APPROVED

JINR DIRECTOR

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PROJECT PROPOSAL FORM

Opening/renewal of a research project/subproject of the large research infrastructure project within the Topical plan of JINR

1. General information on the research project of the theme

1.1 Theme code (for extended projects) - *the theme code includes the opening date, the closing date is not given, as it is determined by the completion dates of the projects in the topic.*
04-9-1077

1.2 Project subproject code (for extended projects)

1.3 Laboratory

Laboratory of Radiation Biology

1.4 Scientific field

Radiation Research in Life Sciences

1.5 Title of the project

Radiation-biophysical and astrobiological research

1.6 Project leader(s)

Chizhov Alexei Vladimirovich, Rozanov Alexei Yurievich

1.7 Project deputy leader(s) (scientific supervisor(s))

2 Scientific case and project organization

2.1 Annotation

A wide range of sources of ionizing radiation available at JINR, especially beams of heavy ions of various energies, offers a unique opportunity to solve a number of fundamental problems of radiobiology and astrobiology, as well as practical problems related to space exploration and the development of radiation medicine.

Due to the high complexity and cost of performing biological experiments at accelerator complexes, it is of paramount importance to improve experimental methods, ensure dosimetry and radiation safety, as well as running appropriate computer simulations. The most pressing issues here are the need for experimental reproduction of the energy and spectral composition of cosmic and other types of ionizing radiation, the search for methods for non-destructive analysis of unique samples and automated processing of biological experiment data, as well as the high complexity and resource intensity of computer simulation of processes in living systems.

This project is aimed at solving a complex of the above problems arising in radiobiological and astrobiological research. In the course of its implementation, it is planned to develop new stations for irradiation and dosimetry systems, introduce methods for non-destructive analysis of unique samples, develop and test systems for automated computer processing of biological data, formulate new mathematical models and computational approaches for radiobiology, bioinformatics and radiation medicine, identify mechanisms and pathways for the catalytic synthesis of prebiotic compounds under the action of radiation.

2.2 Scientific case (aim, relevance and scientific novelty, methods and approaches, techniques, expected results, risks)

Radiation-biophysical research

Photon and charged particle ionizing radiations fundamentally differ in the mechanisms that determine their biological effect on living organisms. This is due both to the peculiarities of the physicochemical processes that occur during the passage of particles through cells, and to differences in the spectrum of induced DNA damage and their repair pathways. Unlike the electromagnetic ionizing radiations, whose energy is distributed uniformly over the volume of the irradiated cell's nucleus, in the case of accelerated heavy ions passing through matter, energy is deposited along the particle's track, inducing hard-to-repair clustered DNA damage. These features must be taken into account when solving both fundamental problems related to the study of the mechanisms of the biological action of ionizing radiation with different physical characteristics, and solving a number of applied problems related to improving the methods of radiation therapy of tumors and assessing radiation risks on Earth and in space.

Radiobiological experiments at the nuclear physics facilities of the Institute will be aimed at studying the mechanisms of action of ionizing radiation with different physical characteristics at the molecular, cellular, tissue and organismal levels of biological organization. Special attention will be paid to the development of new approaches to improving the biological effectiveness of radiation therapy of tumors, and to studying the mechanisms of functional disorders in the brain under the action of radiation in order to estimate the risk of radiation exposure to the astronauts during interplanetary flights, as well as to take into account the possible side effects of the radiation therapy of malignant neoplasms.

The main goal of this part of the project is the scientific and methodological support for the above radiobiological studies to improve the methods of irradiation and processing of experimental data, to ensure dosimetry and radiation safety, as well as to carry out appropriate computer modeling.

Improving methods of irradiation and dosimetry in radiobiological experiments

Sources of photonic types of ionizing radiation are used as reference sources for determining relative biological efficiency (RBE) in radiobiological experiments. Also, photon beams are the gold standard in oncology centers when conducting and modeling external beam radiation therapy.

The CellRad X-ray unit manufactured by Precision X-ray Inc. (USA) and the Small Animal Radiation Research Platform (SARRP) manufactured by Xstrahl (UK) will be used at JINR to irradiate biological objects with photon beams. The CellRad unit is designed to irradiate biological cultures with high-energy radiation from an X-ray tube with adjustable voltage from 30 to 130 kV and current up to 5 mA with automatic dose control. SARRP is a multifunctional complex for the complete simulation of the radiation therapy using photon beams on small laboratory animals. This setup allows for conformal irradiation of a given area of the animal body with an accuracy of 1 mm by a collimated beam of photons from an X-ray tube with adjustable voltage from 5 to 225 kV and current up to 30 mA, installed on a rotating gantry. There is a system of positioning and anesthesia of the animal. Irradiation planning and dose labeling is achieved using built-in calibrated dosimetry systems and an X-ray computed tomography system. It is planned to develop a system for dosimetry and spectrometry of the low-energy part of the X-ray spectrum (<30 keV), which is caused by insufficient knowledge of its biological effectiveness.

In the course of the project, it is planned to expand the capabilities of the SARRP system with additional modules that will help to provide multimodal tomography of small laboratory animals. Together with the DLNP team, it is planned to develop color X-ray tomography, SPECT and PET tomography. The possibilities of using optical tomography by dint of fluorescent labels and optoacoustic tomography will also be explored. This will make it possible to carry out intravital studies of each laboratory animal at different times after irradiation without resorting to euthanasia, which, for example, is required to study the dynamics of tumor regression, the pharmacokinetics of drugs, and to detect long-term disorders in the structures of the central nervous system and other critical organs. As a result, it will be possible to clearly determine the influence of the individual characteristics of an animal in a statistical sample when studying the response of an organism to the action of radiation with different physical characteristics.

Irradiation of cell cultures and small laboratory animals with accelerated charged particles will be carried out at the following facilities of the Institute, existing and under construction: Linac-200 linear accelerator (electrons up to 200 MeV), superconducting medical cyclotron MSC230 (protons up to 230 MeV) at DLNP, U400M cyclotron (accelerated multiply charged ions up to 50 MeV/nucleon) at FLNR and on the ARIADNA applied beams of the NICA complex (SIMBO station, accelerated multiply charged ions up to 600 MeV/nucleon) at VBLHEP.

According to the technical designs, it is assumed that the user stations for the irradiation of biological samples at the heavy charged particle accelerators of the DLNP and VBLHEP will have the necessary infrastructure for objects positioning, beams diagnostics, and control of irradiation parameters.

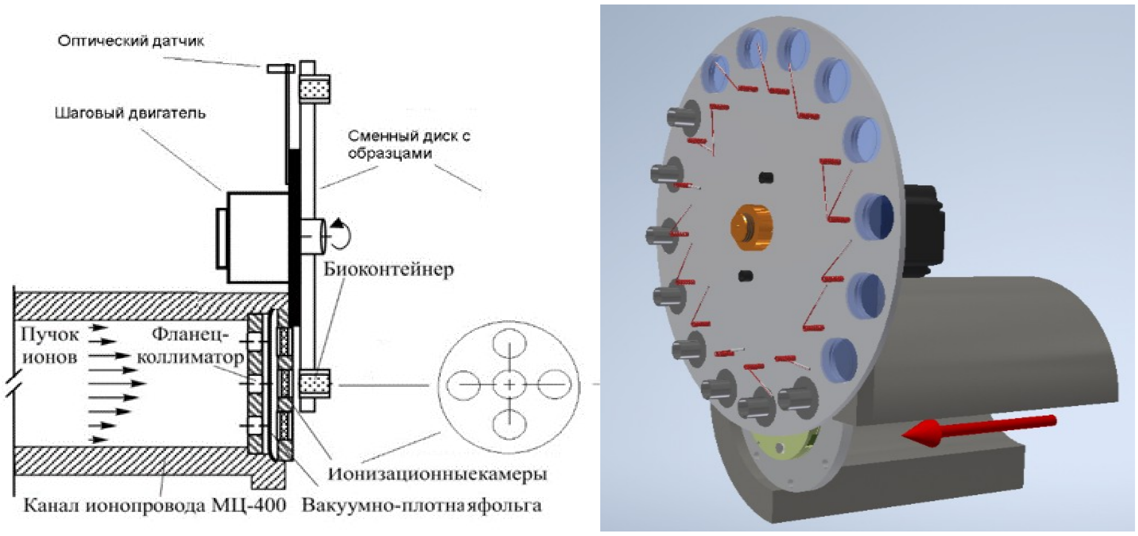

Fig.1. Scheme of the "Genome-3" station and positioner for automated irradiation of samples.

To ensure the conduct of radiobiological experiments at U400M, FLNR and LRB engineers will carry out the next stage of modernization of the Genome-3 station (Fig. 1). This LRB unit is designed for automatic irradiation of biological samples (cells in a nutrient solution, blood samples, etc.) in a specialized container. Irradiation of each sample is carried out in a flat uniform field of particles with a characteristic diameter of 35 mm, so that the distribution of the absorbed dose is uniform throughout the sample. The values of absorbed doses can vary from units of cGy to tens of Gy.

To solve the problem of irradiation with ions of light elements (including radioactive beams) of a zone of a shallow tumor in small laboratory animals (rats, mice), additional equipment for obtaining narrow (less than 1 mm in diameter) collimated beams will be installed on the same channel. The animals must be fixed during irradiation in special devices with the possibility of anesthesia. The size of the irradiation field can vary both in width and depth depending on the individual tumor volume. In this case, the maximum depth of ion path in the tumor can reach 5-8 mm.

Experimental research in the field of space radiobiology, due to the specificity of cosmic radiation, is carried out in terrestrial conditions at charged particle accelerators, since at the moment there are no other ways to obtain such high-energy charged particles. As a rule, ground-based experiments are carried out using monoenergetic particle beams of a certain type, which does not correspond to the real composition of cosmic rays, in particular, the most dangerous for living organisms galactic cosmic radiation, which has a complex energy and charge spectrum of multiply charged ions. Due to the lack of a sufficiently accurate and, at the same time, a simple method for creating mixed radiation that simulates a complex multicomponent radiation field inside a spacecraft or on a celestial body, it becomes necessary to develop a special facility. In the world, only three approaches to modeling complex radiation fields have been proposed and are being actively developed. One of them was proposed and implemented at the joint NASA Space Radiation Laboratory (NSRL) and Brookhaven National Laboratory (BNL) in Brookhaven (USA) based on the RHIC collider booster. Another simulator was later proposed at the Helmholtz Center for Heavy Ion Research (GSI). The simulator developed and patented by the LRB JINR team for modeling complex radiation fields compares favorably with its simplicity and accuracy from existing analogues.

The computer model of the developed simulator (Fig. 2) in option for the beam of ^{56}Fe nuclei with an energy of 1 GeV/nucleon reproduces in the correct ratio all components of the radiation field inside the spacecraft, averaged over solar activity. It is planned to optimize the variants of the cosmic radiation simulator for various types of accelerated heavy ions, develop software, as well as experimental design work on the manufacture and testing of a prototype on heavy ion beams of the NICA complex. During testing, it is planned to carry out a cycle of work on measuring the energy spectra of the mixed field components behind the simulator.

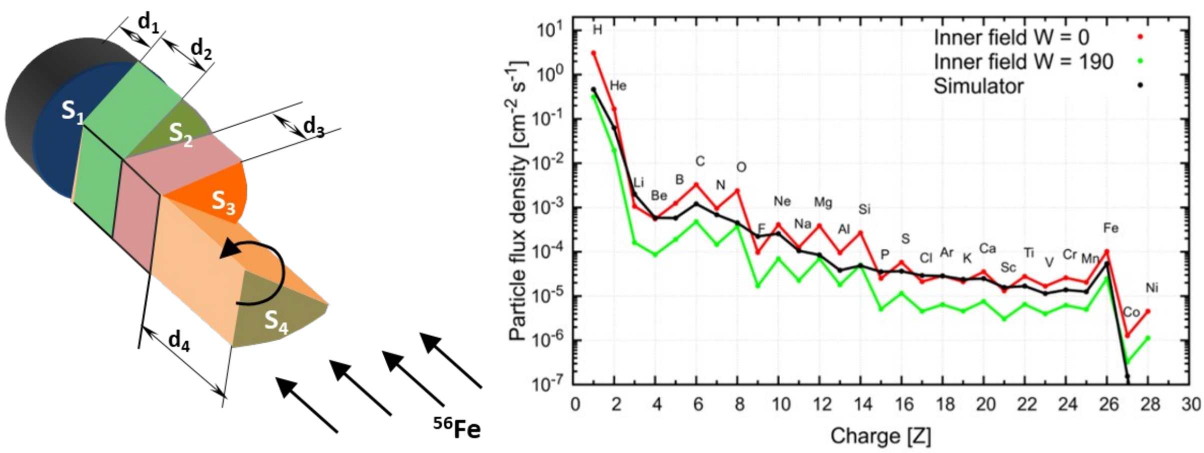

Fig.2. Scheme of the simulator of galactic cosmic radiation (left) and comparison of the spectra on the simulator with the spectrum of cosmic radiation inside the spacecraft at different Wolf numbers W (right). S_i and d_i are the areas and thicknesses of the converter components, respectively.

In the course of the project, it is also planned to do research on the dosimetry of mixed fields of gamma radiation and neutrons, which are necessary for performing radiobiological experiments at the IREN facility at FLNP.

A number of radiobiological studies require performing experiments with radionuclide labels and radiopharmaceuticals. In this regard, during the implementation of the project, it is planned to design and equip specialized rooms for radiobiological research at the LRB, licensed to a third-class radiochemical laboratory. The complex of works will include rational placement, layout and decoration of premises; efficient ventilation and sewerage systems; control over compliance with the norms and rules of radiation safety; organization of a system for the transportation, receipt, storage and accounting of radioactive isotopes, collection and disposal of radioactive waste; selection and development of technological regimes, protective equipment and equipment; development of a forecast of possible emergencies and measures to eliminate them.

When organizing radiobiological research at JINR high-energy accelerators, one of the important problems is to ensure the dosimetry of biological samples directly in the irradiation zone, as well as the radiation safety of personnel behind radiation protection. The main attention will be paid to the development of computational and experimental methods for dosimetry of biological objects in complex radiation fields.

In various modes of operation of high-energy accelerators, when the beam interacts with targets and shielding materials, fields from secondary and scattered radiation, as well as induced radioactivity, arise. To calculate such radiation fields, models based on the solution of transport and diffusion equations by the Monte Carlo method, including using the GEANT4, MCNP, FLUKA and PHITS software codes, will be used. For a comprehensive assessment of radiation fields, it is also required to develop a method for restoring maps of the density of surface radioactive contamination of premises based on the results of measurements of the ambient dose equivalent rate. The implementation of the method is supposed to be performed by the inverse problem method based on the numerical solution of the Fredholm equation of the 1st kind, including using the possibilities of parallel computing on the JINR Govorun supercomputer.

Another important task of ensuring radiation monitoring is measuring the dose of neutrons with energies above 10-15 MeV, since the contribution of such neutrons to the total radiation dose behind the accelerator shields can be significant (up to ten percent). Therefore, the task of designing and testing dosimeters for neutron radiation of such an energy range is topical.

Within the framework of the joint research program with Space Research Institute of RAS and FLNP JINR, the operation of the DAN (Dynamic Albedo Neutrons) experimental facility and participation in the creation, testing and calibration of nuclear planetary instruments for studying the elemental composition of the surface of celestial bodies of the Solar System using a neutron generator will continue with an energy of 14 MeV.

Expected results:

- Provision of dosimetry and organization of irradiation of biological samples at JINR accelerators;
- Modernization and commissioning of "Genome-3";

- Development of a multimodal tomography system for small laboratory animals;
- Equipping a room for radiobiological experiments using radionuclides;
- Creation of a prototype space radiation simulator;
- Development and testing of instruments for neutron dosimetry and spectrometry.

Automation of data processing of radiobiological experiments

When processing the results of radiobiological experiments, researchers often face the need to manually process a significant amount of data and then systematize them. For example, conducting studies of histological sections and performing manual morphological analysis takes an average of about a month, depending on the number of structures studied. The method of video recording when observing the behavior of an experimental animal in the arena of the installation is also widely used in modern physiological research. For these purposes, digital video cameras and computer programs for data analysis are used, for example, EthoVision XT (Noldus). Despite the possibility of defining a number of parameters in commercial programs of this type, there are many elements of behavior that are not automatically recorded and the researcher has to manually process the video material again.

Automation of processing the results of experiments will make it possible to obtain qualitatively more accurate data, identify new patterns that reflect the nature of changes after exposure to ionizing radiation with different characteristics, and reduce the likelihood of errors in classification and the timing of obtaining significant scientific results. One of the most promising areas for solving these problems is the development and implementation of machine and deep learning methods for creating solutions based on neural network approaches.

Work on the development of automation systems is planned to be carried out by the existing team of MLIT and LRB scientists. As a result, it is planned to develop a software environment for solving problems of radiobiological research using high-performance computing systems. The processing of images and video materials in this system is based on a combination of classical computer vision methods and methods for using several types of deep convolutional neural network architectures. Based on the accumulated and digitized experimental data, a database of images and videos will be created and marked up for training neural network models. The developed information system based on machine and deep learning methods and neural network approaches will also provide centralized storage and access to experimental data in a form convenient for complex statistical analysis.

It is also planned that the information system will include a module for processing data from multimodal computed tomography and electroencephalography of the brain of laboratory animals. This module is required to work with streams of heterogeneous experimental data (conversion, transportation, storage, processing, mathematical modeling, neuroimaging, statistical analysis, etc.) and to obtain a complete picture of the dysfunction of the central nervous system after the irradiation.

Expected results:

- Development of an information system for working with experimental data in the form of two-dimensional images, computed tomography data and video recordings;
- Development of protocols for labeling two-dimensional images and video materials, formation of a labeled database;

- Testing of implemented analysis algorithms, development and registration of software designed for automated data processing.

Mathematical modeling of radiation-induced effects

Methods of mathematical modeling and computational experiment are becoming increasingly important in modern radiobiology. First of all, this is due to the need to systematize and extrapolate a limited set of data from radiobiological experiments to various types of ionizing radiation in a wide range of physical characteristics. In addition, a number of fast processes in the interaction of radiation with matter are very difficult to measure experimentally. Finally, the high complexity and hierarchical organization of living systems requires significant computational costs when conducting a computational experiment, which has only recently been overcome due to the rapid increase in the performance of computer technique.

The main goal of future research is to create a hierarchy of models that allow systematizing experimental data and studying the pathways of how radiation-induced pathologies develop at different organization levels (from molecules to cell populations) and time scales (acute and long-term radiation effects). This will require the involvement of a wide range of computational methods from different fields of knowledge (modeling the transport of charged particles through matter, molecular dynamics, polymer biophysics, genetic regulatory networks, models of cell population dynamics, processing and transmission of information in neural networks of the brain), as well as the computing resources of a supercomputer JINR.

The basic task in modeling radiobiological effects is to study the interaction of ionizing radiation with cell matter. Based on the primary fast physical and chemical processes during the passage of particles, the spectrum of molecular damage in the genetic apparatus of normal and tumor cells of mammals and humans will be calculated. The formation and repair of the main types of DNA damage (primarily double-strand breaks of both direct and enzymatic nature) will be modeled using the specialized GEANT4-DNA software environment. Reproduction of a further chain of events will make it possible to calculate the probabilities of erroneous DNA repair leading to the formation of mutations and chromosomal aberrations, which will require the use of the apparatus of quantum chemistry and molecular dynamics. Using the methods of molecular dynamics, it is also supposed to study the violations of the structure and functions of mutant and oxidized forms of proteins. Based on the obtained data on DNA damage, models of radiation-induced death of normal and tumor cells will be formulated and validated on the basis of known experimental data.

Developed basic models will be applied to solve two important problems related to the search for new approaches to increase the efficiency of radiation therapy of tumors and to the study of the mechanisms of functional disorders in the brain under the action of radiation.

During the implementation of the project, scenarios of remote and radionuclide radiation therapy using various sources of ionizing radiation will be simulated. Unlike common approaches used for therapy planning, a detailed distribution of DNA damage in the tumor will be obtained, not just the absorbed dose. In this case, it is also supposed to assess damage in more detail not only in tumor cells, but also in adjacent normal tissues. Detailed models of tumor growth will be formulated and its dynamics after irradiation will be investigated. This approach is planned to be generalized to the case of several promising mechanisms for enhancing the effectiveness of therapy. Both modern physical mechanisms for increasing the biological effectiveness of ionizing radiation (targeted delivery of nanoparticles that enhance energy release when interacting with a therapeutic beam) and the most promising biological mechanisms (using inhibitors of DNA synthesis and other molecular agents) will be considered. It is supposed to search for the optimal parameters of such therapy, taking into account the concentrations of active substances, the choice of beam parameters, the therapeutic dose, its fractionation, etc.

It is also planned to evaluate the effect of charged particles on the functioning of neural networks in critical parts of the brain. Special attention will be paid to the optimization of models of cells of the central nervous system (CNS), which is a difficult target to calculate due to the complex geometry. Scenarios of both acute local exposure (assessment of the safety of radiation therapy) and total chronic exposure (the effect of cosmic rays on cells during interplanetary flights) will be considered. In the latter case, it is planned to consider for the first time the effect of the spectrum of particles with different energies and fluences on the yield of DNA damage and the dynamics of cell populations. For further assessment of possible pathologies in the CNS after irradiation, work will be carried out to study various mutant and oxidized forms of synaptic receptors that provide interneuronal interaction, the dynamics of neurogenesis and gliogenesis. The data obtained will be systematized and included in the modeling of the functional activity of various parts of the brain. This will allow us to estimate the probability of memory and learning failures, which is critical for the theoretical evaluation of radiation risks.

Expected results:

- Development of mathematical models for the formation of various types of DNA damage and their repair, models for the formation of mutations and chromosomal aberrations;
- Modeling of violations of the structure and functions of mutant and oxidized forms of proteins by the method of molecular dynamics;
- Development of mathematical models of radiation-induced death of tumor cells and prediction of tumor growth during the application of promising methods of radiation therapy;
- Theoretical evaluation of radiation-induced disorders of the CNS on the basis of mathematical models of brain neural networks, taking into account damage to synaptic receptors, oxidative stress, impaired neurogenesis and gliogenesis.

Astrobiological research

One of the promising areas in modern astrobiology is the search for traces of extraterrestrial life in the form of organic compounds or microbial fossils (microfossils).

In recent decades, advances in bacterial paleontology have made it possible to identify the fossilized remains of microorganisms in meteorites (microfossils). Particularly rich material was obtained during the study of carbonaceous chondrites. Very promising in the study of the substance of meteorites is the use of nuclear physics methods such as scanning electron microscopy, X-ray microtomography, neutron activation and X-ray spectral analysis. One of the most important problems is the comparison of finds in meteorites with terrestrial analogues and confirmation of the absence of terrestrial contamination.

It is assumed that meteorites can be carriers of organic molecules that are formed in space conditions. In the interstellar medium, the most common triatomic organic compound is hydrocyanic acid HCN, and the most common triatomic inorganic compound is water H_2O. As a result of their combination, formamide (NH_2COH) is formed. Formamide is found in large quantities in the interstellar medium, in various parts of the universe. In continuation of this chain, the question arises of the emergence of more complex prebiotic compounds necessary for the existence of life. Most experiments on abiogenic prebiotic synthesis do not pay enough attention to such an important energy factor as high-energy particles that are part of cosmic radiation. Therefore, it is very promising to study the corresponding processes with the help of charged particle accelerators.

The astrobiological research in this project will be aimed at revealing the mechanisms of abiogenic synthesis of prebiotic compounds under the action of radiation and the study of cosmic matter by nuclear physics methods, the search for microfossils and organic compounds in meteorites.

Study of abiogenic synthesis of prebiotic compounds

In the pioneering experiments carried out by the LRB JINR together with colleagues from the University of Tuscia (Viterbo, Italy), on the irradiation of aqueous solutions of formamide with 170 MeV protons and with 500 MeV/nucleon carbon ions in the presence of meteorites as catalysts, the synthesis of a large number of prebiotic compounds was observed for the first time: amino acids, carboxylic acids, sugars, nucleic bases and even nucleosides. These compounds have not previously been found in experiments with other types of exposure.

Further research will be aimed at modeling the sequence of processes that can lead to the formation of a complete, chemically active prebiotic environment in combination with meteorites or ancient terrestrial rocks. It is planned to continue experiments on the irradiation of the formamide + catalyst system with radiations with different physical characteristics in order to find the optimal conditions and pathways for the synthesis of prebiotic compounds, as well as the conditions under which oligo- and polymeric biomolecules can be formed. To identify organic substances in the resulting complex mixture, gas chromatography and mass spectrometry methods will be used.

Search for microfossils and organic compounds in meteorites

The study of meteorites using scanning electron microscopy allows for morphological analysis and classification of the found objects. More than 30 samples of meteorites and terrestrial rocks have been studied using the Tescan Vega 3 scanning electron microscope in the astrobiology sector of the LRB. Several hundred images of fossil microorganisms have been obtained and analyzed, and the world's first atlas of finds in the Orgueil meteorite has been published.

The study of the elemental and mineral composition of meteorites and terrestrial rocks is possible by X-ray energy-dispersive microanalysis. The study of the composition of meteorites will make it possible to draw conclusions about their origin and about the conditions that existed on the parent body. During the study of meteorites, it is necessary to be able to distinguish ancient microfossils native to the meteorite from terrestrial contaminants and abiogenic structures. In this regard, a comparative micropaleontological study of the most ancient terrestrial rocks is also required. For an extended study of finds in meteorites, it is also planned to use X-ray microtomography, which, unlike scanning electron microscopy, makes it possible to make three-dimensional images of microfossils without destroying unique samples.

Expected results:

- Study of possible pathways and conditions for the formation of prebiotic compounds by irradiation of cosmic matter or terrestrial rocks in combination with the simplest organic molecules;

- Search and structural analysis of microfossils and organic compounds in various meteorites by nuclear physics methods.

Development of research infrastructure

As the project's international radiobiology and astrobiology research program progresses, equipment upgrades and new facilities need to be phased in. The development of research infrastructure includes the following components:

1) design, creation and commissioning of the Genom-3 station, modernization of the SARRP facility;
2) design and commissioning of equipment for multimodal tomography of animals;
3) design, construction and licensing of radiochemical block for research on cell cultures and laboratory animals;
4) design, manufacture and testing of a simulator prototype for modeling complex radiation fields, purchase of spectrometers and dosimetry equipment.

Risk assessment

Most critically, the project depends on providing the necessary time at JINR accelerators, as well as resources of the JINR Multifunctional Information and Computing Complex. Possible technical and organizational problems can be solved through interaction with coordinators from the collaborating JINR Laboratories.

The financial risks may be due to difficulties in the supply of unique high-tech equipment, materials, and reagents. In this case, it is possible to temporarily use equipment of organizations participating in the project.

The risks of personnel shortages are not foreseen. The participants include both world-renown scientists and a large number of young specialists.

2.3 Estimated completion date

2024-2028

2.4 Participating JINR laboratories

FLNR	Kaminski G., Mitrofanov S.V., Teterev Yu.G., Timoshenko K.D., Pavlov L.A.
FLNP	Shvetsov V.N., Pyataev V.G., Udovichenko K.V., Kučerka N., Churakov A.V., Zinkovskaya I., Frontasyeva M.V., Yushin N.S.
LIT	Streltsova O.I., Nechaevsky A.V., Zuev M.I., Khvedelidze A., Palii Yu.
DLNP	Glagolev V.V., Shelkov G.A., Rozhkov V.A., Sotensky R., Inoyatov A.Kh., Karamysheva G.A., Mitsyn G.V.
VBLHEP	Syresin E.M., Baldine A.A.

2.4.1 MICC resource requirements

Computing resources	Distribution by year				
	1st year	2nd year	3rd year	4th year	5th year
Data storage (TB) - EOS - Tapes	200 -	200 -	200 -	200 -	200 -
Tier 1 (CPU core hours)	-	-	-	-	-
Tier 2 (CPU core hours)	-	-	-	-	-
SC Govorun (CPU core hours) - CPU - GPU	500 000 70 080	500 000 70 080	500 000 70 080	500 000 70 080	500 000 70 080
Clouds (CPU cores)	-	-	-	-	-

2.5. Participating countries, scientific and educational organizations

Organization	Country	City	Participants	Type of agreement
RAU	Armenia	Yerevan	Mamasakhlisov E.Sh.	
Institute of Mechanics	Bulgaria	Sofia	Vitanov N.	
RINP BSU	Belarus	Minsk	Kulagova T.A.	coop. program
SA SPC NAS of Belarus for materials science	Belarus	Minsk	Khasanov O.Kh., Gusakov V.E.	
Institute for Tropical Technology VAST	Vietnam	Hanoi	Tran Dai Lam Pham Thi Lan	
UNITUS	Italy	Viterbo	Di Mauro E. Saladino R.	
NUM	Mongolia	Ulan Bator	Lkhagva O.	
IPE RAS	Russia	Borok	Tselmovich V.A.	
FEFU	Russia	Vladivostok	Shirmovsky S. Eh.	
FRC KazSC RAS	Russia	Kazan	Kalachev A.A. Nikiforov V.G. Semashko V.V.	
IKI RAS	Russia	Moscow	Mitrofanov I.G.	
FMBC FMBA	Russia	Moscow	Barchukov V.G., Kryuchkov V.P.	

MSU	Russia	Moscow	Chernyaev A.P.	
SAI MSU	Russia	Moscow	Busarev V.V.	
IGEM RAS	Russia	Moscow	Sharkov E.V.	
PIN RAS	Russia	Moscow	Samylina O.S. Zhegallo E.A.	
NRC KI	Russia	Moscow	Volkov A.E.	
Institute of Catalysis SB RAS	Russia	Novosibirsk	Snytnikov V.N.	
IPCBP SS RAS	Russia	Puschino	Alekseev A.O. Rivkina E.M.	
IZMIRAN	Russia	Troitsk	Ragulskaya M.V.	
ISAN	Russia	Troitsk	Naumov A.V.	
SUSU	Russia	Chelyabinsk	Sokolinsky L.B.	agreement
INS «Vinča»	Serbia	Belgrade	Čevizović D., Zdravković S., Čosić M., Galović S.	coop. program
University of Kragujevac	Serbia	Kragujevac	Marković Z.	coop. program
Institute of Materials Science AS RUz	Uzbekistan	Parkent	Razzokov Dzh.	
INP AS RUz	Uzbekistan	Tashkent	Kulabdullaev G., Kim A.A.	
iThemba LABS	SAR	Faure	Vandervoorde Ch.	coop. program

2.6. Key partners *(those collaborators whose financial, infrastructural participation is substantial for the implementation of the research program. An example is JINR's participation in the LHC experiments at CERN).*

3. Manpower
3.1. Manpower needs in the first year of implementation

№№ n/a	Category of personnel	JINR staff, amount of FTE	JINR Associated Personnel, amount of FTE
1.	research scientists	24	-
2.	engineers	6.5	-
3.	specialists	-	-
4.	technicians	-	-
	Total:	**30.5**	

3.2. Available manpower
3.2.1. JINR staff

No.	Category of personnel	Full name	Division	Position	Amount of FTE
1.	research scientists	Bugay A.N.	LRB	Director	24
		Krasavin E.A.		Scientific Director	
		Chizhov A.V.		Deputy Director	
		Rozanov A.Yu.		Head of Sector	
		Krylov V.A.		Deputy Head of Dept	
		Dushanov E.B.		Head of Sector	
		Chausov V.N.		Group Leader	
		Parkhomenko A.Yu.		Senior Researcher	
		Chizhov K.A.		Senior Researcher	
		Beskrovnaya L.G.		Researcher	
		Gordeev I.S.		Researcher	
		Kapralov M.I.		Researcher	
		Lhagwaa B.		Researcher	
		Munkhbaatar B.		Researcher	
		Sadykova O.G.		Researcher	
		Severyukhin Yu.S.		Researcher	
		Khramko T.S.		Researcher	
		Aksenova S.V.		Junior Researcher	
		Batova A.S.		Junior Researcher	
		Vasilyeva M.A.		Junior Researcher	
		Glebov A.A.		Junior Researcher	
		Enyagina I.M.		Junior Researcher	
		Kolesnikova E.A.		Junior Researcher	
		Kolesnikova I.A.		Junior Researcher	
		Lesovaya E.N.		Junior Researcher	
		Panina M.S.		Junior Researcher	
		Ryumin A.K.		Junior Researcher	
		Saprykin E.A.		Junior Researcher	
		Tudevdorzh T.		Junior Researcher	
		Utina D.I.		Junior Researcher	
2.	engineers	Stolyarov A.V.	LRB	Assistant Director	6.5
		Tyupikova T.V.		Leading Engineer	
		Budyonny S.A.		Senior Engineer	
		Lomakin N.V.		Senior Engineer	
		Pavlik E.E.		Senior Engineer	
		Afanaseva A.N.		Engineer	
		Davydov D.V.		Senior Technician	
3.	specialists	-	-	-	-
4.	technicians	-	-	-	-
	Total:	**37**			**30.5**

3.2.2. JINR associated personnel

No.	Category of personnel	Partner organization	Amount of FTE
1.	research scientists	-	-
2.	engineers	-	-
3.	specialists	-	-
4.	technicians	-	-
	Total:	-	-

4. Financing

4.1 Total estimated cost of the project

The total cost estimate of the project (for the whole period, excluding salary).
The details are given in a separate table below.

3 310 000 $

4.2 Extra funding sources

Expected funding from partners/customers – a total estimate.

—

Project Leader __________/___________/

Project Leader __________/___________/

Date of submission of the project to the Chief Scientific Secretary: _________
Date of decision of the laboratory's STC: _________ document number: _________

Year of the project start: ________________

(for extended projects) – Project start year: _______

Proposed schedule and resource request for the Project

Expenditures, resources, funding sources			**Cost (thousands of US dollars)/ Resource requirements**	**Cost/Resources, distribution by years**				
				1st year	2nd year	3rd year	4th year	5th year
		International cooperation	310 k$	50	50	50	70	70
		Materials	250 k$	50	50	50	50	50
		Equipment, Third-party company services	2 100 k$	400	450	450	400	400
		Commissioning	-	-	-	-	-	-
		R&D contracts with other research organizations	-	-	-	-	-	-
		Software purchasing	-	-	-	-	-	-
		Design/construction	650 k$	150	200	200	50	50
		Service costs (*planned in case of direct project affiliation)*	-	-	-	-	-	-
Resources required	**Standard hours**	Resources						
		- the amount of FTE,	152.5	30.5	30.5	30.5	30.5	30.5
		- accelerator/installation: SARRP (LRB)	240	48	48	48	48	48
		U400M (FLNR)	200	40	40	40	40	40
		Nuclotron (SIMBO station) (VBLHEP)	480	96	96	96	96	96
		Linak-200 (DLNP)	150	30	30	30	30	30
		IREN (FLNP)	150	30	30	30	30	30
		- reactor,…						
Sources of funding	**JINR Budget**	JINR budget *(budget items)* 5, 6, 10, 14, 18, 19 4	3 000 k$ 310 k$	600 50	700 50	700 50	500 70	500 70

	Extra fudning (suplementary estimates)	Contributions by partners	-	-	-	-	-	-
		Funds under contracts with customers	-	-	-	-	-	-
		Other sources of funding	-	-	-	-	-	-

Project Leader __________/_________________/

Project Leader __________/_________________/

Laboratory Economist __________/_________________/

APPROVAL SHEET FOR PROJECT

TITLE OF THE PROJECT

Radiation-biophysical and astrobiological research

SHORT DESIGNATION OF THE PROJECT

PROJECT CODE

THEME CODE

04-9-1077-2009

NAME OF THE PROJECT LEADERS

Chizhov Alexei Vladimirovich, Rozanov Alexei Yurievich

AGREED

JINR VICE-DIRECTOR	SIGNATURE	NAME	DATE
CHIEF SCIENTIFIC SECRETARY	SIGNATURE	NAME	DATE
CHIEF ENGINEER	SIGNATURE	NAME	DATE
LABORATORY DIRECTOR	SIGNATURE	NAME	DATE
CHIEF LABORATORY ENGINEER	SIGNATURE	NAME	DATE
LABORATORY SCIENTIFIC SECRETARY	SIGNATURE	NAME	DATE
THEME LEADERS	SIGNATURE	NAME	DATE
	SIGNATURE	NAME	DATE
PROJECT LEADERS	SIGNATURE	NAME	DATE
	SIGNATURE	NAME	DATE
APPROVED BY THE PAC	SIGNATURE	NAME	DATE