Programme Advisory Committee for Nuclear Physics

58th meeting, 29–30 January 2024

Recommendations

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 134th session of the JINR Scientific Council (September 2023) and the decisions of the JINR Committee of Plenipotentiaries (November 2023).

JINR Chief Scientific Secretary S. Nedelko presented the Seven-Year Plan for the Development of JINR for 2024–2030 approved by the JINR Committee of Plenipotentiaries, which includes the main themes and projects for research and development of the JINR infrastructure for this period.

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. On the work plans for scientific research and infrastructure development of JINR laboratories in the field of nuclear physics within the framework of themes and projects for 2024

Theme "Neutron Nuclear Physics" and the status of projects within the theme

The PAC heard with interest the report on the work plan within the framework of the theme "Neutron Nuclear Physics" and its projects for 2024 presented by E. Lychagin.

The scientific programme of the theme "Neutron Nuclear Physics" will be implemented within the framework of three projects: two scientific projects ("Investigations of neutron nuclear interactions and properties of the neutron" and "TANGRA"), and one scientific and technical project ("Modernization of the EG-5 accelerator and its experimental infrastructure"). Work on developing the concept of a UCN source at a pulsed reactor is separated into a different activity.

Within the framework of the project "Investigations of neutron nuclear interactions and properties of the neutron", it is planned to resume measurements of angular correlations and γ-ray yields for already known p-wave resonances in various nuclei, and also to search for new p-resonances and new effects promising violation of parity

and T-invariance. The main work is expected to be carried out at the IREN resonance neutron source.

In 2024, it is planned to carry out a study of resonance neutron capture in ^{176}Lu and ^{177}Lu in the neutron energy range of 1–300 eV. The goal of the experiment is to study the effect of Coriolis interaction on the structure of nuclear excited states. The measurements are planned to be carried out at the IREN resonance neutron source and at the China Spallation Neutron Source (CSNS).

Research into rare fission modes (ternary, quaternary, and quinary) of nuclei will be continued for neutron induced fission of uranium isotopes ^{233}U and ^{235}U. The measurements are planned to be carried out at the VVR-K nuclear research reactor (Kazakhstan).

In 2024, it is planned to measure reaction cross sections (n, α) on gas samples Ar, F, O, Ne at EG-5 (FLNP, JINR) (E_n=3–5 MeV) and at the tandem accelerator HI-13 of the China Institute of Atomic Energy (CIAE) (E_n=8–11 MeV).

The project “TANGRA” is dedicated to solving fundamental and applied problems using the tagged neutron method. The area of interest of the project is nuclear reactions induced by neutrons with an energy of about 14 MeV. The main areas of research in 2024:

– it is planned to measure the reaction cross sections (n, xγ) for 22 elements. This information is necessary for elemental analysis, Monte Carlo simulations of nuclear instruments, and verification of theoretical calculations;

– it is planned to measure the angular correlations of scattered neutrons and γ-rays in inelastic neutron scattering from carbon. Experiments to study correlations (n, n' γ) are important for understanding the mechanism of reactions (n, n');

– the development of methods for elemental analysis of soils will be continued in collaboration with Diamant LLC. It is planned to assemble and test a prototype of the field setup.

Within the project “Modernization of the EG-5 accelerator and its experimental infrastructure”, it is planned to replace the high-voltage system of the EG-5 facility, the main result of which will be an increase in the ion beam current from 2–3 μA to 100–250 μA while maintaining its energy and spatial stability.

The PAC notes the good prospects of the proposed scientific programme within the framework of the theme “Neutron Nuclear Physics” and its projects.

Recommendations. The PAC supports the implementation of the scientific programme for 2024 proposed within the framework of the theme “Neutron Nuclear

Physics” and the projects “TANGRA”, “Investigations of neutron nuclear interactions and properties of the neutron” and “Modernization of the EG-5 accelerator and its experimental infrastructure”, as well as the *activity* aimed at developing the concept of a UCN source at the IBR-2 reactor.

Theme "Synthesis and Properties of Superheavy Elements, Structure of Nuclei at the Limits of Nucleon Stability” and the projects within the theme

The PAC heard with interest the report on the plans for investigations with heavy-ion beams at FLNR for 2024 presented by S. Sidorchuk. The research programme will be implemented within two projects: “Investigation of heavy and superheavy elements” and “Light exotic nuclei at the borders of nucleon stability”.

The project “Investigation of heavy and superheavy elements” implemented at the SHE Factory will focus on the following tasks:

– the continuation of the $^{54}Cr+^{238}U$ experiment, which is extremely important for preparing the synthesis of new superheavy elements 119 and 120. Previously, in this experiment launched in 2023, two events of the synthesis of the new isotope ^{288}Lv were observed. The estimate of the ^{288}Lv production cross section with a ^{54}Cr beam, which is about 2 orders of magnitude lower than that obtained with a ^{48}Ca beam, confirms the disadvantage of using beams heavier than ^{48}Ca to synthesize superheavy elements evidenced in studies on quasifission.

– it is planned to prepare and conduct the first experiments on the spectroscopy of isotopes of superheavy elements synthesized in the reaction $^{48}Ca+^{242}Pu$. The experiment will be carried out using the GRAND separator and the detection setup GABRIELA-2 comprising five clover high-purity germanium γ-detectors. It is expected to detect α-decays of the even-even nucleus ^{286}Fl to the first excited state ^{282}Cn, which is expected to be of a rotational nature. This experiment opens the door to experimental evaluation of the deformation of nuclei in the region of the SHE island of stability;

– the continuation of the development and testing of the setup for studying the chemical properties of SHE by thermochromatography. The main efforts will be focused on increasing the efficiency and speed of extraction of SHE atoms from the stop chamber and transporting them to the detector. The highest-priority objective of constructing the setup is to conduct experiments on the chemistry of elements Cn and Fl with high statistics.

Research at the CORSET setup will mainly focus on studying the dynamics of multinucleon transfer reactions leading to the formation of two or more than two heavy reaction products in the exit channel.

The main task of the project “Light exotic nuclei at the borders of nucleon stability” in 2024 will be the preparation and conduct of the first experiments aimed at studying the structure of light nuclei near the borders of nucleon stability at the ACCULINNA and ACCULINNA-2 fragment separators of the upgraded U-400M accelerator. The commissioning of the accelerator is expected in the second quarter of 2024.

In 2024, research will focus on studying the structure of heavy helium isotopes ^{6,7}He and the reaction mechanisms leading to the formation of unbound exotic systems such as 4n. In particular, elastic and inelastic scattering of ^{6}He on the ^{4}He nucleus will be studied over a wide range of center-of-mass angles, including back scattering corresponding to the 2n transfer. This reaction begins a series of investigations of the structure of neutron-rich nuclei and the mechanism of the neutron transfer reaction using secondary beams of helium and beryllium isotopes. As part of the study of the mechanisms of quasi-binary transfer reactions with the formation of unbound states such as ^{7}H and 4n, experiments will be carried out to study the ^{5}H and 2n states in the reactions ^{2}H(^{6}He,^{6}Li)2n and ^{2}H(^{6}He,^{3}He)^{5}H.

Recommendation. The PAC supports the scientific and technical programmes for 2024 under the theme “Synthesis and Properties of Superheavy Elements, Structure of Nuclei at the Limits of Nucleon Stability”, as they were presented at the current PAC meeting in comparison with the programmes presented 6 months ago, and the continuation of work on the projects “Investigation of heavy and superheavy elements” and “Light exotic nuclei at the borders of nucleon stability”. The PAC recommends theoretically exploring in detail the pxn reaction channel for the production of SHE nearest to the island of stability, also in the regions of masses below the island of stability and verifying the sensitivity of detecting such channels with the present mass spectrometer and implantation detectors.

JINR large research infrastructure “Development of the FLNR Accelerator Complex and Experimental Setups (DRIBs-III)”

The PAC heard with interest the report on the development of FLNR’s accelerator and experimental base presented by V. Semin. In 2024, the main efforts within the project will be focused on:

– providing beams with the required characteristics for the implementation of FLNR’s experimental programme at the existing accelerator complexes DC-280 (SHE Factory) and U-400;

– completing the upgrade and commissioning work at the U-400M accelerator, as well as ensuring first experiments with beams of radioactive nuclei;

– completing the construction of the DC-140 accelerator complex for applied heavy-ion investigations.

Under the project “Construction of the U-400R accelerator complex”, the improvement of the technical parameters of the components of the upgraded U-400R accelerator, the construction of a new experimental hall, as well as the designing of novel setups for this experimental hall will continue. The shutdown of the U-400 facility and the beginning of its upgrade are scheduled for the second half of 2024.

The project “Development of the experimental setups to study the chemical and physical properties of superheavy elements” is aimed at developing the multi-reflection time-of-flight mass spectrometer and pre-separator GASSOL based on a gas-filled superconducting solenoid. In 2024, the construction documentation for the mass spectrometer is expected to be ready, and the GASSOL pre-separator be manufactured and delivered to JINR.

Recommendation. The PAC endorses the proposed programme for 2024 for the development of FLNR’s accelerator and experimental base under the JINR large research infrastructure project “Development of the FLNR Accelerator Complex and Experimental Setups (DRIBs-III)”.

III. Review of nuclear physics at the Dzhelepov Laboratory of Nuclear Problems

The PAC heard with interest the review of the nuclear physics scientific programme at DLNP presented by E. Yakushev. Areas of nuclear physics research in the Laboratory include both classical spectrometry of radioactive isotopes and the investigation of various rare phenomena by nuclear physics methods. The section “Nuclear Physics” of the JINR Topical Plan includes one of the major DLNP scientific themes: “Non-Accelerator Neutrino Physics and Astrophysics”, which is aimed at searching for evidence of the existence of new physics beyond the Standard Model. The main directions of the theme are: investigation of double β-decay by various calorimetric and track-calorimetric methods, investigation of the properties of neutrinos from different sources, search for dark matter, etc. A significant part of the Laboratory’s scientific programme is devoted to the investigation of processes inside the nuclear reactor core using neutrinos. There are three projects in the theme: “Nuclear spectrometry for the search and investigation of rare phenomena”, “Investigations of

reactor neutrinos on a short baseline" and "Radiochemistry and spectroscopy for astrophysics and nuclear medicine". The projects complement each other because their implementation is linked by common approaches and resources.

A significant part of the Laboratory's manpower involved in the nuclear physics programme is assigned to the construction and commissioning of the Baikal-GVD gigaton volume neutrino telescope, which is a part of the large research infrastructure of JINR.

In 2024, the Laboratory plans to commission two new basic facilities: the LINAC-200/800 electron accelerator and a spectrometry cluster working in tandem with the accelerator. The Laboratory enhances the radiochemistry investigations with new methods: ICP-MS spectrometry, Mössbauer spectrometry. These methods are required for the development of clean materials for neutrino related studies as well as for the study of radiopharmaceuticals and their precursors. The Laboratory develops experimental techniques and conducts applied research with monochromatic positron beams. A new setup is being developed: the MSC-230 proton cyclotron for the new clinical and research centre for proton therapy.

The PAC notes that DLNP applies a wide range of nuclear physics methods to design and conduct experiments and obtain physics results at the cutting edge of modern science.

Recommendations. The PAC recommends that the support of the experiments conducted in the frame of the DLNP nuclear physics scientific programme be continued. The PAC emphasizes the importance of efforts to further improve the experimental base at JINR and approves the presented plans for 2024 to commission the new basic facilities of the Laboratory.

IV. Scientific reports

The PAC heard with interest reports: "Verification of T-invariance in the total interaction cross section of neutrons with unpolarized nuclei using the polarization–asymmetry theorem" presented by V. Skoy, and "Study of the properties and applications of nanodiamond reflectors of low-energy neutrons" presented by A. Nezvanov. The PAC supports the continuation of these studies.

V. Short presentations by young scientists

The PAC reviewed 9 short presentations in the field of nuclear physics research by young scientists from FLNP. Three best short presentations selected are: “Enhanced directional extraction of very cold neutrons using a diamond nanoparticle powder reflector” presented by A. Nezvanov, “Chromium, nickel and zinc accumulation and translocation in root and leafy vegetables irrigated with industrial effluents – a laboratory study” presented by A. Kravtsova, and “Experimental setup for elemental analysis using prompt gamma rays at research reactor IBR-2” presented by C. Hramco.

The PAC recommends the poster “Enhanced directional extraction of very cold neutrons using a diamond nanoparticle powder reflector” to be reported at the session of the Scientific Council in February 2024.

VI. General recommendations

The PAC recommends an improvement of the interlaboratory links between FLNR, DLNP, FLNP and BLTP on topics, which are of common interest, to boost research results both experimentally and theoretically. The PAC recommends engaging BLTP scientists into research projects of FLNR, DLNP, and FLNP and conducting joint seminars of experimentalists and theoreticians.

The PAC would like to hear scientific reports on developing/applying radiochemical research in JINR laboratories including the production of radioisotopes for ecology and medicine as well as application of nuclear methods and related analytical techniques for the investigation of cultural heritage objects.

VII. Visit to FLNR

The members of the PAC thank the Directorate of the Flerov Laboratory of Nuclear Reactions for the organization of the visit to this laboratory.

VIII. Next meeting of the PAC

The next meeting of the PAC for Nuclear Physics will be held on 13–14 June 2024. Its tentative agenda will include:

– reports and recommendations on themes and work on the projects to be completed in 2025;
– status of the SHE Factory and its scientific programme;
– results of experiments (fully completed and processed) at the ACCULINNA-2 fragment separator;
– consideration of new experiments and projects;
– scientific reports;
– short presentations of new results and proposals by young scientists in the field of nuclear physics.

V. Nesvizhevsky

Chair of the PAC
for Nuclear Physics

N. Skobelev

Scientific Secretary of the PAC
for Nuclear Physics