Programme Advisory Committee for Nuclear Physics

59th meeting, 13–14 June 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 135th session of the JINR Scientific Council (February 2024) and the decisions of the JINR Committee of Plenipotentiaries (March 2024).

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. Status of the U-400M accelerator

The PAC heard with interest the report on the status of the FLNR accelerators presented by V. Semin. Particular emphasis was placed on the status of the U-400M cyclotron that is in the final stage of its upgrade aimed at enhancing the operation reliability and stability of the accelerator (replacement of the main magnet coils, accelerator vacuum system components, control system, and radiation control system), as well as at increasing the intensity and energy of heavy-ion beams.

Improving the magnetic system allowed an increase in the mean field and the extraction radius by 10–17 mm, which consequently increased the beam energy by 10–15%. The new magnetic channel for the extraction system allowed for a significant improvement of beam focus. A new ion source DECRIS-2M with higher intensity as compared to DECRIS-2 was installed. Furthermore, some U-400M components were reconstructed: the water-cooling system was improved; new power supply sources were installed; pre-vacuum equipment, compressors, and vacuum cryopumps were replaced; and the control system was upgraded.

The commissioning of the U-400M accelerator and first experiments using it are planned for the second half of 2024.

Recommendation. The PAC noted the immense work on the upgrade of the U-400M cyclotron and recommends that thorough monitoring be provided during the commissioning of all the above-mentioned systems in order to guarantee the reliable performance of the U-400M cyclotron with design parameters. The PAC recommends

that the FLNR Directorate should concentrate its efforts on preparing the first experiments.

III. Synthesis and study of the decay properties of isotopes of superheavy elements Ds and Lv

The PAC heard with interest the report “Synthesis and study of the decay properties of isotopes of superheavy elements Ds and Lv” presented by N. Kovrizhnykh. These results were obtained under the project “Investigation of heavy and superheavy elements”. Experiments to synthesize isotopes ^{275,276}Ds in the reaction ^{48}Ca+^{232}Th were continued on the gas-filled DGFRS-2 separator of the DC-280 cyclotron at the SHE Factory. The PAC notes that the data on the properties of nuclei in the ^{275,276}Ds decay chains are of great importance for the identification of a new element with Z=120 that can be synthesized in the ^{54}Cr+^{245}Cm reaction.

The complete fusion reaction ^{48}Ca+^{232}Th was studied at four beam energies above the Coulomb barrier. One decay chain of the ^{276}Ds isotope, discovered in 2022, was detected at two maximum beam energies. In addition, six decay chains of the new isotope ^{275}Ds were identified. ^{275}Ds was for first produced in a reaction with ^{48}Ca and identified through sequential α-decays leading to the known nuclei ^{271}Hs, ^{267}Sg, and ^{263}Rf previously synthesized in the ^{248}Cm(^{26}Mg,3n)^{271}Hs reaction.

The production cross section for ^{276}Ds was shown to be an order of magnitude lower than that of the lighter isotope ^{270}Hs in the ^{226}Ra(^{48}Ca, 4n)^{270}Hs reaction, whereas when moving to heavier elements (Z>110), the cross section increases, reaching maximum values for elements 114–115, and subsequently decreases. Such behavior is in good agreement with theoretical models. Two decay chains of ^{273}Ds with a cross section of 0.2 pb were registered in the ^{238}U+^{40}Ar reaction. The properties of nuclei synthesized in both reactions point to the existence of isomeric states in ^{267}Sg, ^{271}Hs, ^{273}Ds and its daughter nuclei. A possible decay scheme of the synthesized isotopes was proposed on the basis of these results.

For the first time, the new isotope ^{288}Lv was synthesized in the reaction of ^{54}Cr with actinide target nuclei, and the cross section for the ^{238}U+^{54}Cr reaction was measured to be about 70 fb. The PAC notes that the experiment with the ^{54}Cr beam is an important step for setting up experiments on the synthesis of elements with Z>118.

Recommendation. The PAC recommends that work on the synthesis of the isotopes of superheavy elements and study of their decay properties be continued, in particular, using ^{54}Cr and ^{50}Ti beams.

IV. Results of the first experiments at the ACCULINNA-2 separator and the scientific programme for 2024

The PAC heard with interest the report on the results of first experiments carried out at the ACCULINNA-2 fragment separator in 2018–2020 and on the research programme for 2024 under the project “Light exotic nuclei at the borders of nucleon stability”, presented by V. Chudoba.

In 2018–2020, first experiments with the high-intensity radioactive beams of ^{6}He, ^{8}He, and ^{9}Li, were carried out at the ACCULINNA-2 separator of the U-400M accelerator complex. The characteristics of produced radioactive ion beams were in good agreement with technical specifications and estimations. The analysis of the experimental data made it possible to determine energy resolution as a function of the deuterium target thickness, and the efficiency of the detection system registration. The report presented interesting and important data on the low-energy spectra of the unbound nuclear systems 4n, $^{5–7}$H, ^{7,9}He, ^{8,10}Li produced in transfer reactions. The results are published in Phys. Rev. Lett., Phys. Rev. C, and other journals.

In the second half of 2024, experiments are planned to study the neutron, proton, and α-particle transfer reactions using radioactive ^{6,8}He beams and a cryogenic ^{2}H gas target. In particular, the reaction ^{2}H(^{6}He,^{6}Li)2n was proposed, which can provide additional data on the formation mechanism of the tetraneutron in the similar reaction ^{2}H(^{8}He,^{6}Li)4n. Furthermore, it is planned to study the exotic structure of ^{6,8}He nuclei in the 2- and 4-neutron transfer reactions ^{4}He(^{6}He,^{6}He)^{4}He, ^{4}He(^{8}He,^{8}He)^{4}He, and ^{4}He(^{8}He,^{6}He)^{6}He.

Recommendation. The PAC acknowledges the important results obtained in experiments at the ACCULINNA-2 separator conducted prior to upgrading the U-400M accelerator complex, to mention in particular the resolution of ^{6}H and ^{7}H ground states and a complicated experiment with ^{7}H with extremely low cross sections. The PAC looks forward to the results of the first experiments on the upgraded accelerator, in particular profiting from the new efficient neutron detection system.

V. Development of low-temperature detection systems for the study of coherent elastic scattering of neutrinos on atoms and nuclei and measurement of electromagnetic characteristics of neutrino

The PAC has heard the proposal of a new project “Nuclear bolometer” presented by V. Trofimov. This project is part of the programme “Study of coherent elastic neutrino

scattering on atoms, nuclei and electrons and measurements of neutrino electromagnetic properties using a high-intensity tritium antineutrino source" (SATURNE project, SArov TritiUm neutRiNo Experiment) being financed by the federal budget of the Russian Federation and Rosatom. Within this project, DLNP JINR is involved in the development of low-temperature detection systems operating in the energy range below 1 eV, namely – in manufacturing prototypes of low-temperature helium and silicon detectors using the ^{3}He/^{4}He dilution cryostat, and also in investigations of different techniques for generating and detecting elementary excitations in superfluid helium. Such detectors would allow, in particular, the measurements of coherent elastic scattering of low energy neutrino on helium and silicon nuclei, also designing compact detectors for the solar pp-neutrino flux monitoring. Modern scientific equipment, high quality detectors and qualified staff are available to perform this work.

Recommendations. The PAC supports the opinion that it is timely and important to develop novel detection systems intended for studying rare events in the range of low energies. The PAC highlights that the project "Nuclear bolometer" does not require extra financing from JINR, and recommends that the above-mentioned work be carried out as an activity within the theme "Non-Accelerator Neutrino Physics and Astrophysics".

VI. Status and prospects of radiochemical research at the Dzhelepov Laboratory of Nuclear Problems

The PAC has heard with interest the report "Status and prospects of radiochemical research at the Dzhelepov Laboratory of Nuclear Problems of JINR" presented by A. Baimukhanova. Radiochemical research carried out at the DLNP JINR is implemented within the project "Radiochemistry and spectroscopy for astrophysics and nuclear medicine". It is devoted to the development of radiochemical methods for studying rare processes, associated with weak interaction and a number of problems in astrophysics, as well as for synthesizing radiopharmaceuticals.

The PAC notes the following methods developed at DLNP JINR: 1) production and purification of radionuclide preparations for the synthesis of radiopharmaceuticals and manufacture of spectrometric sources; 2) production of low-background materials with a uniquely low content of radioactive impurities; 3) analysis of radiopharmaceuticals and their precursors, as well as the purity of resulting radiopreparations and low-background materials.

Recommendations. The PAC highly appreciates the radiochemical research carried out at DLNP JINR, its high-quality and high-precision results, and notes a

significant contribution of this research to nuclear medicine, spectrometry and astrophysics. The PAC recommends that work on radiochemical research be continued within the framework of the project “Radiochemistry and spectroscopy for astrophysics and nuclear medicine”.

VII. Scientific reports

The PAC heard with interest the reports “Supercomputer “Govorun” for JINR tasks” presented by D. Podgainy, and “Radiobiological research at JINR: applications in radiation medicine and space exploration” presented by A. Bugay. The PAC supports the continuation of these studies.

VIII. Short presentations by young scientists

The PAC reviewed 6 short presentations in the field of nuclear physics research by young scientists from DLNP. The PAC appreciates the high quality of presented works and the talks. The Committee selected three best short presentations: “Real-time follow-up of multimessenger alerts at the Baikal-GVD telescope” by V. Dik, “Production of trivalent radionuclides for nuclear medicine and analysis via nuclear-spectrometric methods” by E. Kurakina, and “Status of the Ricochet experiment” by D. Ponomarev.

The PAC recommends the presentation “Real-time follow-up of multimessenger alerts at the Baikal-GVD telescope” to be reported at the session of the JINR Scientific Council in September 2024.

The PAC appreciates that JINR accepted our proposal to replace poster sessions of young scientists by their short presentations, also recommends that young scientists should better underline their personal contributions to the presented works when preparing their talks.

IX. Next meeting of the PAC

The next meeting of the PAC for Nuclear Physics will be held on 23–24 January 2025. Its tentative agenda includes:

– reports on the results of projects to be completed in the second half of 2024;

– reports and recommendations on themes and work on the projects to be completed in 2025;

– experiments at the SHE Factory and its scientific programme;

– results of experiments at the Baikal-GVD;

– consideration of new experiments and projects;

– proposed visit to the Veksler and Baldin Laboratory of High Energy Physics;

– scientific reports;

– short presentations of the 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