

**I. Preamble**

The Chair of the PAC for Nuclear Physics, M. Lewitowicz, presented an overview of the implementation of the recommendations taken at the previous meeting.

JINR Vice-Director S. Dmitriev informed the PAC about the resolution of the 130th session of the JINR Scientific Council (September 2021) and the decisions of the JINR Committee of Plenipotentiaries (November 2021).

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 Scientific Council and the Directorate.

**II. Report on the closing theme “Investigations of Neutron Nuclear Interactions and Properties of the Neutron” and proposal for its extension**

The PAC heard with interest a report on the implementation of the theme “Investigations of Neutron Nuclear Interactions and Properties of the Neutron” for 2020–2022 presented by E. Lychagin and a proposal for its extension until the end of 2023. Within the framework of the theme, three projects are being realized: TANGRA (since 2017), ENGRIN (since 2022) and the modernization of EG-5 accelerator (since 2022).

In the study of neutron-induced nuclear reactions, a detailed analysis of the results from the previously performed measurements of P-even and T-odd correlations in the fission of  $^{236}\text{U}$  compound nuclei at neutron energies of 0.06 eV and 0.27 eV was carried out, which made it possible for the first time to compare the rotation angles of the fission axis at different neutron energies.

Within the framework of the TANGRA project, angular distributions and yields of gamma-rays in the  $(n,n'\gamma)$  reaction for 14-MeV neutrons for C, O, Mg, Al, Si, Cr, Fe nuclei were measured using the Romasha detector system consisting of 18 BGO and HPGe (high-purity germanium) detectors.

In cooperation with physicists from the Czech Technical University in Prague, measurements of rare modes of spontaneous fission of  $^{252}\text{Cf}$  with a highly active sample (~400 kBq) were carried out. Timepix detectors with upgraded electronic boards were used to detect light particles. The main goal of the study was to detect the quaternary fission of  $^{252}\text{Cf}$ . The collection of statistics for two months of measurements made it possible to identify p, d, t,  $\alpha$ , Li, Be, B, and C as the lightest particle in ternary fission as well as measurement of

the spectra of detected particles ( $p$ ,  $d$ ,  $t$ ,  $\alpha$ ). The cluster resolution power of the Timepix detector made it easy to separate ( $\alpha$ ,  $\alpha$ ) and ( $\alpha$ ,  $t$ ) pairs from quaternary fission.

The study of nonstationary processes of interaction of slow neutrons was continued using the example of reflection from a traveling surface wave. Significant progress is achieved in the development of ever first efficient reflectors for slow neutrons based on powders of diamond nanoparticles.

A wide range of activities was carried out using various nuclear physics techniques to solve problems in ecology, materials science, archeology, art history, medicine, research of objects of extraterrestrial origin, etc. These studies were carried out in cooperation with a large number of scientists from research centres of JINR Member States. In particular, cooperation is carried out with the Institute of Archeology of the Russian Academy of Sciences, the State Institute of Art Studies, the Volokolamsk Kremlin Museum and Exhibition Complex, and the Dubna Museum.

The scientific and methodological areas of research within the framework of the continuation of the theme were reported to the PAC. In particular, in 2023 it is planned:

- to carry out measurements of gamma-ray spectra in s- and p-resonances, aimed at searching for P-even and T-odd effects in reactions with slow polarized neutrons;
- to obtain data for nuclear power and astrophysics;
- to measure integral and differential neutron cross sections, angular correlations in the energy range from cold neutrons to  $\sim 1$  GeV;
- to measure mass-energy and angular distributions of fragments, neutrons and gamma rays from fission;
- to search for rare fission modes;
- to measure cross-sections and angular correlations in ( $n, n'\gamma$ ) and ( $n, 2n$ ) reactions in the interaction of fast neutrons with nuclei (TANGRA project).

In 2023, it is planned to explore the experimental technique for measuring the neutron lifetime on the extracted beams of the IBR-2 reactor and IREN (beam-based, original method) and to study nonstationary quantum effects and models of the interaction of slow neutrons with diamond nanostructures.

In 2023, the following methodological activities will be continued at the Frank Laboratory of Neutron Physics:

- modernization of the EG-5 electrostatic generator, expansion of the range of instruments for the accelerator complex;
- preparation of a test experiment with ultracold neutrons (UCN) time focusing at IBR-2;
- development and construction of neutron and gamma detectors for spacecraft;

– determination of the elemental composition and surface structures of various samples by nuclear physics methods for solving problems in materials science, ecology, history, archeology, restoration and life sciences, as well as development of techniques for gamma activation analysis and prompt gamma-ray analysis for IREN, etc.

The PAC recognizes the important involvement of the Frank Laboratory of Neutron Physics in the development of the new neutron source at JINR and proposes that the scientific programme as well as experimental instruments in the field of nuclear physics be also actively developed for the new source.

Recommendation. The PAC took note of the report for 2020–2022 on the theme “Investigations of Neutron Nuclear Interactions and Properties of the Neutron”. The PAC appreciates the many results achieved and the many new ideas that appeared at FLNP in recent years. In particular, experimental studies of time focusing of neutrons and nanodiamond reflectors are important for developing and implementing the instruments based on sources of UCN. The PAC recommends extending the theme until the end of 2023 with first priority for further research in the field of nuclear physics using FLNP neutron facilities.

### **III. Update on the experiments at the SHE Factory**

The PAC heard with great interest the report “Update on the experiments at the SHE Factory” presented by N. Kovrizhnykh. In 2021, three series of experiments were performed at the new gas-filled separator DGFRS-2 of the SHE Factory at FLNR. The fusion reactions of  $^{243}\text{Am}$ ,  $^{242}\text{Pu}$ , and  $^{238}\text{U}$  isotopes with  $^{48}\text{Ca}$  ions accelerated at DC-280 were used to determine parameters of the new separator and the possibilities to continue studies of superheavy nuclei at a higher sensitivity level as well as a detailed study of the properties of Mc, Fl, Cn isotopes and their daughter nuclei.

In the  $^{243}\text{Am} + ^{48}\text{Ca}$  reaction at five  $^{48}\text{Ca}$  energies with an intensity of up to 1.3  $\mu\text{A}$ , 6 new chains of  $^{289}\text{Mc}$  (2n channel), 58 of  $^{288}\text{Mc}$  (3n channel), two of  $^{287}\text{Mc}$  (4n channel) were synthesized and a new isotope  $^{286}\text{Mc}$  (5n channel) was produced. In previous experiments,  $^{287}\text{Mc}$  was observed only in three chains and daughter nuclei of  $^{286}\text{Mc}$  — in two chains.

The  $\alpha$ -decay of  $^{268}\text{Db}$  was detected for the first time, its branch and half-life were measured, and a new isotope  $^{264}\text{Lr}$  was produced. The spontaneous fission of  $^{279}\text{Rg}$  was registered for the first time. It was shown that the transmission of DGFRS-2 is two times higher than that at DGFRS-1.

In the experiment with  $^{242}\text{Pu}$ , the intensity of  $^{48}\text{Ca}$  reached 3  $\mu\text{A}$ ; 25 and 69 decay chains of  $^{286}\text{Fl}$  and  $^{287}\text{Fl}$  were synthesized at two energies. The cross-section also turned

out to be twice as high as the previous values. In irradiation of  $^{238}\text{U}$ , the intensity of  $^{48}\text{Ca}$  reached 6.5  $\mu\text{A}$ . During September–October 2021, 16 decay chains of  $^{283}\text{Cn}$  were observed.

In the entire series of experiments, 177 decay chains of Mc, Fl, and Cn have been registered, the decay properties of about 30 isotopes of elements from Rf to Mc have been measured with higher precision, the reaction cross-sections were measured at different  $^{48}\text{Ca}$  energies.

The PAC notes that the new gas-filled separator DGFRS-2, tested in operation with a beam of accelerated  $^{48}\text{Ca}$  ions and with various transuranic targets, is operating within design parameters, which makes it possible to conduct new experiments on the study of superheavy nuclei at a higher sensitivity level.

Recommendation. The PAC heard with interest the information about new data on experiments at the SHE Factory. The Committee congratulates the FLNR team for the spectacular results obtained at the SHE Factory on the synthesis and decay of superheavy nuclei. The PAC encourages the FLNR Directorate to publish the first results of these experiments as soon as possible.

#### **IV. Scientific report**

The PAC heard with interest the report “The double  $\gamma$ -decay width of the nuclear  $2^+_{1}$  state” presented by A. Severyukhin. This report examined the situation in which the  $\gamma\gamma$ -decay of the low-energy quadrupole state occurs in a nuclear transition which could proceed by a single- $\gamma$  decay in competition. The  $\gamma\gamma$ -decay reactions are formally analogous to neutrinoless double- $\beta$  decay processes where in the latter two  $\beta$ -particles and in the former two  $\gamma$ -quanta appear in the final state and share the total energy of the nuclear transition. To describe the  $\gamma\gamma$ -decay, formalism relates the electromagnetic interaction up to second order. It is shown that the  $\gamma\gamma$ -decay width is sensitive to the interaction between one- and two-phonon configurations. The maximal branching ratio of the competitive  $\gamma\gamma$ -decay relative to its single  $\gamma$ -decay is predicted for  $^{48}\text{Ca}$  as  $3 \cdot 10^{-8}$ .

Recommendation. The PAC took note of the information about implementation of the electromagnetic interaction for describing the  $\gamma\gamma$ -decay and for calculating the maximal branching ratio of the competitive  $\gamma\gamma$ -decay relative to its single  $\gamma$ -decay for the  $^{48}\text{Ca}$  case. It will be interesting to adopt this type of calculations for the existing and future experimental data in other nuclei.

## **V. Presentations of new results and proposals by FLNR young scientists in the field of nuclear physics**

The PAC reviewed 8 reports in the field of nuclear physics research by young scientists from FLNR. The best posters selected are: “Detailed study of radioactive decay properties of No isotopes with  $\alpha$ ,  $\beta$ ,  $\gamma$ -spectroscopy method” presented by M. Tezekbayeva, “Creation of a set-up and development of a method for studying symmetric combinations in multinucleon transfer reactions ( $^{238}\text{U} + ^{238}\text{U}$ )” presented by K. Novikov, and “Production of radioactive targets for the first experiments at the SHE Factory” presented by A. Bodrov.

The PAC recommends that the report “Detailed study of radioactive decay properties of No isotopes with  $\alpha$ ,  $\beta$ ,  $\gamma$ -spectroscopy method” be reported at the session of the Scientific Council in February 2022.

## **VI. Next meeting of the PAC**

The next meeting of the PAC for Nuclear Physics will be held on 30 June 2022 – 1 July 2022.

Its tentative agenda includes:

- reports and recommendations on projects to be completed in 2022;
- update on experiments at the SHE Factory;
- scientific reports;
- proposals for the JINR Seven-Year Development Plan (2024–2030) in the field of nuclear physics research;
- poster presentations of new results and proposals by young scientists in the field of nuclear physics research.



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