Nuclear Physics

The following main areas of research in the field of low-energy nuclear physics will be further developed in 2017–2023: synthesis of superheavy elements using heavy ions and study of their physical and chemical properties, basic research with neutrons, and applied investigations.

The unique opportunities of JINR's heavy-ion accelerators and experimental research instruments have led to the establishment of broad international collaborations with research centres of the JINR Member States and other countries.

Synthesis of superheavy elements and study of their nuclear properties

Construction of the Factory of Superheavy Elements will allow FLNR during 2017–2023 to conduct an in-depth study of the nuclear properties of isotopes of superheavy elements with Z=113–118. Comparative examinations of reactions between actinide targets and ^{48}Ca and between actinide targets and heavier projectiles, like ^{50}Ti, ^{54}Cr, and ^{58}Fe, will make it possible to proceed to the synthesis of elements with Z=119, 120. Significant attention will be given to experiments on the synthesis of new isotopes of superheavy elements to determine the borders of the "island" of increased stability of SHE.

Investigation of incomplete fusion reactions of massive nuclei

The next step in research of heavy and superheavy neutron-rich nuclei will be investigation of deep inelastic transfer and quasi-fission reactions as an instrument for the synthesis of heavy nuclei with a large neutron excess and study of the influence of shell effects on reaction mechanisms.

Synthesis of new nuclides in the heavy nuclei region and study of their properties

Heavy neutron-rich nuclei located in the region Z= 60–90 near the neutron closed shell N=126 will be studied in multinucleon transfer reactions using high-intensity beams of heavy ions.

Nuclear structure of elements of the "second hundred"

Experiments on α-, β-, and γ-spectroscopy of heavy and transfermium isotopes, which will allow physicists to obtain data on structures of nuclear levels and to clarify the parameters of models describing SHE properties, will be continued.

Study of mechanisms of reactions with stable and radioactive nuclei, search for new decay modes

Set-ups equipped with cryogenic targets ^{3}He, ^{4}He, H_2, D_2, T_2 and multiparameter charged-particle, neutron, and gamma-quanta detecting systems will be used to implement programmes to search for 2n and 4n radioactivity and to study 2p radioactivity as well as 2n, 4n, 2p, and 4p decays near the borders of nuclear stability.

Study of characteristics of reactions with weakly bound stable and radioactive nuclei in the vicinity of the Coulomb barrier as well as mechanisms of nuclear reactions with cluster nuclei will be continued. These investigations will allow the role of exotic nuclei in astrophysical nucleosynthesis to be evaluated.

Nuclear physics with neutrons

Research in the field of nuclear physics with neutrons will be carried out at the IREN facility. Experiments will also be carried out at the IBR-2 reactor (mainly those that require high neutron fluxes), at the EG-5 facility (experiments with fast neutrons, low-background measurements and applied studies) and at external neutron sources.

The research activities will be continued in three main directions:

1. Investigations of the violation of fundamental symmetries in neutron-nuclear interactions and related data

In 2017–2023, efforts of the corresponding research teams will be focused on the high-priority investigations related to the study of the violation of fundamental symmetries in neutron-nuclear interactions. The main tasks in this field are:

– Search for neutral currents in weak nucleon-nucleon (NN) processes in experiments to measure P-odd asymmetry in the reactions of slow polarized neutrons with light nuclei, in particular measurements of P-odd asymmetry in the $^{3}He(n,p)^{3}H$ reaction with cold polarized neutrons (ILL, PIK).

– Investigation of T-odd and P-odd effects in fission. Measurement of characteristics and correlations in the emission of neutrons, gamma quanta and light charged particles in fission (IREN, IBR-2, ILL, FRM-2).

– Investigations of T-odd, P-odd and P-even effects in the (n,γ), (n,p), (n,α) reactions in the resonance neutron energy range (IREN, EG-5, n_TOF).

– Investigation of prompt neutrons produced in nuclear fission and properties of superfluidity of fission fragments (IREN).

– Measurements of total and partial neutron cross-sections, angular correlations, multiplicity fluctuations, yields of reaction products in neutron-nuclear interactions (IREN, EG-5, n_TOF).

2. Investigations of fundamental properties of the neutron and UCN physics

The research activities in the field of UCN physics during 2017–2023 will be focused on the preservation and promotion of the existing scientific school. The world trend in the development of this research area is to build high-density UCN sources. Putting a UCN source with a density of 10^4 n/cm^3 into service will open new prospects for improving the accuracy of precision experiments with UCN, for implementing new techniques and extending the area of application of ultracold neutrons (for example, use of UCN to study the surface and related physical phenomena). JINR is planning to actively participate in the development and construction of such a source at the most intense neutron sources: PIK reactor (Gatchina, Russia) or reactor in ILL (Grenoble, France).

The most exciting physics problem that can be addressed with a high-density source is to determine the neutron lifetime with an accuracy of ~ 0.1 s. The solution of this problem will be a top-priority task for the seven-year period. The use of an intense UCN source will require the application of new experimental techniques and approaches which should be preliminarily developed and tested.

The available neutron sources at JINR do not allow high-density UCN sources to be developed, but such a source would be indispensable for test experiments as well as for attracting and training young specialists. One of the tasks in this direction in 2017–2023 is to study the possibility of developing a source of very cold neutrons (VCN) at the IBR-2 reactor and a UCN source on its basis. The development of a VCN source itself has interesting prospects for using it to solve problems both in fundamental physics and condensed matter investigations.

3. Applied and methodological research will include:

– Studies using neutron activation analysis at the REGATA facility of the IBR-2 reactor and atomic absorption spectrometer (AAS) within the framework of international and national projects in the field of life sciences.

– Non-destructive analysis of the elemental composition of objects using thermal, resonance and fast neutrons by neutron and gamma spectrometry.

– Development and application of the tagged neutron method for fundamental studies of interactions of fast neutrons with nuclei. Application of the method for elemental analysis.

– Analysis of surfaces of solids and nanostructures at the EG-5 accelerator. Development of a microbeam based on this accelerator.

– Simulation and calibration of neutron detectors for space vehicles.

Financing schedule (k$)

	2017	2018	2019	2020	2021	2022	2023	Total
Fundamental studies of neutron-induced nuclear reactions	416.0	425.0	632.0	645.0	630.0	590.0	562.0	**3 900.0**
Investigations of fundamental properties of the neutron and UCN physics	180.0	180.0	190.0	274.0	300.0	550.0	570.0	**2 244.0**
Applied and methodological research	304.0	350.0	200.0	175.0	240.0	110.0	210.0	**1 589.0**
Total	**900.0**	**955.0**	**1 022.0**	**1 094.0**	**1 170.0**	**1 250.0**	**1 342.0**	**7 733.0**