In total the completed form should not exceed 20 pages (together with tables).

Annex 3.

Form of opening (renewal) for Project / Sub-project of LRIP

APPROVED

JINR DIRECTOR

_____________/___________________

"_____" ______________________ **202_ г.**

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/subproject of the large research infrastructure project (hereinafter LRIP subproject)

1.1. Theme code / LRIP (for extended projects) **01-3-1137-2019/2023**

1.2 Project/LRIP subproject code (for extended projects)

1.3 Laboratory of Theoretical Physics

1.4 Scientific field Theory of Condensed Matter

1.5 Title of the project/LRIP subproject Quantum Field Theory Methods in Complex Systems

1.6 Project/LRIP subproject leader(s) Hnatic Michal

1.7 Project/LRIP subproject deputy leader(s) (scientific supervisor(s))

2 Scientific case and project organization

2.1 Annotation

Complex physical phenomena such as developed turbulence, transport phenomena, nonequilibrium phase transitions, percolation, chemical reactions and surface growth in random media are difficult to study theoretically and experimentally, however in light of their wide distribution in nature such studies prove themselves to be very valuable.

The main task of the project will be the formulation of the corresponding theoretical models, which can be investigated using the methods of quantum field theory and non-equilibrium statistical physics. The main goal is to study the statistical characteristics of fluctuating fields (velocity fields, magnetic fields, concentration fields, order parameter fields) in the region of large spatial scales, identify phase transitions and to calculate universal critical exponents and non-universal amplitudes.

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

Dynamic nonlinear systems in which nonequilibrium (stochastic) fluctuations of physical quantities play decisive role, is one of the most important research topics by leading scientific teams in the world. They cover a wide range phenomena that we observe in the world around us. Stochasticity is a fundamental property of physical, chemical, biological and even socio-economic phenomena.
Notable examples of stochastic processes include - hydrodynamic and magnetohydrodynamic turbulence, describing, in particular, turbulent movements in the Earth's atmosphere and oceans, the spread of pollutants in them substances (including chemically active), as well as chaotic motions of plasma on surface of the sun and in space. One of the important consequences of the existence of mechanical instabilities in electrically conducting turbulent media is an exponential growth of magnetic fluctuations leading to the formation of observed nonzero averaged magnetic fields only due to the kinetic energy of the turbulent medium.
Another important example of stochastic systems are percolation processes. They describe phenomena such as seepage in porous media, filtration, spread of infectious diseases, forest fires and others. Their universal feature is the existence of a nonequilibrium phase transition to an inactive (absorbing) state that extinguishes all activity of the observed system.
Obviously, the study of transitions between a stationary active (which does not correspond to thermal equilibrium) and the inactive phase is of great practical importance. Note that these transitions are continuous and are especially interesting as prototypical examples of strongly non-equilibrium critical behavior.

The main object of study are physical quantities that depend on space-time coordinates and therefore are fluctuating fields, and the measured quantities are their statistical averages. The most important of them are non-zero average field values, response functions, multipoint correlation functions, two-point simultaneous correlations (structural functions), including composite fields (operators). In the region of large spatial and temporal scales, their scaling behavior with universal critical exponents is observed. The analysis of stability regions of scaling regimes and the calculation of indices is a priority goal in the study of stochastic nonlinear systems.

The main **goal** of the project is to study stochastic nonlinear dynamic systems, such as developed (magneto)hydrodynamic turbulence, nonequilibrium phase transitions, phase transitions in systems with high spins, kinetics of chemical reactions, percolation processes, surface growth in random media and self-organized criticality.

Scientific **novelty** and **relevance** is found in the study of scaling regimes, which includes the calculation of critical exponents and representative physical constants and parameters of the systems under consideration in higher orders of perturbation theory.

General **methods** of theoretical research and approaches to solving the formulated problems are based on the use and improvement of the methods of quantum field theory and nonequilibrium statistical physics. They include the theory of renormalizations, calculations of multi-loop Feynman diagrams, algorithms for resumming the terms of a perturbation theory series with respect to a formally small parameter, the technique of the renormalization group, the functional renormalization group, methods for solving equations like the Langevin equation and its generalizations, the Fokker-Planck equation, master equations for distribution functions, high-performance computations, including computations on a supercomputer.

The main expected **results** will consist in the calculation of fixed points of the renormalization group and their areas of attraction, critical exponents, analysis of phase diagrams and calculation of representative parameters. The results will be presented at the Laboratory's seminars, international conferences and published in leading scientific journals.

The solution of the project tasks will be carried out in cooperation with colleagues from scientific institutes and universities in Russia and other countries with whom we have stable long-term contacts, interaction and joint publications based on the results obtained in scientific areas that form the basis of the project. These are, first of all, the Pavel Josef Šafárik University in Kosice, the Institute of Experimental Physics of the Slovak Academy of Sciences in Kosice, the University of Helsinki, St. Petersburg State University and the Peoples' Friendship University of Russia in Moscow.

The specific goals and objectives of the project are as follows:

1. Investigation within the BEC-BCS functional renormalization group of the crossover in systems of multicomponent fermions: analysis of phase diagrams and calculation of transition temperatures to the ordered state. Approbation and adaptation of computational methods for solving nonperturbative equations of the functional renormalization group.
2. Development of computational methods for calculating the contributions of multiloop diagrams to the renormalization group functions of dynamical models. Investigation of the dynamics of the superconducting phase transition in low-temperature superconductors.
3. Study of the effects associated with the violation of mirror symmetry in magnetohydrodynamic developed turbulence. Calculation of two-loop Feynman diagrams generated by the Lorentz force and two-loop diagrams of the response function leading to an exponential growth of magnetic field fluctuations in the region of large scales. Study of the phenomenon of turbulent dynamo.
4. Construction of effective field-theoretical models of chemical reactions of various types of particles occurring in random media. Study of infrared scaling behavior of statistical correlations of particle densities by renormalization group methods.
5. Study of isotropic and directed percolation. Calculation of multiloop Feynman diagrams generating ultraviolet divergences. Finding fixed points of the renormalization group equations and calculating critical exponents for physically significant and experimentally observable quantities - response functions, density of active nodes (agents), effective radius and mass of active zones.
6. Study of the effect of isotropic motion of a medium with different statistical characteristics on the possibility of anisotropic scaling in the Hua-Kardara self-organized criticality model. Investigation by the functional renormalization group method of possible asymptotic regimes corresponding to the non-universal scaling behavior of a surface growing in a random environment and described by a model that includes an infinite number of types of interactions.

2.3 Estimated completion date 2028

2.4 Participating JINR laboratories

Meshcheryakov Laboratory of Information Technologies (Jan Busa senior)

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					
Tier 1 (CPU core hours)					
Tier 2 (CPU core hours)					
SC Govorun (CPU core hours) - CPU - GPU					
Clouds (CPU cores)					

2.5. Participating countries, scientific and educational organizations

Organization	Country	City	Participants	Type of agreement
SPSU	Russia	Sankt Petersburg	Gulitsky N. + 2	common publications
RUDN	Russia	Moscow	Kulyabov D. + 2	common publications
P J Šafarik University	Slovakia	Košice	Lucivjansky + 2	common publications
Helsinki University	Finland	Helsinki	Honkonen J.	common publications
Leipzig University	Germany	Leipzig	Bordag M.	common publications
IM BAS	Belarus	Minsk	Malyutin V.	common publications

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	8	
2.	engineers		
3.	specialists		

4.	office workers		
5.	technicians		
	Total:	**8**	

3.2. Available manpower
3.2.1. JINR staff

No.	Category of personnel	Full name	Division	Position	Amount of FTE
1.	research scientists	Hnatič M.	SDTCM	Sector head	1
		Kalagov G.A.		researcher	1
		Lebedev N.M.		researcher	1
		Mižišin L.		senior researcher	1
		Molotkov Y.G.		researcher	1
		Sevastyanov L.A.		leading researcher	0.5
		Adzhemyan L.Ts.		leading researcher	0.25
		Nalimov M.Yu.		leading researcher	0.25
		Antonov N.V.		leading researcher	0.25
		Kompaniets M.V.		leading researcher	0.25
2.	engineers				
3.	specialists				
4.	technicians				
	Total:				**6.5**

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

The project will be funded through the theme "Theory of complex systems and advanced materials"

Project (LRIP subproject) Leader __________/___________/

Date of submission of the project (LRIP subproject) to the Chief Scientific Secretary:
Date of decision of the laboratory's STC: **13.04.2023** document number: **14**

Year of the project (LRIP subproject) start: **2024**

APPROVAL SHEET FOR PROJECT / LRIP SUBPROJECT

TITLE OF THE PROJECT/LRIP SUBPROJECT

SHORT DESIGNATION OF THE PROJECT / SUBPROJECT OF THE LRIP

PROJECT/LRIP SUBPROJECT CODE

THEME / LRIP CODE

NAME OF THE PROJECT/ LRIP SUBPROJECT LEADER

AGREED

	SIGNATURE	NAME	DATE
JINR VICE-DIRECTOR			
CHIEF SCIENTIFIC SECRETARY			
CHIEF ENGINEER			
LABORATORY DIRECTOR			
CHIEF LABORATORY ENGINEER			
LABORATORY SCIENTIFIC SECRETARY THEME / LRIP LEADER			
PROJECT / LRIP SUBPROJECT LEADER			

	SIGNATURE	NAME	DATE
APPROVED BY THE PAC			

Annex 4.

Project (LRIP subproject) report form

PROJECT REPORT

1. General information on the project / LRIP subproject

1.1. Scientific field

1.2. Title of the project / LRIP subproject

1.3. Project (LRIP subproject) code

Example (04-4-1140-1-2024/2027)

1.4. Theme / LRIP code

Example (theme 04-4-1140-2024, **MIP** ***04-4-1140-2024)***

1.5. Actual duration of the project/ LRIP subproject

1.6. Project / LRIP subproject Leader(s)

2. Scientific report

2.1. Annotation

2.2. A detailed scientific report

2.2.1. Description of the mode of operation and functioning of the main systems and equipment (for the LRIP subproject).
2.2.2. A description of the conducted experiments (for experimental projects).
2.2.3. A description of the research undertaken and the results obtained.
2.2.4. A list of the main publications of the JINR authors, including associated personnel on the results of the project (list of bibliographical references).
2.2.5. A complete list of publications (electronic annex, for journal publications with journal impact factor).
2.2.6 List of talks given at international conferences and meetings (electronic annex).
2.2.7. Patent activity (if any)

2.3. Status and stage (TDR, CDR, ongoing project) of the project (subproject) (including percentage of implementation of the declared milestones of the project (LRIP subproject) *(if applicable)*

2.4. Results of related activities

2.4.1. Research and education activities. List of defended dissertations.
2.4.2. JINR grants (scholarships) received.
2.4.3. Awards and prizes.
2.4.4. Other results (expert investigation, organizational, outreach activities).

3. International cooperation
Actually participating countries, institutions and organizations

Organization	Country	City	Participants	Type of agreement

4. Analysis of planed vs actually used resources: manpower (including associated personnel), financial, IT, infrastructure

4.1 Manpower (actual at the time of reporting)

No.	Personnel category	JINR staff, amount of FTE	JINR associated personnel, amount of FTE
1.	research scientists		
2.	engineers		
3.	specialists		
	Total:		

4.2 The actual estimated cost of the project/ LRIP subproject

<table>
<tr><th colspan="3" rowspan="2">Names of costs, resources, funding sources</th><th rowspan="2">Cost (thousands of US dollars) / Resource request</th><th colspan="5">Proposal from the laboratory for allocation of funding and resources</th></tr>
<tr><th>1 year</th><th>2 year</th><th>3 year</th><th>4 year</th><th>5 year</th></tr>
<tr><td colspan="2" rowspan="8"></td><td>International cooperation</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Materials</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Equipment, Third-party company services</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Commissioning</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>R&D contracts with other research organizations</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Software purchasing</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Design/construction</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Service costs (planned in case of direct project affiliation)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Resources</td><td rowspan="2">Standard hours</td><td>Resources</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>– the amount of FTE,</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

required		– accelerator/installation,						
		– reactor,…						
Sources of funding	JINR Budget	JINR budget *(budget items)*						
	Extra fudning (supplementary estimates)	Contributions by partners Funds under contracts with customers Other sources of funding						

4.3 Other resources

Computer resources consumed MICC	**Distribution by years**				
	1st year	**2nd year**	**3rd year**	**4th year**	**5th year**
Data storage (TB) - EOS - Tapes					
Tier 1 (CPU core hours)					
Tier 2 (CPU core hours)					
SC Govorun (CPU core hours) - CPU - GPU					
Clouds (CPU cores)					

5. Conclusion

6. Proposed reviewers

Theme / LRIP Leader

______________/_______________/
"______"____________________ 202_г.

Project leader (project code) / LRIP subproject
______________/____/
"______"_____________ 202_г.

Laboratory Economist
_______/________/
"______"____________ 202_