Form №21

APPROVED

JINR Vice-Director

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«___»_____2020

SCIENTIFIC AND TECHNICAL JUSTIFICATION FOR OPENING A NEW THEME in JINR TOPICAL PLAN for 2021-2025

Theme code:	04-4-….-2021/2025
Laboratory:	FLNP
Department:	Department of Neutron Investigations of Condensed Matter (NICM)
Field of research:	Condensed Matter Physics, Radiation and Radiobiological Research (04)
Theme title:	Investigations of functional materials and nanosystems using neutron scattering
Theme leaders:	D.P. Kozlenko, V.L. Aksenov, A.M. Balagurov

Brief annotation

A study of relationships between the structural features of materials and their physical properties at the microscopic level is one of the fundamental tasks that determine the development of modern concepts in the field of condensed matter physics, materials science, chemistry, geophysics, engineering, biology and pharmacology. The unique advantages of using neutron research methods (diffraction, small-angle neutron scattering, reflectometry, inelastic scattering, radiography and tomography) make their application the most optimal, and in some cases the only approach for solving a wide range of topical fundamental and applied problems related to the investigation of microscopic mechanisms of the development of physical properties and phenomena observed in functional materials and nanosystems; synthesis of materials with desired properties for the development of modern technologies; study of properties of biological molecules and membranes, polymers; creation of new drugs; research of geophysical processes; non-destructive analysis of residual stresses in structural materials and industrial products; analysis of the internal structure of cultural heritage objects, etc.

The results of scientific research in the framework of the expiring theme 04-4-1121-2015/2020 “Investigations of Condensed Matter Using Modern Neutron Scattering Methods” clearly demonstrate the high efficiency of using neutron scattering techniques for the successful solution of the above listed problems. A number of key scientific, applied and methodological areas of research formulated within the framework of the theme remain relevant at the present time, and in some areas, the investigations have been carried out to the appropriate extent and do not require continuation. At the same time, new promising areas of research, trends and priorities in the development of experimental facilities have emerged. In this regard, it is reasonable to

open a new theme for a five-year period for carrying out investigations, taking into account the above factors.

The activities under the theme “Investigations of functional materials and nanosystems using neutron scattering” in 2021-2025 will be primarily focused on the implementation of the tasks set out in the JINR seven-year development plan in the field of condensed matter physics research. There are all the necessary prerequisites for this:

- most of the activities under the theme will be carried out at the JINR basic facility—the modernized IBR-2 reactor, which has world-class parameters and is the only one in the JINR Member States;
- the user program for scientists from the JINR Member States is being efficiently realized;
- the development program for the IBR-2 spectrometers’ complex is being successfully implemented;
- Department employees are relatively young (average age is just over 40) and at the same time, are highly qualified specialists.

High-priority fundamental and applied research areas of the theme are:

1. Condensed matter physics and materials science;
2. Physics of nanosystems and nanoscale phenomena;
3. Physics of complex fluids and polymers;
4. Biophysics and pharmacology;
5. Applied materials science and engineering.

Main tasks within these areas are:

1.1. Investigation of structure and properties of new organic and inorganic functional materials;
1.2. Investigation of structural and magnetic properties of materials under extreme conditions;
1.3. Real-time investigations of physical and chemical processes in functional materials;
1.4. Computer simulation of structure and properties of new functional materials and nanosystems;
2.1. Investigation of structural and magnetic properties of layered nanostructures;
2.2. Investigation of structure of carbon-and silicon-containing nanomaterials;
2.3. Investigation of molecular dynamics of functional materials;
3.1. Investigation of dispersed systems and complex fluids in bulk and at interfaces;
3.2. Investigation of structural organization of polymer nanomaterials;
4.1. Investigation of supramolecular structure and functional characteristics of biological nanosystems;
4.2. Investigations of structure and properties of lipid membranes and complexes;
4.3 Investigations of structure and properties of biohybrid complexes;
5.1. Investigation of internal stresses and microstrains in structural materials and industrial products;
5.2. Investigation of features of internal structure of cultural and natural heritage objects, structural materials and industrial products;
5.3. Investigation of texture and properties of rocks and minerals, structural materials;

5.4. Study of radiation damage effects in solid-state materials.

In addition, the activities in the framework of the theme will include the development of a number of neutron methods for condensed matter research:

- poly- and single-crystal diffraction analysis;
- neutron optics with polarized and non-polarized neutrons (reflectometry, small-angle neutron scattering, spin-echo);
- inelastic neutron scattering techniques;
- diffraction analysis of internal stresses and textures of materials;
- radiography and tomography.

The research activities in the framework of the theme will be carried out mainly on the basis of a suite of spectrometers of the modernized IBR-2 reactor. Some experimental investigations will be performed in other neutron and synchrotron centers in Russia and abroad. In addition to the neutron and synchrotron radiation scattering techniques, for a number of studies, complementary methods of optical and x-ray spectroscopy will be employed.

List of projects:

Project	**Leader**	**Priority (period of realization)**
Development and construction of an inverse geometry inelastic neutron scattering spectrometer at the IBR 2 reactor	D.M. Chudoba	1 (2021-2023)

Stages

In 2021-2025, planned investigations and experiments will be carried out in the framework of the user program on the basis of the IBR-2 spectrometers along with methodological activities on their modernization and the development of new neutron diffraction methods. In some cases, experiments will be conducted in other neutron centers in Russia and abroad, as well as with the application of complementary methods of synchrotron radiation scattering and optical spectroscopy.

I. Scientific investigations

1.1. Study of structure and properties of new inorganic and organic functional materials

Experiments to study the features of atomic and magnetic structure and properties of new inorganic and organic crystalline and nanostructured functional materials using neutron scattering techniques and complementary methods, data processing (2021-2025).

Responsible persons: Balagurov A.M., Kozlenko D.P., Tyutyunnikov S.I. (VBLHEP)

Main researchers:	*Bobrikov I.A., Kichanov S.E., Turchenko V.A., Beskrovnyi A.I., Savenko B.N.*
Other participants:	*Askerov E.B., Golosova N.O., Kraus M.L., Lukin E.V., Mironova G.M., Popov E.P., Pavlyukoych A., Samoilova N.Yu., Sikolenko V.V., Sumnikov S.V., Zlokazov V.B. (LIT), Shalyapin V.N., Efimov V.V., Kovalev Yu.S., Rogachev A.V., Zamyatin N.I., Kryachko I.A., Artyukh V.A. (VBLHEP).*

1.2. Investigation of structural and magnetic properties of materials under extreme conditions

Experiments to study the atomic and magnetic structure and properties of functional materials under external high pressures and low temperatures, data processing (2021-2025).

Responsible persons:	*Kozlenko D.P.*
Main researchers:	*Kichanov S.E., Lukin E.V., Savenko B.N.*
Other participants:	*Belozerova N.M., Golosova N.O., Rutkauskas A.V.*

1.3. Real-time investigations of physical and chemical processes in functional materials

Real-time/in-operando experiments to study physicochemical processes in functional materials under changing external conditions, data processing (2021-2025).

Responsible persons:	*Balagurov A.M.*
Main researchers:	*Bobrikov I.A., Beskrovnyi A.I.*
Other participants:	*Sumnikov S.V., Ivanshina O.Yu., Popov E.P., Samoilova N.Yu., Simkin V.G., Mironova G.M., Vershinina T.N.*

1.4. Computer simulation of structure and properties of new functional materials and nanosystems

Theoretical calculations of structural and dynamic properties of new functional materials and nanosystems, including bioactive materials, molecular crystals and glasses, ionic-molecular inclusive materials, complexes with electric charge transfer, metal-organic frameworks using molecular modeling and molecular dynamics methods (2021-2025).

Responsible persons:	*Pawlukojć A.*
Main researchers:	*Kholmurodov Kh.T.*

2.1. Investigation of structural and magnetic properties of layered nanostructures

Experiments to study structural and magnetic properties of layered nanostructures with a spatial resolution of down to 1 nm using neutron polarization reflectometry, complemented by detection of secondary radiation, data processing (2021-2025).

Responsible persons:	*Nikitenko Yu.V.*
Main researchers:	*Zhaketov V.D., Kozhevnikov S.V., Petrenko A.V.*

2.2. Investigation of structure of carbon-and silicon-containing nanomaterials

Investigation of internal structure, stabilization methods, and aggregation mechanisms of nanoparticles based on carbon- and silicon-containing materials in various solid and liquid media, including dispersions of fullerenes, nanodiamonds, etc., with a view to their further application in nanotechnological processes. Study of the structure of bioactive systems based on materials of this class and investigation of the relationship between their structural characteristics and toxicity to living organisms (2021-2025).

Responsible person	*Aksenov V.L.*
Main researchers:	*Tropin T.V., Kyzyma O.A., Tomchuk A.A.*
Other participants:	*Chudoba D.M., Nagornaya T.V., Jazdzewska M., Nazarova A.Zh.*

2.3. Investigation of molecular dynamics of functional materials

Experiments using the NERA spectrometer to study the molecular dynamics of bioactive materials, liquid crystals and glasses, ionic-molecular inclusive materials, complexes with electric charge transfer, metal-organic frameworks and nanomaterials for storing hydrogen and carbon dioxide, fluorescent dyes. Synthesis and complex physicochemical studies of multifunctional backbones of nanomaterials, isotope effect using experimental and theoretical methods. Data processing (2021-2025).

Responsible persons:	*Chudoba D.M.*
Main researchers:	*Goremychkin E.A., Bilski P.*
Other participants:	*Krawczyk J., Nagornaya T.V.*

3.1. Investigation of dispersed systems and complex fluids in bulk and at interfaces

Investigation of advanced dispersed systems based on liquid and solid solutions of nanoparticles and nanoscale complexes in regard to the mechanisms of their stability in bulk and at interfaces, including biorelevant systems; development of neutron scattering methods of analysis of the atomic and magnetic structure of magnetic colloidal systems, investigation of electrochemical interfaces (2021-2025).

Responsible persons:	*Avdeev M.V.*
Main researchers:	*Petrenko V.I., Nagornyi A.V., Gapon I.V.*
Other participants:	*Tomchuk A.V., Kosiachkin E.N.*

3.2. Investigation of structural organization of polymer nanomaterials

Investigation of structural and functional characteristics of new polymers, layered and nanodispersed structures, holding promise for nanotechnological applications using small-angle neutron scattering and complementary methods (2021-2025).

Responsible persons:	*Balasoiu M.*
Main researchers:	*Kuklin A.I., Islamov A.Kh.*
Other participants:	*Ivankov O.I., Soloviev D.V., Rogachev A.V.*

4.1. Investigation of supramolecular structure and functional characteristics of biological nanosystems

Investigation of structural and functional characteristics, phase transitions of biological macromolecules, complexes and proteins embedded in membranes, phase transitions in lipid structures using small-angle neutron scattering, X-ray scattering, light scattering, P-V-T, densitometry and other complementary methods (2021-2025).

Responsible persons:	*Kuklin A.I.*
Main researchers:	*Murugova T.N., Ivankov O.I., Soloviev D.V., Gorshkova Yu.E.*
Other participants:	*Islamov A.Kh., Soloviev A.G. (LIT), Kovalev Yu.S., Rogachev A.V., Skoy V.V.*

4.2. Investigations of structure and properties of lipid membranes and complexes

Investigation of the nanostructure of a model lipid matrix in the outermost layer of human skin (stratum corneum), study of the role of individual ceramides in the formation of diffusion properties of the matrix for drug penetration. Study of diffusion of pharmaceutical solutions through model lipid matrices. Development and study of unilamellar vesicles with high deformation properties as a basis for formulating promising vesicular drug carriers for transdermal delivery. Study of the structure of vesicles and phospholipid transport nanosystem (2021-2025).

Responsible persons:	*Kiselev M.A.*
Main researchers:	*Kichanov S.E., Lukin E.V., Savenko B.N.*
Other participants:	*Maslova V.A., Ivankov O.I., Zemlyanaya E.V. (LIT)*

4.3. Investigations of structure and properties of biohybrid complexes

Experiments to study the structure of composite materials based on bacterial and nanocrystalline cellulose using small-angle neutron scattering. Analysis of mechanisms of formation of lyogels and airgels, analysis of the structure of biohybrid polymer complexes based on airgels and ultralight ultraporous carbon materials. Structural studies of drug delivery systems consisting of DNA biohybrids, biomimetic membranes, “green” nanometals and therapeutic agents using small-angle neutron scattering and other complementary methods: small-angle X-ray scattering and X-ray diffraction, scanning electron and atomic force microscopy, optical spectroscopy, dynamic light scattering (2021-2025).

Responsible persons:	*Gorshkova Yu.E.*
Main researchers:	*Tropin T.V., Ivanshina O.Yu.*

5.1. Investigation of internal stresses and microstrains in structural materials and industrial products

Neutron diffraction studies of internal stresses and microstrains in advanced structural materials, industrial materials and products, cermets, shape memory alloys (2021-2025).

Responsible persons:	*Bokuchava G.D.*

Main researchers:	*Vershinina T.N.*
Other participants:	*Papushkin I.V., Kruglov A.A., Tamonov A.V., Mukhametuly B., Taran Yu.V.*

5.2. Investigation of features of internal structure of cultural and natural heritage objects, structural materials and industrial products

Nondestructive neutron radiography and tomography studies of internal structure and processes in objects of cultural and natural heritage, structural materials, industrial products and rocks (2021-2025).

Responsible persons:	*Kozlenko D.P.*
Main researchers:	*Kichanov S.E.*
Other participants:	*Savenko B.N., Lukin E.V., Nazarov K.M., Rutkauskas A.V., Zel I.Yu.*

5.3. Investigation of texture and properties of rocks and minerals, structural materials

Experiments for neutron diffraction analysis of texture and stresses in polycrystalline materials and rocks in combination with other physical methods to study the nature of seismic anisotropy of the Earth's lithosphere and other geodynamic phenomena. Investigation of the effect of phase transitions on the loss of stability of polycrystalline materials using neutron diffraction and acoustic emission methods.
Experiments for neutron diffraction analysis of texture in structural materials (magnesium, aluminum, nickel, titanium and other alloys). Investigation of the effect of modification on the evolution of texture and stresses in wheel steels (2021-2025).

Responsible persons:	*Nikolaev D.I.*
Main researchers:	*Ivankina T.I., Vasin R.N.*
Other participants:	*Sikolenko V.V., Lychagina T.A., Altangerel B.*

5.4. Study of radiation damage effects in solid-state materials

Obtaining data on mechanisms of radiation damage to solids by relativistic particles and fast neutrons using X-ray scattering methods; selection of structural materials with high radiation damage resistance to fast neutrons; obtaining long-life operating data on radiation damage resistance of solid-state materials.
Data collection and processing (2021-2025).

Responsible persons:	*Tyutyunnikov S.I. (VBLHEP)*
Main researchers:	*Shalyapin V.N., Efimov V.V., Levterova E.A., Kovalev Yu.S., Rogachev A.V., Zamyatin N.I., Kryachko I.A., Artyukh V.A. (VBLHEP), Sikolenko V.V. (FLNP)*

II. Methodological developments

1. Development of IBR-2 spectrometers

Development and construction of basic configuration of a small-angle scattering and imaging spectrometer on beamline 10 (2021-2025); development and construction of main elements of a new inverse geometry inelastic neutron scattering spectrometer (according to the project within the framework of the theme); development of the DN-6 diffractometer for studies of microsamples and GRAINS reflectometer with vertical scattering plane. Modernization of IBR-2 spectrometers. (2021-2025)

Responsible persons:	*Avdeev M.V., Kozlenko D.P., Chudoba D.M.*
Main researchers:	*Beskrovnyi A.I., Bobrikov I.A., Bodnarchuk V.I., Kichanov S.V., Kuklin A.I., Lukin E.V., Nikitenko Yu.V., Petrenko A.V., Savenko B.N., Simkin V.G., Sukhanov V.I., Turchenko V.A., Bokuchava G.D., + 20 pers.*

2. Development of neutron methods to study functional materials and nanosystems

Development and testing of neutron methods for studying the structure and dynamics of functional materials and nanosystems, nondestructive testing of bulk products, including spin-echo, correlation diffractometry, neutron standing waves, radiography, tomography, and other techniques. Continuation of activities on development and construction of a prototype of small-angle spin-echo scattering spectrometer on beamline 9, development of radiography and tomography spectrometer on beamline 14 and FSS spectrometer on beamline 13.

Development of neutron reflectometry in an oscillating magnetic field. Continuation of development and construction of a neutron interferometer for the spin-echo neutron reflectometer.

Responsible persons:	*Bodnarchuk V.I., Bokuchava G.D., Kozlenko D.P., Avdeev M.V.*
Main researchers:	*Kichanov S.E., Lukin E.V., Kozhevnikov S.V., Nikitenko Yu.V., Rutkauskas A.V., Yaradaykin S.P., Zhaketov V.D., Kosiachkin E.N.*

Expected results upon completion of the theme:

1. Determination of characteristics of the atomic and magnetic structure of giant magnetostrictive alloys depending on thermodynamic conditions, synthesis conditions, alloying additives and thermomechanical processing.
2. Determination of parameters of the atomic and magnetic structure of simple and complex oxides with a spinel-type structure under high pressure.
3. Determination of parameters of crystal, magnetic and electronic subsystems of multifunctional oxides based on cobalt, manganese, iron in the region of spin transition and antiferromagnetic-ferromagnetic-paramagnetic and metal-insulator phase transitions in a wide range of temperatures and pressures.
4. Complex analysis of relationships between structural distortions of the crystal and magnetic structure, local atomic and electron structure with macroscopic electrical and magnetic transport properties to refine the most reliable model necessary to explain the nature and mechanisms of physical phenomena observed in complex oxides based on cobalt, manganese, and iron.
5. Study of structural mechanisms of the magnetoelectric effect in multiferroics.

6. Study of the effect of microstructure of electrodes with varying composition on charge-discharge processes in compact electric power sources. Clarification of structural mechanisms responsible for the capacity and lifetime of batteries. Selection of optimal discharge/charge modes during cycling.
7. Analysis of processes of deposition and intercalation of electrically active ions and their derivatives from liquid and solid electrolytes at electrochemical interfaces in compact electric power sources. A comparative study of characteristics of adsorption layers (density, thickness, homogeneity) at electrochemical interfaces for electrolytes and electrodes.
8. Study of phenomena and effects induced by the interaction of ferromagnetic and superconducting order parameters in complex structures with helicoidal magnetic ordering.
9. Investigation of structural stability of colloidal systems, including biomedical solutions, in bulk and at interfaces under various conditions. Determination of characteristics of adsorption layers at interfaces in case of loss of stability as a result of external influence of gradient electric and magnetic fields, as well as temperature effects. Study of the effect of aggregate formation in bulk on adsorption.
10. Investigation of the structure of a number of advanced nanosystems based on composite carbon- and silicon-containing materials, including those based on fullerenes, nanodiamonds and their bioactive derivatives. Study of complex multicomponent systems. Determination of conditions for synthesis of homogeneous systems. Investigation of effects of phase separation in advanced practical systems.
11. Determination of structural characteristics of magnetic elastomers and carbosilane dendrimers, holding promise for technological applications.
12. Study of structure and vibrational spectra of molecular complexes: ionic-molecular inclusive materials and complexes with electric charge transfer, structural and dynamic parameters of hydrogen bonds in bioactive materials.
13. Investigation of molecular mechanisms of protein interaction, dimerization and functional characteristics of supramolecular structures and molecular complexes. Study of regularities and relationships between structural characteristics and functions of proteins, protein complexes and membrane-protein aggregates. Analysis of the effect of composition and external parameters on the phase state of membranes.
14. Determination of structural characteristics and diffusion properties of lipid nanosystems for transport of drugs and nano-drugs.
15. Analysis of metamorphic, geodynamic and evolutionary processes in the lithosphere using data on textures of deep-seated and near-surface rocks. Study of regularities in the development of instability of rocks under high temperatures and pressures. Investigation of relationships between seismic anisotropy of lithosphere rocks and textures of minerals, preferentially-oriented cracks and pores.
16. Nondestructive testing of residual internal stresses and microstrains in real industrial products and advanced structural materials induced by various technological processes (metal and heat treatment, welding, rolling, stamping, 3D printing, etc.).
17. Investigation of relationships between microstructure and thermomechanical properties of advanced functional and structural materials (high-strength steels, aluminum and magnesium alloys, composites, cermets, etc.), analysis of mechanical behavior of structural materials under external influences (load, temperature).

18. Analysis of internal structure and construction of 3D models of objects of cultural and natural heritage, industrial materials and products using neutron tomography and radiography data.
19. Clarification of mechanisms of radiation damage to solids, obtaining long-life operating data on radiation damage resistance of materials.

Expected methodological results:

1. Development and construction of elements of basic configuration of a small-angle scattering and imaging spectrometer on beamline 10.
2. Development and construction of elements of a neutron guide system for a new inverse geometry inelastic scattering spectrometer.
3. Development of neutron guide and detector system for the new DN-6 diffractometer for studies of microsamples, aimed at improving its technical parameters and expanding the available range of high pressures.
4. Improvement of technical parameters and expansion of experimental capabilities of the GRAINS multifunctional reflectometer (startup of a new neutron beam chopper, development of electrochemical and liquid cells for conducting experiments).
5. Modernization of the available IBR-2 spectrometers (HRFD, RTD, DN-12, YuMO, FSD, REFLEX, REMUR, SKAT, EPSILON) aimed at improving their technical characteristics (enhancement of luminosity, suppression of neutron background, improvement of data acquisition systems and expansion of experimental capabilities).
6. Development and construction of a prototype of a small-angle spin-echo scattering spectrometer on beamline 9.
7. Improvement of technical characteristics of the radiography and tomography spectrometer on beamline 14 (spatial resolution, radiation resistance of the detector system).
8. Upgrade of the FSS correlation spectrometer on beamline 13 and improvement of its technical parameters. Further development of the RTOF correlation method.
9. Development of neutron methods for condensed matter research, including spin-echo, neutron standing waves, neutron wave splitting, neutron magnetic resonance, radiography, tomography, and other techniques.
10. Development of neutron scattering methods for in-operando monitoring and study of electrochemical materials and interfaces.

Participants from JINR

Laboratory	Name
BLTP	Osipov V.A. + 3 persons
LIT	Zlokazov V.B., Zemlyanaya E.V., Soloviev A.G.
FLNR	Skuratov V.A.
VBLHEP	Tyutyunnikov S.I. + 8 persons

List of participating countries, institutes and organizations

Collaboration:

Country or international organization	City	Institute or Laboratory
Argentina	Bariloche	CAB CNEA
Azerbaijan	Baku	IP ANAS, AzTU
Belarus	Minsk	BSTU, IAP NASB, RI PCP BSU, INP BSU, SPMRC NASB, ISEI BSU
Bulgaria	Sofia	ASCI Ltd, IE BAS, IEES BAS, IMS BAS, INRNE BAS, ISSP BAS
China	Harbin	Harbin Engineering Univ.
Czech Republic	Prague	CTU, IG CAS, IMC CAS, IP CAS, BC CAS
	Ostrava	V\v SB-TUO
	Rez	NPI CAS
Egypt	Cairo	EAEA
	Giza	CU
France	Grenoble	IBS
	Saclay	LLB
Germany	Berlin	HZB, BAM
	Bayreuth	Univ.
	Bochum	RUB
	Bonn	Univ.
	Darmstadt	TU Darmstadt
	Dortmund	TU Dortmund
	Dresden	TU Drezden, IKTS
	Freiberg	TUBAF, IMF TUBAF
	Gottingen	Univ.
	Geesthacht	HZG
	Halle	MLU
	Hamburg	DESY
	Julich	FZJ
	Karlsruhe	KIT
	Kiel	CAU
	Konstanz	Univ.
	Potsdam	GFZ
	Rostock	Univ.
	Stuttgart	MPI-FKF
Hungary	Budapest	Wigner RCP
	Szeged	US

India	Gurgaon	AMITY
	Patna	NIT Patna
Italy	Trento	UniTn
Japan	Matsumoto	Shinshu Univ.
	Minato	Keio Univ.
Kazakhstan	Almaty	INP
	Rudny	RII
Latvia	Riga	ISSP UL, IPE
Moldova	Chisinau	IMB ASM
Mongolia	Ulaanbaatar	IPT MAS, MUST
Norway	Trondheim	NGU
Poland	Warsaw	INCT
	Białystok	UwB
	Wroclaw	WUT, UW
	Krakow	JU, NINP PAS, AGH-UST
	Lodz	UL
	Lublin	UMCS
	Otwock (Swierk)	NCBJ
	Poznan	AMU
	Siedlce	UPH
	Szczecin	WPUT
Russia	Moscow	GC RAS, IA RAS, IBMC, IC RAS, ICP RAS, Inst. Immunology, IEPT RAS, IGEM RAS, IGIC RAS, IMET RAS, INMI RAS, ITEP, IPE RAS, ISPM RAS, NNRU "MEPhI", MIET, MITHT, MISiS, MSU, NRC KI, OKSAT NIKIET, PIN RAS, SINP MSU, SC "VNIINM"
	Moscow, Troitsk	HPPI RAS, ISAN, INR RAS
	Chernogolovka	ISSP RAS
	Dolgoprudny	MIPT
	Dubna	Dubna State Univ., EI, Lition
	Gatchina	PNPI RAS
	Kazan	KFU, KNRTU
	Kaliningrad	IKBFU
	Krasnoyarsk	KIP SB RAS, SibFU
	Nizhny Novgorod	UNN, IPM RAS
	Perm	ICMM UrB RAS, ITCh UrB RAS
	Petrozavodsk	IG KarRC RAS
	Podolsk	GIDROPRESS

	Rostov-on-Don	RIP SFU
	St. Petersburg	Ioffe Institute, SPbSU, IMC RAS
	Sterlitamak	SB BashSU
	Tomsk	NPI TPU
	Tula	TSU
	Yekaterinburg	IMP UB RAS, UrFU
Romania	Bucharest	CNMN, IFIN-HH, INCDIE ICPE-CA, INFLPR, ISS, NIMP, UB, UMF, UPB, UTM
	Baia Mare	TUCN-NUCBM
	Cluj-Napoca	INCDTIM., RA BC-N, UBB, UTC-N
	Constanța	UOC
	Craiova	UC
	Iasi	NIRDTP, UAI, UAIC, TUIASI, USAMV
	Pitesti	SCN, UPIT
	Targoviste	UVT
	Timisoara	ICT, ISIM, LMF CCTFA, RA TB, UPT, UVT
	Tulcea	DDNI
Serbia	Belgrade	INS “VINCA”
	Novi Sad	UNS
Slovak Republic	Bratislava	CU
	Kosice	IEP SAS
South Africa	Pretoria	Necsa
Spain	Madrid	CENIM-CSIC
Switzerland	Villigen	PSI
	Zurich	ETH
Taiwan	Hsinchu	NSRRC
Tajikistan	Dushanbe	IChem ASRT
United Kingdom	Didcot	RAL
Ukraine	Kiev	DonIPE NASU, NUK, ISC NASU
	Kharkov	IERT NASU, NSC KIPT
	Donetsk	DonIPE, DonNU
USA	Berkeley	Univ. of California
Uzbekistan	Tashkent	INP AS RUz
Vietnam	Hanoi	IOP VAST
	Da Nang	DTU

Realization period:

The research and methodological activities indicated above will be carried out during the period of 2021-2025.

Total estimated cost of the theme:

N of budget items	Description of budget items	TOTAL 2021-2025 kUSD	incl. 2021 kUSD
1	Salaries	11158.9	1874.7
2	Insurance payments	3370.0	566.2
3	Social fund	725.3	121.9
4	International scientific and technical cooperation:	843.5	168.7
	a) trips to JINR Member States	88.5	17.7
	b) trips to JINR Non-Member States	239	47.8
	c) trips within Russia	99	19.8
	d) reception of foreign specialists	400	80
	e) organization of meetings, representation expenses	17	3.4
5	Materials	3500	650
6	Equipment	7700	1420
10	Payment for services of research organizations	300	50
11	Information, including information service	90	15
	TOTAL:	**27687.7**	**4866.5**
	IBR-2	19000	3200
	Design Bureau	100	17.5
	FLNP Workshop	400	69.0
	General and administrative expenses	4900	850.0
	TOTAL:	**52087.7**	**9003.0**

Cost estimate of the theme:

№	Description of activities	Total cost	Expenses per year, kUSD				
			2021	2022	2023	2024	2025
1.	Development and construction of elements of basic configuration of small-angle scattering and imaging spectrometer on beamline 10.	**1290**	350	290	250	200	200
2.	Development of new spectrometers (DN-6, GRAINS, tomography and radiography, FSS).	**2150**	450	450	450	400	400
3.	Development and construction of elements of neutron guide system for a new inverse geometry inelastic scattering spectrometer.	**2750**	500	500	500	650	600
4.	Modernization and reconstruction of existing spectrometers (HRFD,	**4560**	750	870	920	950	1070

	YuMO, RTD, DN-12, FSD, NERA, REMUR, REFLEX, SKAT, EPSILON).						
5.	Activities on development of neutron methods for investigation of nanosystems and materials.	**450**	70	80	100	100	100
	TOTAL	**11200**	**2120**	**2190**	**2220**	**2300**	**2370**

Other sources of financing:

Grants and Programs of Plenipotentiaries of JINR Member States (Poland, Czech Republic, Slovakia, Romania, Bulgaria, Belarus).

BMBF-JINR Agreement

ARE-JINR Agreement

RSF and RFBR Grants

AGREED:

JINR Chief Scientific Secretary

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FLNP Director

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Head of Planning Department

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FLNP Scientific Secretary

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Head of Scientific-Organization Department

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FLNP Economist

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Theme Leaders

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