBR-2 pulsed reactor.

Recommendation. The PAC recommends opening the new project “Investigations of neutron nuclear interactions and properties of the neutron” for a period of 5 years until the end of 2028. The PAC also recommends extending the project “TANGRA” for a period of 5 years until the end of 2028 and the project “Modernization of the accelerator EG-5 and its experimental infrastructure” for a period of 3 years until the end of 2026. In connection with the proposals to open the new project, extend two other projects, as well as to open the new activity, the PAC recommends opening the new theme “Nuclear Physics with Neutrons” for a period of 7 years until the end of 2030.

VII. Project “BECQUEREL2023”

The PAC heard a report on extending the project “BECQUEREL2023” at the Nuclotron-NICA accelerator complex to study peripheral interactions of relativistic nuclei presented by P. Zarubin. The project is focused on the search for α-particle Bose–Einstein condensate (αBEC). Identification of decays ^{8}Be → 2α, ^{9}Be → 2α, and ^{12}C(0^{+}_{2}) → ^{8}Beα (the Hoyle state) by the invariant mass was tested for light nuclei, including radioactive ones. A trend of increasing ^{8}Be with the growing number of α-particles as well as ^{9}B and ^{12}C(0^{+}_{2}), recently discovered for medium and heavy nuclei, indicates an opportunity of 4αBEC synthesis. In continuation of studies with light nuclei in the dissociation of ^{9}Be and ^{10}C, the search for isobar-analogue states of ^{8}Be and ^{9}B is underway.

In December 2022, as a result of irradiation of nuclear emulsion layers with a ^{124}Xe nuclei beam at an energy of 3.8 GeV/nucleon, the proper material was obtained for the analysis of multiple states of α-particles and nucleons. In general, the combination of classical nuclear techniques and the use of the unique motorized microscope provides the possibility for further investigations with relativistic radioactive isotopes at JINR by attracting young researchers to this project.

Recommendation. The PAC recommends extending work on the project “BECQUEREL2023” in the status of activity.

VIII. Proposal for extending the project “E&T&RM” with the new title “ADSR”

The PAC took note of the report on the project “E&T&RM” and the proposal for its extension with the new title “Accelerator driven subcritical reactor (ADSR)” presented by

M. Paraipan. The project is aimed at developing new principles for simulating the regimes of accelerator driven subcritical systems, which are neutron sources for a wide range of nuclear studies. The PAC notes that, in spite of the almost general opinion that the optimal beam for ADS is a proton beam with an energy of about 1–1.5 GeV, it was shown that heavier ion beams have a superior energy efficiency than protons. Research within the framework of the project will be aimed at studying the conditions, which maximize the energy efficiency of ADS systems and ensure a high burnup. The PAC welcomes the development of two options for the ADS target: a block of lead (cylinder or parallelepiped) with holes disposed in concentric layers for the fuel rods and empty in the centre, and a parallelepiped graphite target with reduced dimensions.

Recommendation. The PAC appreciates the work done during the previous period of the project implementation and supports its extension for the period 2024–2027 with updated content and the title “Accelerator driven subcritical reactor (ADSR)”.

IX. Project “Study of the nucleon spin structure in strong and electromagnetic interactions (GDH&SPASCHARM&NN)”

The PAC heard a detailed report on the project “Study of the nucleon spin structure in strong and electromagnetic interactions (GDH&SPASCHARM&NN)” and a proposal for its extension presented by Yu. Plis. This project includes three independent experiments related to the study of the spin structure of the nucleon in strong and electromagnetic interactions:

– experiments with photon beams at the MAMI microtron in Mainz and ELSA in Bonn: photoproduction of mesons on nucleons and nuclei and Compton scattering on nucleons in order to confirm experimentally the Gerasimov–Drell–Hearn sum rule (GDH);

– experiments on the study of single-spin asymmetry in the production of various light particles using a pion beam with an energy of 28 GeV and the study of the proton spin structure using a polarized proton beam (SPASCHARM project) at the U-70 accelerator (IHEP, Protvino);

– experiments on the transmission of neutrons through the polarized deuteron target at neutron energies lower than 16 MeV to measure $\Delta\sigma_T$ and $\Delta\sigma_L$, where the theory predicts a significant effect of three-nucleon forces (3NF).

In December 2022, a methodical session was conducted on a polarized target at IHEP (Protvino) in order to determine the state of the equipment for subsequent operation on the beam. During the reporting period, work was carried out to process the obtained physical data at the MAMI and ELSA accelerators. The results of experiments were processed at the

installation of a source of polarized deuterons at the Czech Technical University in Prague, and a publication was prepared.

Recommendation. The PAC recommends extending the project “Study of the nucleon spin structure in strong and electromagnetic interactions (GDH&SPASCHARM&NN)” until the end of 2028.

X. Project “Radiochemistry and spectroscopy for astrophysics and nuclear medicine”

The PAC heard a proposal to open a new project “Radiochemistry and spectroscopy for astrophysics and nuclear medicine” presented by A. Baimukhanova. Scientific research in the project is devoted to the development of nuclear spectroscopy and radiochemistry methods to study rare phenomena associated with the weak interaction and a number of problems in astrophysics, as well as the development of radiopharmaceuticals and their application in nuclear medicine. The project focuses on the following areas of work: designing novel detectors; high-resolution “post-decay” spectroscopy of electrons and other emissions with an emphasis on extremely low energies; gamma-spectroscopy based on semiconductor detectors; development of methods for the production and purification of radionuclide preparations for the synthesis of radiopharmaceuticals; development and application of methods and techniques for the production and analysis of low-background materials with a uniquely low content of radioactive impurities.

Recommendation. The PAC recommends opening the new project “Radiochemistry and spectroscopy for astrophysics and nuclear medicine” until the end of 2028.

XI. Project “Investigations of reactor neutrinos on a short baseline”

The PAC heard a proposal to open a new project “Investigations of reactor neutrinos on a short baseline” presented by I. Zhitnikov. The project combines research on the fundamental properties of neutrinos in the DANSS, vGeN, and Ricochet experiments with JINR’s participation. These experiments are aimed at solving the following scientific problems:

– the search and investigations of Coherent Elastic neutrino Nuclear Scattering (CEvNS) with low-threshold germanium detectors (vGeN) and cryogenic detectors (Ricochet);

– the search for the neutrino magnetic moment (vGeN and Ricochet);

– the search for short-baseline reactor antineutrino active-sterile oscillations with a highly-segmented plastic scintillator detector and remote monitoring of the nuclear reactor core operation by measuring the antineutrino flux (DANSS, DANSS-2).

The participants of the proposed project have all the necessary expertise, as well as many years of experience in studying the properties of neutrinos both in reactor and low-background experiments.

Recommendation. The PAC recommends opening the new project “Investigations of reactor neutrinos on a short baseline” until the end of 2028.

XII. Project “Nuclear spectrometry for the search and investigation of rare phenomena”

The PAC heard a proposal to open a new project “Nuclear spectrometry for the search and investigation of rare phenomena” presented by E. Yakushev. The project combines research on the fundamental properties of neutrinos and the search for dark matter particles in the experiments with JINR’s participation:

– LEGEND (Large Enriched Germanium Experiment for Neutrinoless double beta-Decay);

– TGV (Telescope Germanium Vertical);

– SuperNEMO (Neutrino Ettore Majorana Observatory);

– MONUMENT (Muon Ordinary capture for the NUclear Matrix elemENTs);

– EDELWEISS (Expérience pour DétEcter Les WIMP En Site Souterrain).

The above experiments are aimed at solving the following main scientific problems:

– the search and study of neutrinoless double beta-decay using detectors enriched with ^{76}Ge (LEGEND), low-background germanium detectors (TGV spectrometer) as well as the application of a unique potentially zero-background tracking-calorimetric technique (SuperNEMO);

– measurements of muon capture on several daughter nuclei, candidates for 0ν2β-decay (MONUMENT);

– the direct search for dark matter using the array of single-crystal germanium bolometers (EDELWEISS).

These experiments have the common area of research – neutrino physics and the search for dark matter, largely coinciding scientific problems. Combining the ongoing and planned activities into a single project will allow the concentration of available resources, improvement of the organization of research, and lay a reliable foundation for next-generation experiments.

Recommendation. The PAC notes the significant contribution of JINR scientific groups to the above experiments and recommends opening the project “Nuclear spectrometry for the search and investigation of rare phenomena” until the end of 2028.

XIII. Large research infrastructure project “BAIKAL-GVD”

The PAC heard a progress report on implementing the project “BAIKAL-GVD” and a proposal for its extension presented by I. Belolaptikov. The project is being implemented within the framework of the theme “Non-Accelerator Neutrino Physics and Astrophysics”.

The presented gigaton neutrino detector BAIKAL-GVD, the largest operating neutrino telescope in the Northern Hemisphere, is an infrastructure aimed primarily at studying astrophysical neutrino fluxes. The detector uses the water of Lake Baikal, at the depth of which optical sensors are installed that detect the Cherenkov radiation from secondary particles produced in interactions of high-energy neutrinos inside and near the instrumented volume. During 2016–2023, the BAIKAL collaboration deployed 12 full-scale clusters with about 3,500 optical modules. The analysis of the data taken during 2018–2021 confirms for the first time the IceCube observation of an astrophysical diffuse neutrino flux with a significance of 3σ, which is, indeed, a promising result.

Current rates of production and deployment of additional clusters on Baikal make it possible to achieve, by 2028, a detection volume of 1 km^3 with about 6000 optical modules for detecting high-energy astrophysical neutrinos. The PAC underlines the important role played by the project “BAIKAL-GVD” together with the IceCube experiment to study high-energy neutrino flux from all directions of the sky. The PAC notes the importance of developing and maintaining the project’s onshore infrastructure.

Recommendation. The PAC appreciates the high scientific importance of the project “BAIKAL-GVD” and JINR’s leading role in its implementation. The PAC strongly recommends extending the project “BAIKAL-GVD” as a large research infrastructure project until the end of 2028.

XIV. Next meeting of the PAC

The next meeting of the PAC for Nuclear Physics will be held on 29–30 January 2024. Its tentative agenda includes:

– reports and recommendations on themes and projects to be completed in 2024;
– scientific reports;
– poster presentations of new results and proposals by young scientists in the field of nuclear physics.

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