Form №21

APPROVED

JINR Vice-Director

_____

«___»_____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
Division:	Division of Condensed Matter Research and Developments (CMRD)
Department:	Department of IBR-2 Spectrometers' Complex (SC)
Field of research:	Condensed Matter Physics (04)
Theme title:	Scientific and methodological research and developments for condensed matter investigations with IBR-2 neutron beams
Theme leaders:	S.A. Kulikov, V.I. Bodnarchuk, V.I. Prikhodko

Issues addressed and main goals of research:

Regular operation, modernization and development of control systems for CM-201 and CM-202 cryogenic moderators. Development and equipping of new spectrometers, as well as modernization and reconstruction of equipment for the existing IBR-2 spectrometers in order to improve their parameters, expand experimental capabilities and ensure their faultless operation. Scientific and technical support for the development of beam-forming systems, neutron detectors, sample environment systems, cryostats and cryomagnetic systems, as well as electronics and software of data acquisition systems. Development of FLNP information and computing infrastructure.

Brief annotation:

In 2015/20, in all areas of methodological investigations and developments of expiring theme 1122 "**Development of Experimental Facilities for Condensed Matter Investigations with Beams of the IBR-2 Facility**" (cold moderators; calculations and simulation of spectrometers; cryogenic studies; detectors and electronics; control systems for actuators, sample environment equipment and neutron beam choppers; local area network and software) important results were obtained that are of key importance for successful implementation of the development program of the IBR-2 spectrometers' complex and for conducting condensed matter research. All these areas were included in the JINR Seven-Year Development Plan for 2017–2023. Among the completed works, first of all, the following activities can be noted:

● A control system for the CM-201 cryogenic moderator, which is ready for commissioning into trial operation, was developed and constructed.

● To date, the CM-202 cryogenic moderator has operated trouble-free for physics experiments for about 4000 h, including about 1000 h with a new cryogenic system with a capacity of 1900 W. Simultaneously with the regular operation of CM-202, work was carried out to automate the shutoff valves of vacuum equipment and pipelines for supplying and discharging helium to/from the moderator chamber, as well as preparatory work was conducted for putting the second cold moderator CM-201 into trial operation.

● Unique ring-shaped neutron detectors were developed, manufactured and put into operation at DN-6 and RTD spectrometers.

● A large-scale modernization of the radiation research facility (IBR-2 beamline 3) was carried out. In particular, a robotic arm with video surveillance and distance measuring equipment for handling highly active samples in high ionizing radiation fields and with a local dosimetry system for automatic measuring of doses during irradiation sessions was installed.

● Work on the project "**Development of a PTM sample environment system for the DN-12 diffractometer at the IBR-2 facility**" aimed at developing a horizontal-vertical cryostat with a superconducting magnet with a magnetic field strength of up to 4 T and a variable temperature in the range of 4-300 K is successfully nearing completion.

● In 2018, the activities on the creation of a clean room for assembling neutron detectors in FLNP bldg 119 were completed. At present, work is underway to equip it with technological equipment.

● Work on the project "**Development of a wide-aperture backscattering detector (BSD) for the HRFD diffractometer**" aimed at developing a technical design, technology of manufacturing detector components and at solving the problem of neutron focusing, as well as constructing one (out of twelve) segments of the detector along with electronics and software, proceeds successfully.

● For the NERA spectrometer, a new detector system was developed, manufactured and put into operation, and the modernization of the shaft cryostat was carried out.

● A 2D gas-filled PSD with a sensitive area of 200×200 mm^2 was manufactured and put into operation at the HRFD diffractometer.

● A new ring detector for obtaining neutron spectra at a scattering angle of 45° was developed and put into operation at the DN-6 diffractometer.

● The FLNP local area network is being upgraded to operate at a data rate of 100 Gb/s. A wireless local Wi-Fi network was installed in the main buildings of the Laboratory.

● A large amount of work was carried out to maintain and develop the Sonix+ software package (including at the request of users).

In a number of other directions, a considerable amount of scientific and technical groundwork has been done over the four years of the seven-year period, and therefore, it is proposed to open a new theme "**Scientific and methodological research and developments for condensed matter investigations with IBR-2 neutron beams**" in 2021-2025, as well as to open a new project "**Construction of a wide-aperture backscattering detector (BSD) for the HRFD diffractometer**", the implementation of which to the full extent will make it possible to increase the solid angle for the HRFD diffractometer by a factor of more than 10 compared to that covered by the currently used detector. The Activity reports of theme 1122 were presented and approved at the 46^{th} and 52^{nd} sessions of the PAC for Condensed Matter Physics.

The conduction of condensed matter investigations at a state-of-the-art level is characterized by continuous improvement of experimental techniques, increase in the number of controlled parameters as well as in the number of detectors and sample environment systems used in the experiment and their sophistication, heightened requirements for accuracy and operation speed of data acquisition equipment, necessity to provide remote control over spectrometer subsystems and the experiment as a whole, and requires constant development of both the spectrometers and IBR-2 research nuclear facility, including in particular, the complex of cold moderators.

The user policy carried out at the IBR-2 spectrometers imposes additional requirements for the equipment of the spectrometers, control systems, and data acquisition systems, which should be easy to master and easy to use, should have convenient graphic interface and provide access to measurement results via the Internet, etc.

For the staff of the SC Department, the fulfillment of all these requirements was the main goal of the activities carried out in the framework of expiring theme 1122 (to be completed in 2020) and remains to be the key objective of the new theme. The employees of the SC Department are highly qualified specialists with extensive experience in international cooperation. The upcoming work is a natural continuation of the activities performed in 2015-2020.

At present, the Department's staff comprises 64 employees (including 6 secondary job employees); among them are 2 Doctors of Science and 7 Candidates of Science. The average age of the employees is 47 years. During the implementation of theme 1122, one Doctor and one Candidate degree dissertations were defended (one Candidate degree dissertation was prepared for defense). The Department employs two postgraduate students (from MIPT and Dubna State University), and every year several students receive practical training and work on their Master's theses. Five International Schools for Young Scientists and Students "Instruments and Methods of Experimental Nuclear Physics. Electronics and Automatics of Experimental Facilities" were held.

During the period of implementation of the theme, 75 papers in specialized journals were published and about 60 reports were presented at International and Russian conferences. Three series of studies carried out in the framework of the theme were awarded prizes in the JINR Prize Competitions (two Second Prizes and one Encouraging Prize). The employees of the Department received 3 patents and 4 certificates of state registration of computer programs.

In recent years, the Department's infrastructure has improved significantly: the workplaces of engineers and programmers were equipped with modern high-performance computers and testing-and-measuring devices; Wi-Fi LAN equipment was installed to provide Wi-Fi access throughout the building; the machinery equipment of the Department's Express Workshops was almost completely upgraded.

At the 52nd meeting of the PAC for Condensed Matter Physics, detailed reports on theme 1122 and related PTM and BSD projects (being completed in 2020), as well as scientific and technical justification for opening a new theme, "**Scientific and methodological research and developments for condensed matter investigations with IBR-2 neutron beams**" with top priority in 2021-2025, and a proposal to open a new project "**Construction of a wide-aperture backscattering detector (BSD) for the HRFD diffractometer**", were considered and approved. Here we would like to highlight some important features of the activities both completed and upcoming and briefly formulate plans for 2021-2025 in the main research areas:

● At present, some practical experience has been gained in operating the CM-202 cold moderator in the direction of beamlines № 7,8,10,11. The CM-202 has a unique design with the moderating substance consisting of solid mesitylene (a mixture of mesitylene and m-xylene) shaped as beads, which are loaded into the moderator chamber by means of gaseous helium circulating in the circuit. The CM-202 design includes various sophisticated systems, unique devices and developments that have been applied for the first time (for example, pellet-dispensing device, helium-aided pellet-

feeding system, helium flow control system and pellet jam monitoring device, etc.) Work will continue on the automation of the CM-201 and CM-202 cold moderators, as well as on searching for ways to increase the duration of operation of the pelletized cold moderator for physics experiments.

The installation of the entire complex of cryogenic moderators at the IBR-2 reactor will allow a significant reduction in the measurement time for a wide range of experiments due to an increase in the cold neutron yield from the moderator surface and will ensure that in the near future the IBR-2 reactor will maintain and strengthen its leading position in the world among high-intensity neutron sources in the field of condensed matter research.

● In the experiments on the IBR-2 reactor a variety of specialized equipment is widely used to create certain conditions on the sample under study (for example, temperature, pressure, magnetic or electric field, etc.), to move and spatially orient samples as well as to change them. Within the framework of theme 1122 a significant progress has been made in providing spectrometers with such equipment and its standardization, as well as in the unification of control systems. Among important features of the new systems are that all of them are designed according to a unified scheme; control systems are realized as an independent module connected to a PC through a USB interface; all basic elements of the systems (sensors, motors, movement controllers, temperature controllers, etc.) and their interfaces are unified. And wherever possible, industrial equipment is used.

● At present, the data acquisition systems of all IBR-2 spectrometers consist of 1-2 basic electronic modules, one of which (De-Li-DAQ) processes and accumulates data from two-dimensional position-sensitive detectors, and the other (MPD) – from an array of point detectors (gas and scintillation counters). From the viewpoint of hardware the basic modules are identical, and the setting of all parameters, modes and operation algorithms specific to a concrete spectrometer, is realized on the level of microprograms, which are stored and executed in field-programmable gate arrays (FPGA) of the respective module. All these data are stored in the common configuration file of the spectrometer computer and are written by the control program to the FPGA during initialization. The DAQ systems make it possible to work both in the histogram mode and in the **raw data accumulation** mode, which in some cases is of principal importance (for example, for Fourier diffractometers).

● It should be noted that the manufacturing technology of state-of-the-art electronic modules is quite complex and requires expensive equipment that pays off only in mass serial production. Therefore, multichannel digitizers that have appeared on the market are currently being studied from the point of view of their possible use in DAQ systems at the IBR-2 spectrometers, which is one of the tasks of the new theme. The aim of the activities in this direction is to achieve a harmonious combination of measuring and computing technologies.

In conclusion, a few words should be said about the **competitiveness** of the activities under the proposed theme. Work on the cryogenic moderators is a pioneer project and, of course, beyond competition. The designs of cryostats and detector systems with electronics and software are at a world class level, which is evidenced by the fact that we have won tenders for their delivery to NRI (Řež, Czech Republic), as well as their use in NFRI (Daejeon, Republic of Korea); HZB (Berlin, Germany) and several organizations in the Russian Federation.

Stages of work for 2021-2025:

The main objectives of the theme are to develop (in cooperation with the FLNP Department of Neutron Investigations of Condensed Matter (NICM)), as well as to improve the technical characteristics and expand the experimental capabilities of existing and newly developed spectrometers of the IBR-2 reactor in accordance with the JINR Seven-Year Development Plan. At a joint meeting of the Scientific Council of SC and NICM departments on February 11, 2020, the results of the activities in the framework of theme 1121 (NICM) and 1122 (SC) were discussed and prospects for the development of IBR-2 spectrometers for the coming years were outlined. At this meeting, plans were announced to develop and construct three new facilities: a neutron radiography and tomography station (beamline 10a); SANSARA small-angle neutron scattering instrument (also channel 10a) and an inverse

geometry inelastic neutron scattering spectrometer (beamline 2). It was also reported on general plans for the development of almost all IBR-2 spectrometers. In the framework of the theme to be opened, scientific and methodological work will be carried out in the following areas:

- construction and development of the complex of cold moderators;
- detector and cryomagnetic systems;
- analog electronics and data acquisition electronics;
- control systems for actuators;
- sample environment equipment and choppers for spectrometers;
- software;
- information and computing infrastructure;
- investigation of radiation resistance of materials;
- calculation and simulation of spectrometers.

1. Cold moderators; investigation of radiation resistance of materials:

Responsible persons — *Kulikov S.A., Bulavin M.V.*

Main researchers: *Bulavin M.V. + 5 engineers, Kirilov A.S. + 1 engineer, Altynov A.V. + 2 engineers, Mukhin K.A.*

1.1. Maintenance of regular operation of the complex of CM-201 and CM-202 cryogenic pelletized moderators for physics experiments at different temperatures, depending on the needs of users of the IBR-2 reactor. Automation of the vacuum system and the system for supplying helium to the pneumatic transport pipeline, as well as upgrade of software for control systems of the CM-201 and CM-202 moderators. Startup and adjustment of a new dispensing device with an increased volume on the CM-201 test stand and the CM-201 cryogenic moderator. Operational testing of the new dispensing device, determination of the loading time of the CM-201 moderator chamber with its help.

1.2. Investigation (in cooperation with JINR laboratories, as well as with institutes of JINR Member States and other countries) of radiation resistance of materials using the radiation research facility. Neutron activation analysis of irradiated samples using high-purity germanium spectrometers.

2. Calculation and simulation of spectrometers:

Responsible person — *Bodnarchuk V.I.*

Main researchers: *2 persons*

2.1. Development and application of VITESS and other software packages for simulation of neutron scattering in samples and in individual components of spectrometers. Complex calculations and optimization of spectrometers.

2.2. Methodological studies of neutron background at IBR-2 spectrometers. Determination of its sources, level and influence on experimental results. Development of recommendations to reduce the background level at particular spectrometers of the IBR-2 reactor, as well as of the future JINR neutron source, using the results of measurements and model calculations.

3. Cryogenics:

Responsible person — *Chernikov A.N.*

Main researchers: *Kichanov S.E., Buzdavin A.P. + 1 engineer.*

3.1. Operation and development of the horizontal-vertical cryostat with a superconducting magnet.

3.2. Development, modernization and introduction of new, as well as repair and maintenance of the existing cryogenic and vacuum equipment on the IBR-2 spectrometers at the request of users.

3.3. Development of the existing cryogenic test stand for working with liquid helium and its adaptation to produce pure high-pressure helium-3 for filling gas neutron detectors.

4. Detectors and electronics:

Responsible persons — *Churakov A.V., Kruglov V.V., Bogdzel A.A., Kirilov A.S.*

Main researchers: *Milkov V.M. + 3 engineers, Drozdov V.A. + 3 engineers, Zhuravlev V.V. + 2 engineers, Murashkevich S.M. + 1 engineer, Simkin V.G.*

4.1. Carrying out of work in accordance with the schedule of the new project "**Construction of a wide-aperture backscattering detector (BSD) for the HRFD diffractometer**":

− manufacturing of 11 detector sectors (4 sectors per year);

− installation and testing of BSD sectors in their regular position on HRFD;

− installation and tuning of MPD32-USB3-based data acquisition electronics and software for BSD at the HRFD diffractometer;

− commissioning of the BSD detector.

4.2. Development of a 2D position-sensitive detector with a central opening for a direct beam for the REMUR spectrometer.

4.3. Investigation of boron-based neutron converters.

4.4. Calculation, simulation, development and study of characteristics of position-sensitive counters with a resistive anode wire up to 1 m long and detector modules based on them; development of detector electronics for these PSD.

4.5. Development of a 2D large-area (~1 m^2) scintillation detector for small-angle neutron scattering experiments. Manufacturing and investigation of the detector prototype.

4.6. Manufacturing and tuning of new MPD32-USB3 and De-Li-DAQ_2 data acquisition modules and upgrade of electronics of all detector systems of IBR-2 spectrometers on their basis.

4.7. Development and equipping of IBR-2 spectrometers with 2D position-sensitive beam monitors.

4.8. Operation and maintenance of detector systems of IBR-2 spectrometers.

5. Control systems for actuators, sample environment equipment and choppers of spectrometers:

Responsible persons — *Altynov A.V., Kirilov A.S.*

Main researchers: *Chernikov A.N. + 1 engineer, Zhuravlev V.V. + 3 engineers, Zernin N.D. + 1 engineer, Petukhova T.B. + 1 engineer.*

5.1. Development of control systems for actuators:

- modernization of actuators at spectrometers;
- introduction of new actuating mechanisms at the requests of users, including the introduction of robotic manipulators into control systems of spectrometers and equipping spectrometers with video monitoring systems.

5.2. Improvement of control systems for spectrometers and temperature control systems:

- commissioning of new measuring devices and controllers at the request of instrument

responsibles;

- automation of the vacuum control system on beamline 7 (NERA, SKAT spectrometers);
- automation of the current-source control system for the vertical-horizontal cryostat;
- unification of amplifiers used in temperature control systems.

5.3. Modernization of control systems for choppers on beamlines 10 and 11.

5.4. Introduction of programmable logic controllers in automation systems.

6. Software and local area network:

Responsible persons ─ *Kirilov A.S., Prikhodko V.I.*

Main researchers: *Sukhomlinov G.A. + 2 engineers, Kirilov A.S. + 4 engineers, Dolbilov A.G. + 2 engineers.*

Maintenance and development of the Sonix+ software package and introduction of its new versions at IBR-2 spectrometers.

Development of the FLNP central servers and network infrastructure in accordance with the development strategy of the JINR computer network.

Modernization of the Laboratory's mail system and Wi-Fi network. Gradual replacement of lower-level network switches with managed switches. Development of Laboratory's LAN monitoring system.

In 2021-2025, the joint activities in cooperation with the NICM Department will continue on the development of new spectrometers and the routine upgrade of the available instruments. This work will be performed in accordance with previously agreed plans, as well as with requirements specifications from research groups.

Expected results upon completion of the theme:

1. Maintenance and routine upgrade of the CM-202 and CM-201 cryogenic moderators with control systems. Carrying out experiments to study materials for cold moderators.

2. Development and application of VITESS and other software packages for simulation of neutron scattering in samples and in individual components of spectrometers. Complex calculations and optimization of spectrometers. Investigation of neutron background conditions at IBR-2 spectrometers, development of recommendations to reduce the background level.

3. Development of the horizontal/vertical cryostat with a superconducting magnet. Modernization of the cryogenic test bench for working with liquid helium. Development and modernization of cryostats at IBR-2 spectrometers.

4. Completion of development and construction of the backscattering detector. Putting the detector into operation at the HRFD diffractometer. Commissioning of the upgraded ASTRA-M detector at FSD.

5. Development and investigation of prototypes of PSD systems based on counters with a resistive anode wire up to 1 m long and large-area (~1 m^2) scintillation position-sensitive detectors. Development and construction of a 2D position-sensitive detector with a central opening for a direct beam for the REMUR spectrometer. Investigation of boron-based neutron converters. Development and equipping of IBR-2 spectrometers with beam monitors.

6. Introduction of programmable logic controllers in control systems for actuators, sample environment equipment and spectrometers' choppers. Installation of additional equipment for spectrometers at the request of users; development of control systems and interfaces.

7. Investigation of radiation resistance of materials and electronic components using the radiation research facility on IBR-2 beamline 3.

8. Improvement of the software for IBR-2 spectrometers. Maintenance and development of the Sonix+ software package and introduction of its new versions at IBR-2 spectrometers. Modernization of the FLNP mail system and Wi-Fi network. Development of the FLNP network and computing infrastructure in accordance with the needs of the Laboratory and the development strategy of the JINR computer network. Gradual replacement of lower-level network switches with managed switches.

Expected results in the current year:

1. Maintenance of regular operation of the complex of CM-201 and CM-202 cryogenic pelletized moderators for physics experiments. Automation of the vacuum system and the system for supplying helium to the pneumatic transport pipeline of the CM-202 cryogenic moderator; upgrade of software for control systems of the CM-202 moderator.

2. Investigation of radiation resistance of materials using the radiation research facility. Neutron activation analysis of irradiated samples using a high-purity germanium spectrometer.

3. Complex calculations and optimization of spectrometers. Methodological studies of neutron background conditions at IBR-2 spectrometers. Determination of sources of neutron background, its level and influence on experimental results.

4. Development of the horizontal/vertical cryostat with a superconducting magnet. Development of the available cryogenic test bench for working with liquid helium and its adaptation to produce pure high-pressure helium-3 for filling gas neutron detectors. Modernization of cryostats on neutron beams (at the requests of instrument responsibles).

5. Manufacturing, installation in the regular position and testing of 4 sectors of the BSD detector at the HRFD diffractometer (work under the BSD project). Study of a prototype of a 2D large-area (~1 m^2) scintillation detector for small-angle neutron scattering experiments.

6. Equipping of the REFLEX spectrometer with a beam monitor (IBR-2 beamline 9).

7. Manufacturing of elements of the detector system for the REMUR spectrometer. The first stage of the assembly of the detector system.

8. Investigation of solid neutron converters based on boron compounds.

9. Calculation and simulation of position-sensitive counters with a resistive anode wire up to 1 m long; development of a detector electronics system.

10. Study and use of programmable logic controllers (PLC) for their application in automated control systems for actuators, choppers and current sources; development of a PLC test bench and preparation of proposals for the introduction of PLC at IBR-2 spectrometers. Development of technical specifications for software and user interface for PLC.

11. Maintenance and development of the Sonix+ software package at the request of users and in order to improve the internal structure. Upgrade of Sonix+ for the available spectrometers and its installation at new IBR-2 spectrometers.

12. Modernization of the FLNP mail system. Development of Wi-Fi network in FLNP buildings. Creation of a server segment of the network with a rate of 10 Gbit/s.

List of projects:

Project	Leader (period of realization)	Priority
Construction of a wide-aperture backscattering detector (BSD) for the HRFD diffractometer	Kruglov V.V.	1 (2021-2023)

List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR	Main researchers	
1. Maintenance of regular operation and development of the complex of CM-201 and CM-202 cryogenic pelletized moderators. Further automation of moderators' control systems.	**Kulikov S.A.** **Bulavin M.V.**	Realization
2. Investigation of radiation resistance of materials, electronics and detectors for large-scale physics facilities: ANLAS, CMS, NICA, ITER, ESS, etc.; applied research.		
FLNP	Bulavin M.V., Kirilov A.S., Altynov A.V., Mukhin K.A., Shabalin E.P., 8 engineers	
3. Development of VITESS software package and simulation of individual components of spectrometers. Investigation of neutron background conditions at IBR-2 spectrometers, development of recommendations to reduce the background level.	**Bodnarchuk V.I.**	Realization
FLNP	2 engineers	

4. Development of the horizontal/vertical cryostat with a superconducting magnet. Development and modernization of cryostats at IBR-2 spectrometers. Modernization of the cryogenic test bench for working with liquid helium.	**Chernikov A.N.** **Kichanov S.E.**	Realization
FLNP	Buzdavin A.P., 1 engineer, 1 laboratory assistant	
5. Completion of development and construction of the BSD detector. Putting the detector into operation at the HRFD diffractometer. Commissioning of the upgraded ASTRA-M detector at FSD.	**Kruglov V.V.** **Bogdzel A.A.** **Kirilov A.S.**	Realization
FLNP	Milkov V.M., Bokuchava G.D., Simkin V.G., Drozdov V.A., Shvetsov V.V., 3 engineers, 4 laboratory assistants	
6. Development and investigation of prototypes of PSD systems based on counters with a resistive anode wire up to 1 m long and large-area (~1 m^2) scintillation position-sensitive detectors. Development of a 2D PSD with a central opening for a direct beam for the REMUR spectrometer. Investigation of boron-based neutron converters. Development and equipping of IBR-2 spectrometers with beam monitors.	**Churakov A.V.** **Kruglov V.V.** **Bogdzel A.A.**	Realization
FLNP	Zhuravlev V.V., Kurilkin A.K., Milkov V.M. Drozdov V.A., Murashkevich S.M., 3 engineers	
7. Modernization of detector and data acquisition electronics for IBR-2 spectrometers.	**Bogdzel A.A.** **Kirilov A.S.**	Realization

FLNP	Zhuravlev V.V., Litvinenko E.I., Drozdov V.A., Shvetsov V.V., Murashkevich S.M., Milkov V.M., 2 engineers	
8. Introduction of programmable logic controllers in control systems for actuators, sample environment equipment and spectrometers' choppers. Installation of additional equipment at IBR-2 spectrometers at the request of instrument responsibles.	**Bodnarchuk V.I.** **Altynov A.V.**	Realization
FLNP	Zhuravlev V.V., Kirilov A.S., Zernin N.D., Petukhova T.B., 3 engineers	
9. Maintenance and development of the Sonix+ software package and installation of its new versions at IBR-2 spectrometers. Development of FLNP central servers and network infrastructure in accordance with the development strategy of the JINR computer network. Modernization of Laboratory's mail system and Wi-Fi network.	**Kirilov A.S.** **Prikhodko V.I.**	Realization
FLNP	Sukhomlinov G.A. Kirilov A.S., 4 engineers	
LIT	Dolbilov A.G., 1 engineer	

Collaboration

Country or International Organization	City	Institute or Laboratory
Argentina	Bariloche	CAB
Belarus	Minsk	BSTU
Bulgaria	Sofia	INRNE BAS
Czech Republic	Rez	NPI ASCR

Germany	Berlin	HZB
	Darmstadt	GSI
	Julich	FZJ
Hungary	Budapest	Wigner RCP
Republic of Korea	Daejeon	NFRI
Romania	Bucharest	INCDIE ICPE-CA
Russia	Moscow	NNRU "MEPhI"
		NRC KI
	Moscow, Troitsk	INR RAS
	Gatchina	PNPI
	Dubna	Dubna State Univ.
Sweden	Lund	ESS ERIC
Switzerland	Villigen	PSI
Ukraine	L'viv	LPNU
United Kingdom	Didcot	RAL
Uzbekistan	Tashkent	INP AS RUz

Realization period:

The activities under the theme will be carried out in 2021-2025 in accordance with the annual topical plans for JINR research and international cooperation. The full amount of financing of the theme's budget items related to equipment and materials, which corresponds to the estimated figures of the JINR Seven-Year Development Plan for 2017-2023, is shown in **Table 1**:

Table 1

Description of activities	Expenses per year, kUSD				
	2021	2022	2023	2024	2025
Development of control systems for cold neutron moderators and actuators	210	210	255	310	250
Development of detectors, cryogenic equipment, sample environment systems, data acquisition systems; development of FLNP information and computing infrastructure	2 270	2 510	2 740	3140	3720
Total:	2 480	2720	2995	3450	3970

Other sources of financing:

Grants of Plenipotentiaries of JINR Member States (Romania, Belarus, Czech Republic), CremlinPlus project, German dues to JINR.

The total estimated cost of the theme **«Scientific and methodological research and developments for condensed matter investigations with IBR-2 neutron beams»** for 2021-2025:

N of budget items	Description of budget items	TOTAL 2021-2025	incl. 2021
1	Salaries	5415	999
2	Insurance payments	1635	302
3	Social fund	352	65
4	International scientific and technical cooperation:	400	80
	a) trips to JINR Member States	185	37
	b) trips to JINR Non-Member States	100	20
	c) trips within Russia	50	10
	d) reception of foreign specialists	50	10
	e) organization of meetings	15	3
5	Materials	8300	1345
6	Equipment	7140	1100
10	Payment for services of research organizations	75	15
11	Information	100	20
	c) information service	100	20
15	Payment for communication services		
	TOTAL:	23417	3926
	IBR-2		
	Design Bureau	70	13
	FLNP Workshop	336	62
	General and administrative expenses	2710	499
	TOTAL:	**26533**	**4500**

AGREED:

JINR Chief Scientific Secretary

_____

«____» _____2020

FLNP Director

_____

«____» _____2020

Head of Planning Department

_____

«____» _____2020

FLNP Scientific Secretary

_____

«____» _____2020

Head of Scientific-Organization Department

_____

«____» _____2020

FLNP Economist

_____

«____» _____2020

Theme Leaders

_____

_____

_____

«____» _____2020