**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**

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

* 1. **Theme code / LRIP** (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.*

**1.2 Project/LRIP subproject code** (for extended projects)

**1.3 Laboratory** Bogoliubov Laboratory of Theoretical Physics

**1.4 Scientific field** Theoretical Physics

**1.5 Title of the project/LRIP subproject** Supersymmetry, Higher Spins, Gravity

**1.6 Project/LRIP subproject leader(s)** E.A. Ivanov

**1.7 Project/LRIP subproject deputy leader(s) (scientific supervisor(s))** S.A. Fedoruk

**2 Scientific case and project organization**

**2.1 Annotation**

The project as a whole is devoted to the construction of new theories with extended supersymmetry and gauge invariance in various dimensions, the study of their quantum structure and classical solutions of the soliton type with cosmological applications. The main efforts will be concentrated on the construction of new supersymmetric gauge theories, including higher spins and the development of new approaches and methods for studying their quantum structure. The project involves the solutions of a large number of actual problems which are posed by the modern development of the supersymmetric field theory and superstring/brane theory. We suppose to consider the following concrete problems

- Calculation of the one-loop effective action in the theory of hypermultiplet interacting with N=2 superfield supergravity. Construction of the induced effective action of the hypermultiplet interacting with external N=2 supersymmetric bosonic higher spin superfields.

- Constructing the Lagrangian 4D, N=2 supersymmetric gauge theory of fermionic higher spin fields in in terms of 4D, N=2 harmonic superspce. Constructing the Lagrangian 4D, N=2 supersymmetric gauge theory of higher spin fields in AdS space.

- Investigating T-duality in 2D, N=(4,4) supersymmetric hyperkahler and quaternion-kahler sigma models using the language of harmonic superspce, finding out superfield Lagrangians of new sigma models with torsion obtained from the former models by T-duality procedure, exploring their intrinsic geometry and interrelations with string theory.

-Exploring the structure of two-loop divergences in 6D N=(1,1) supersymmetric Yang-Mills theories formulated in 6D N=(1,0) harmonic superspace. Finding out the previously missed leading in the dimensional regularization parameter divergences of the two-loop harmonic supergraphs. Calculating subleading divergences of all two-loop supergraphs.

- Study of gauge infinite spin fields and superfields in diverse space-time dimensions and construction of their Lagrangian superfield formulation by using twistor and BRST methods.

- Construction of the minimal interaction of infinite spin fields and higher spin fields with fixed spin fields. Using the background field method, finding the quantum loop corrections due to this interaction. Generalization of the developed formalizm to the supersymmetric case.

- Construction and study on the classical and quantum levels of the superfield matrix formulation of new N=4 and N=8 supersymmetric integrable many-particle systems. Study of supersymmetric matrix systems with extended deformed supersymmetry and matrix systems of superconformal mechanics. The use of such systems in cosmological models, in black hole physics and nuclear physics.

- Application of the superfield gauging method for constructing new models of N-extended supersymmetric quantum mechanics, which describes the interaction of dynamic and semidynamic multiplets of various types, including mirror multiplets. A new problem is the study of nonlinear N=4 and N=8 multiplets as semidynamical. Quantization of the supersymmetric models constructed.

- Construction of a superfield description of Calogero-type models with extended N≥4 supersymmetries in the framework of the matrix approach, in which it turns out to be essential to use a non-minimal set of fermionic fields.

- Analysis of the integrability of N-extended supersymmetric systems of the Euler–Calogero–Moser and Calogero–Moser–Sutherland types for the A(n-1) series of the Coxeter group by constructing the Lax representation, as well as the generalization of all models from the A(n−1) series to other groups Coxeter.

- Finding an explicit form of the functionally independent conserved Liouville currents, as well as an additional set of conserved currents, in N=2 supersymmetric Calogero models for all root systems of Coxeter groups.

- A study of N=4 supersymmetric mechanics constructed on the basis of nonlinear supermultiplets is planned. In particular, we will extend the known one-particle mechanics of this sort to a wide class of systems parameterized by an arbitrary holomorphic function. Besides, we plan to construct and study multiparticle supersymmetric systems with nonlinear supermultiplets, including integrable models.

- The study of integrable systems with Kahler phase space and their supersymmetrization will be performed. In particular, we plan to construct various generalizations of compactified Ruijsenaars model, and rational Calogero models.

- Considering the systems on Grassmannians, on SU(N) flag manifolds and on their noncompact analogs will allow to find the spin extensions of the compactified Ruijsenaars-Schneider model including its conformally-invariant versions. When supersymmetrizing them, two sorts of Kahler phase superspaces will be used: those associated with the external algebra of initial phase space and special super-extensions of (compact and non-compact) projective spaces and Grassmannians, which should admit constructing N-extended supersymmetric systems with N fermions.

- It is planned to investigate several problems in superconformal field theories in two and four dimensions using the developed apparatus of rarefied elliptic and hyperbolic gamma functions. The elements of the matrix of modular transformations of one-point conformal blocks on the torus in the Neveu-Schwarz sector of N=1 superconformal two-dimensional Liouville field theory will be calculated and the difference equations for the fusion matrix will be analyzed .

- Construction and detailed study of properties of new solutions of extended models of gravity with matter fields, which represent multicomponent charged boson stars and black holes with localized matter fields in gauge theories with spontaneous symmetry breaking and in the models with non-linear scalar potential in asymptotically flat spacetime, as well as in the spacetime with asymptotic AdS geometry. A possible role of multicomponent boson stars in searching for dark matter will be analyzed.

The considered problems are fully consistent with the modern trends of development of modern theoretical physics and interconnected between themselves by unity of methods and approaches. All the proposed objectives are new and are based on the range of issues that have arisen over the past few years. Project participants are familiar with all the techniques needed to solve these problems.

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

The project is aimed at solving fundamental problems of modern theoretical physics associated with the development of superfield methods in gauge theories with extended supersymmetry in various dimensions, including extended supersymmetric mechanics. The implementation of the project includes the construction of new field and quantum-mechanical models with global and gauge symmetries, the development of new, including geometric, methods for studying the structure of such models at the classical and quantum levels, the study of the structure of the corresponding quantum effective actions and classical solutions of these models, including black holes. All tasks of the project are set by the modern development of theoretical physics and are organically joined by the unity of methods and approaches.

One of the leading trends in the development of modern theoretical physics is the development of new approaches to the problem of constructing unified theory of all fundamental interactions, including the description of gravity at the quantum level. A natural ingredient of all such approaches is supersymmetry.

At present, it has already become natural that theories with extended supersymmetry in different dimensions are adequately described within the framework of harmonic superspaces (see, for example, the monograph [A.S. Galperin, E.A. Ivanov, V.I. Ogievetsky, E.S. Sokatchev, Harmonic Superspace, Cambridge Univ.Press, 2001]). Formulations in terms of harmonic superspace are the most symmetric, for example, in the sense that for the maximally extended gauge theories in four dimensions, they keep two or three of the four supersymmetries manifest. Formulations in terms of harmonic superspace are the most symmetric, for example, in the sense that for a gauge theory with the most extended global supersymmetry in four dimensions, they keep two or three of the four supersymmetries explicit. The majority of the problems to be handled in this project will basically use the harmonic approach. The new development of the harmonic method and its application in this project both for perturbative calculations in supersymmetric gauge theories and for constructing, in an explicitly supersymmetric form, new contributions to the quantum effective action will contribute to further understanding of the deep connections of these theories with the theory of superstrings/branes.

Supersymmetric gauge theories in various dimensions have remarkable properties at the classical and quantum levels. Such theories are closely related to the low-energy limit of superstring theory or M-theory (see, for example, the reviews [A. Giveon, D. Kutasov, Rev. Mod. Phys, 71 (1999) 983]; [O. Aharony et al., Phys. Repts., 323 (2000) 183] [C. Becker, M. Becker, J. H. Schwartz, String Theory and M-Theory, Cambridge Univ. Press, 2007] [J. Bagger, N. Lambert, C., Mukhi and C. Papageorgakis, Phys. Rept., 527 (2013) 1] and references therein). This circumstance opens up the possibility of studying low-energy superstring quantum effects using quantum field theory methods. More precisely, low-energy effective actions due to D- or M-brane interactions can be found within supersymmetric gauge quantum field theory in terms of low-energy quantum effective action. The study of the quantum structure of supersymmetric gauge theories in higher dimensions was carried out by various authors using different methods and approaches (see, for example, [E.S. Fradkin, A.A. Tseytlin, Nucl. Phys. B 227 (1983) 252]; [P.S. Howe, K.S. Stelle, Phys Lett. B137 (1984) 175; Phys. Lett. B554 (2003) 190] [G. Bossard, P. S. Howe, K. S. Stelle, Gen. Rel. Grav. 41 (2009) 919; Phys. Lett. B 682 (2009) 137]; [L.V. Bork, D.I. Kazakov, M.V. Kompaniets, D.M. Tolkachev, D.E. Vlasenko, JHEP, 1511 (2015) 059] and references there). Of particular interest in theories with extended supersymmetry in higher dimensions is the problem of ultraviolet divergences. On the one hand, since the gauge coupling constant in such theories is dimensional, it is natural to expect that the theories under consideration are non-renormalizable in power counting. On the other hand, extended supersymmetry can somewhat improve the ultraviolet behavior of the effective action. Indeed, in the above papers, arguments were given that, for example, in the six-dimensional maximally extended globally symmetric gauge theory, the on-shell effective action in the sector of the gauge field turns out to be finite in one- and two-loop approximations. The problem of describing the off-shell structure of effective action in such a theory remained open for a long time.

In recent works of this project participants [I.L. Buchbinder, E.A. Ivanov, B.S. Merzlikin, K.V. Stepanyantz, Phys. Lett. B 820 (2021) 136516; JHEP 08(2020) 169; Nucl. Phys. B 961 (2020) 115249; Phys. Lett. B 798 (2019) 134957; Phys. Lett. B 763 (2016) 375; Phys. Lett. B 778 (2018) 252; Nucl. Phys. B 936 (2018) 638], a new, completely off-shell approach was developed to study the structure of the effective action in the maximally extended global supersymmetric Yang-Mills theory. It is known that in six dimensions the simplest representations of a superalgebra are N=(1,0) and N=(0,1) supersymmetries. From this point of view, the maximally extended global supergauge theory has N=(1,1)=(1,0)+(0,1) supersymmetry and corresponds to the interacting N=(1,0) gauge multiplet and hypermultiplet. The considered N=(1,1) supersymmetric theory can be formulated in 6D, N=(1,0) harmonic superspace, where N=(1,0) supersymmetry is manifest, the second N=(0,1) remains hidden. In our works, we developed the background field method, which ensures manifest gauge invariance and manifest N=(1,0) supersymmetry at all stages of calculating the effective action. A complete off-shell analysis of the N=(1,1) one-loop divergences of the supergauge theory was carried out and it was shown that in such a theory all the divergences under consideration can cancel off-shell, both in the sector of the gauge multiplet and the hypermultiplet. Certain results were also obtained for two-loop divergences, although their full analysis requires additional study, which is planned within the framework of this project.

The theory of higher spin fields is one of the actively developing areas of modern theoretical and mathematical physics (see, for example, the reviews [Vasiliev, Fortschr.Phys. 52 (2004) 7027; X. Bekaert, S. Cnockaert, C, Iazeolla, M.A. Vasiliev, Non -linear higher spin theories in various dimensions, arXiv:hep-th/0503128, A. Fotopoulos, M. Tsulaia, Int. J. Mod. Phys. A24 (2008) 1, X. Bekaert, N. Boulanger, P. Sundell , Rev. Mod Phys. 84 (20012) 987; A. Sagnotti, J. Phys. A46 (2013) 214006; V. E. Didenko, E. D. Skvortsov, Elements of Vasiliev theory, arXiv:1401.2975 [hep-th]; X. Bekaert, N. Boulanger, A. Campaneoli, M. Chodaroli, D. Francia, M. Grigoriev, E. Sezgin, E. Skvortsov, Snowmass White Paper: Higher Spin Gravity and Higher Spin Symmetry, arXiv:2205.01567 [hep-th]. ] and the references therein). We point out only the direction associated with the Lagrangian formulation of higher-spin gauge superfields. In the case of D4, N=1 supersymmetry, such an approach was developed by S.M. Kuzenko and collaborators in terms of N=1 superspace and then developed by many authors. In particular, examples of theories with N=2 supersymmetry have been constructed in terms of N=1 superfields. The general formulation of the theory of higher spin fields with manifest N=2 supersymmetry remained an open problem for a long time. Progress in this direction has been made in the recent works of this project participants [I. Buchbinder, E. Ivanov, N. Zaigraev, JHEP, 12 (2021) 016, 27; 05 (2022) 104; 03 (2023) 036], where, using the methods of harmonic superspace, a manifest N=2 supersymmetric Lagrangian description of free N=2 supergauge higher spin fields was presented and a cubic vertex of their interaction with a hypermultiplet was found . The works mentioned above open up opportunities for posing a large number of new problems and finding methods for solving them. It is planned to consider these problems within the framework of this project.

Quantum aspects of the higher spin field theory have been little studied. In the context of this project, we note the works [X. Bekaert, E. Joung, J. Mourad, JHEP, 1102 (2011) 048; L. Bonora, M. Cvitan, P. Dominis Prester, S. Giaccari, M. Stemberga, JHEP, 12 (2016) 084; 03 (2018) 80; Eur. Phys. J. C 79 (2019) 258; HS flat spacetime. YM-like models, arXiv:1812.05030] related to the construction of the induced quantum effective action in the theory of scalar and spinor fields in an external highe spin field gauge fields. The study of such issues in the theories of higher spin fields with explicit N=2 supersymmetry has never been carried out. Within the framework of this project, it is planned to calculate the induced effective action in the theory of a hypermultiplet in an external N=2 higher spin supergauge fields. The corresponding classical theory was developd in the works of the project participants (see above). As a first step, it is natural to consider the problem of effective action in the theory of a hypermultiplet in an external field of N=2 supergravity. For the manifestly covariant and supersymmetric calculation of the effective action, it is planned to develop a harmonic superfield generalization of the proper time method (Schwinger-DeWitt method).

One more interesting and prospective direction of reserach within the harmonic superspace approach is exploring the concept of T-duality[T.H. Buscher, PLB 159 (1985) 127-130, PLB 194 (1987) 59-62, PLB 201 (1988) 466-472; E. Alvarez, L. Alvarez-Gaume, Y. Lozano, Nucl.Phys.Proc.Suppl.41:1-20,1995] in application to 2D, N=(4,4) supersymmetric hyperKahler and quaternion-Kahler sigma models considered earlier ib terms of harmonic superfields in the works [A. Galperin, E . Ivanov, V. Ogievetsky, E. Sokatchev, Commun. Math. Phys. 103 (1986) 515-526; A. Galperin, E . Ivanov, V. Ogievetsky, E. Sokatchev,Class. Quant. Grav. 4 (1987) 1525-1265]. Such an analysis has not been performed so far, and the manifestly 2D, N=(4,4) supersymmetrivc versions of both abelian and non-abelian T-dualities should give rise to a new class of 2D superfield sigma models with non-trivial torsion on the target space and new understanding of the role of these sigma models in string theory.

Recently, there has been an increased interest in the study of particles and fields associated with various representations of physical symmetry groups, in particular, with infinite (continuous) spin representations of the Poincaré group [E.P. Wigner, Annals Math. 40 (1939) 149, Z. Physik 124 (1947) 665, V. Bargmann, E.P. Wigner, Proc.Nat. Acad. Sci. US 34 (1948) 211]. An interest in such unitary representations is caused by the similarity of the spectrum of states in the infinite spin theory with the spectra in the higher spin theory [M.A. Vasiliev, Annals Phys. 190 (1989) 59, Phys. Lett. B257 (1991) 111, Phys. Lett.B285 (1992) 225] (see also review [X. Bekaert, S. Cnockaert, C. Iazeolla, MA Vasiliev, Proceedings of the 1st Solvay Workshop on Higher Spin Gauge Theories, 12-14 May 2004. Brussels, Belgium, Int. Solvay Institutes, 2006, 132-197]), as well as by the potential relationship of this theory to string theory (see [J. Mund, B. Schroer, J. Yngvason, Phys. Lett. B596 (2004) 156, M.A. Vasiliev, JHEP 08 (2018) 051] and references there), the main candidate for the quantum theory of gravity. Various problems related to the quantum-mechanical and field description of such states have been considered in a number of works devoted to particles and fields of infinite spin (see, for example, the review [X. Bekaert, E.D. Skvortsov, Int. J. Mod. Phys. A32 (2017) 1730019] and links there).

In recent papers [I.L. Buchbinder, S. Fedoruk, A.P. Isaev, A. Rusnak, JHEP 1807 (2018) 031; I.L. Buchbinder, S. Fedoruk, A.P. Isaev, Nucl. Phys. B945 (2019) 114660] the participants of this project have developed a new approach to the description of particles and fields of infinite spin. The proposed formulation is based on a generalization of the twistor formulation of the standard (with fixed helicity) massless particle [R. Penrose, J. Math. Phys. 8 (1967) 345, R. Penrose, M.A.H. MacCallum, Phys. Rept. 6 (1972) 241] to the case of infinite spin massless representations. After quantizing the proposed twistor model, infinite spin twistor fields were obtained, which have expansions into infinite sum of states with all fixed helicities. It was shown that this D=4 twistor model reproduces the D=4 Wigner-Bargmann space-time formulation with an additional spin four-vector coordinate [E.P. Wigner, Annals Math. 40 (1939) 149, Z. Physik 124 (1947) 665, V. Bargmann, E.P. Wigner, Proc.Nat. Acad. Sci. US 34 (1948) 211], as well as the space-time formulation of the infinite integer spin fields with an additional even spinor coordinate [I.L. Buchbinder, V.A. Krykhtin, H. Takata, Phys. Lett. B785 (2018) 315]. In addition, using twistor field transformation, the authors of the project obtained a space-time - spinor formulation of infinite spin fields with half-integer helicities. This formulation allows us to construct the infinite spin supermultiplet and to describe its properties. It should be noted that the aspects of infinite spin supersymmetry have practically not been considered earlier in the literature. In subsequent works, using BRST methods, the project participants constructed actions for gauge fields describing states of an infinite spin with integer and half-integer helicities [I.L. Buchbinder, V.A. Krykhtin, H. Takata, Phys. Lett. B785 (2018) 315; I.L. Buchbinder, S. Fedoruk, A.P. Isaev, V.A. Krykhtin, Nucl. Phys. B958 (2020) 115114]. In recent papers [I.L. Buchbinder, S. Fedoruk, A.P. Isaev, Nucl. Phys. 973 (2021) 115576, Eur.Phys.J. C82 (2022) 733] twistor formulation of the 6D infinite spin particle and its the field light-cone description are constructed. It should be emphasized here that the twistor methods have found recently very wide application in connection with problems related to the description and calculation of various Feynman diagrams, in particular, the so-called MHV amplitudes and their generalizations. Therefore, it is relevant to generalize the developed methods to the case of more complicate systems describing the unitary states of higher-dimensional theories, namely, D=6 massless particles of higher and infinite spins and six-dimensional supersymmetric gauge theories, which are the subject of one of the important areas of research in M-theory [J. Bagger, N. Lambert, S. Mukhi, C. Papageorgakis, Phys. Rept. 527 (2013) 1].

Supersymmetric field theories in one-dimensional space are important in the study of various versions of superconformal mechanics, an interest in which arose in connection with the AdS/CFT correspondence [J.M. Maldacena, Adv. Theor. Math. Phys. 2 (1998) 231; S.S. Gubser, I.R. Klebanov, A.M. Polyakov, Phys. Lett. B428 (1998) 105; E. Witten, Adv. Theor. Math. Phys. 2 (1998) 253], since such models describe the motion of (super)particle in the near-horizon (AdS) geometry of black holes as solutions of supergravity in diverse dimensions. Namely, as noted in [P. Claus, M. Derix, R. Kallosh, J. Kumar, P.K. Townsend, A. Van Proeyen, Phys. Rev. Lett. 81 (1998) 4553], the radial motion of massive charged particle near the horizon of extreme Reissner-Nordström black hole is described by the "relativistic" type of conformal mechanics, which is reduced to the standard conformal mechanics [V. de Alfaro, S. Fubini, G. Furlan, Nuovo Cim. A34 (1976) 569] in the "nonrelativistic" limit. On the other hand, conformal symmetry characterizes an important class of integrable many-particle systems discovered by F. Calogero in his pioneering papers [F. Calogero, J. Math. Phys. 10 (1969) 2191; 10 (1969) 2197]. This close relationship of integrable models with the AdS/CFT correspondence stimulated further work on the study of various models of supersymmetric mechanics, in particular, supersymmetric generalizations of many-particle integrable models and extended superconformal mechanics models. In connection with the said above, it is worth to mention the work [G.W. Gibbons, P.K. Townsend, Phys. Lett. B454 (1999) 187], in which it was shown that, in the limit of a large number of particles N=4, multiparticle superconformal mechanics provides a microscopic description of the dynamics of the Reissner–Nordstrom multicenter extreme black hole near the event horizon.

In the case of N=2 supersymmetry, a supersymmetric extension of the multiparticle rational Calogero system was constructed in [D.Z. Freedman, P.F. Mende, Nucl. Phys. B344 (1990) 317]. But the construction of supersymmetric generalizations with four supersymmetries, as well as with larger number of them, ran into difficult problems (see, for example, [N. Wyllard, J. Math. Phys. 41 (2000) 2826; S. Bellucci, A. Galajinsky, S. Krivonos, Phys. Rev. D68 (2003) 064010; S. Bellucci, A. Galajinsky, E. Latini, Phys. Rev. D71 (2005) 044023]). One of the successful ways to solve this problem was proposed in the works of the project participants [S. Fedoruk, E. Ivanov, O. Lechtenfeld, Phys. Rev. D79 (2009) 105015; JHEP 0908 (2009) 081; JHEP 1004 (2010) 129]. It was shown that such systems arise as a result of superfield gauging of isometries of certain supersymmetric models of matrix mechanics, which also contain semi-dynamical isospin degrees of freedom in addition to dynamical and purely auxiliary degrees. This method is a supersymmetric generalization of the gauge description of bosonic Calogero models developed in [A.P. Polychronakos, Phys. Lett. B266 (1991) 29; JHEP 0104 (2001) 011; A. Gorsky, N. Nekrasov, Nucl. Phys. B436 (1995) 582]. Semi-dynamical variables used in this approach are described by the mechanical Chern-Simons (or Wess-Zumino) action [R. Floreanini, R. Percacci, E. Sezgin, Nucl. Phys. B322 (1989) 255; P.S. Howe, P.K. Townsend, Class. Quant. Grav. 7 (1990) 1655; A.P. Polychronakos, Phys. Lett. B266 (1991) 29] and, after quantization, generate isospin (or spin) degrees of freedom. After transition to component fields and fixing on-shell gauges, supersymmetric generalizations of the corresponding Calogero models are restored. In these papers of the project participants, new N=2 and N=4 superfield systems were constructed, giving rise to the rational Calogero model in the bosonic limit [S. Fedoruk, E. Ivanov, O. Lechtenfeld, Phys. Rev. D79 (2009) 105015; J. Phys. A45 (2012) 173001; Nucl. Phys. B944 (2019) 114633], the Calogero-Sutherland hyperbolic model [S. Fedoruk, E. Ivanov, O. Lechtenfeld, Nucl. Phys. B944 (2019) 114633], as well as the SU(2|1) -supersymmetric Calogero-Moser system [S. Fedoruk, E. Ivanov, O. Lechtenfeld, S. Sidorov, JHEP 1804 (2018) 043]. Such models contain Nn^2 fermions for n bosonic coordinates, in contrast to Nn fermionic fields in the case of standard supersymmetrization. For this reason, an urgent task is to use the methods described above to construct currently unknown supersymmetrizations of many-particle elliptic Calogero systems, as well as many-body Calogero systems with eight supersymmetries. The last problem seems to be especially urgent, given a deep connection between the solutions of the 4D, N=2 supersymmetric Seiberg-Witten theory [N. Seiberg, E. Witten, Nucl. Phys. B426 (1994) 19; Nucl. Phys. B431 (1994) 484] (see also the reviews [AV Marshakov, TMF 112 (1997) 3; 121 (1999) 179]) with many-particle integrable models.

In the paper [S. Krivonos, O. Lechtenfeld, A. Sutulin, Phys. Lett. B 784 (2018) 137] it was proposed a new N-extended supersymmetric *su*(*n*) spin-Calogero model. Employing a generalized Hamiltonian reduction adopted to the supersymmetric case, we explicitly constructed a novel rational *n*-particle Calogero model with an arbitrary even number of supersymmetries.

In the paper [S.Krivonos, O.Lechtenfeld, A.Sutulin, Phys. Lett. B 831 (2022) 137184], the integrability and superintegrability of N = 2 supersymmetric Calogero-Moser model for an arbitrary number of particles, containing n bosonic and n^2 fermionic degrees of freedom, is studied based on the construction of the corresponding Lax pair. An explicit construction is proposed for constructing Liouville currents. The general proof of integrability and superintegrability requires checking the involutiveness and functional independence of the constructed currents, and is require special considiration.

Based on the Hamiltonian description of N=2 supersymmetric Calogero models associated with the classical *An*, *Bn*, *Cn* and *Dn* series, including both rational and trigonometric/hyperbolic systems, there was found in [A.Sutulin, Proc. Sci, ISSN:1824-8039, Изд:SISSA, 394, 2021; S.Krivonos, O.Lechtenfeld, A.Sutulin, JHEP 05 (2020) 132] their superspace description in terms of the constrained superfields. The constructed N = 2 superfield actions lead at the component level to supersymmetric extensions of the corresponding bosonic Calogero models.

In the paper [S. Krivonos, O. Lechtenfeld, A. Sutulin, Phys. Lett. B 790 (2019) 191] there was explicitly constructed a supersymmetric *so*(*n*) spin-Euler-Calogero-Moser model with an arbitrary even number N of supersymmetries. It provided a superspace description for the simplest case of N=2 supersymmetry.

It is also relevant to study alternative supersymmetric models with additional spin degrees of freedom. In the case of N=4 Calogero models, the role of the dynamical multiplet was played by the multiplet (1,4,3) (the multiplets N=4, 1D of supersymmetric mechanics are denoted as (k,4,4-k), where these numbers correspond to the number of bosonic physical fields, fermionic physical fields and bosonic auxiliary fields, respectively). On the basis of the chiral multiplet (2,4,2), N=4 supersymmetric models on Kähler manifolds were studied, in particular, the model on the two-sphere [S.-T. Hong, J. Lee, T.H. Lee, P. Oh, Mod. Phys. Lett. A22 (2007) 1481] and the model on the two-dimensional pseudosphere [S. Bellucci, N. Kozyrev, S. Krivonos, A. Sutulin, Phys. Rev. D85 (2012) 065024]. In such models, spin degrees of freedom ensure an interaction with the magnetic field of Dirac monopole. An enlargement of dynamical multiplets to a higher contents of bosonic physical fields, such as (3,4,1) and (4,4,0), gives an interaction with the Wu-Yang monopole, Yang monopole and BPST instanton [[E. Ivanov, M. Konyushikhin, A. Smilga, JHEP 1005 (2010) 033; S. Bellucci, S. Krivonos, A. Sutulin, Phys. Rev. D81 (2010) 105026], as well as BPS monopole [E. Ivanov, M. Konyushikhin, Phys. Rev. D82 (2010) 085014].

Besides deep relations with supersymmetric theories in higher dimensions and one-dimensional integrable models of the Calogero type, an interest in supersymmetric quantum mechanics, especially in its extended N=4 and N=8 versions, is caused by the remarkable geometric properties of such models, sometimes having no higher-dimensional D >1 analog (see, e.g., [R.A. Cole, G. Papadopoulos, Class. Quant. Grav. 7 (1990) 427]). In particular, most general models of N=4 mechanics based on n “root” supermultiplets (4,4,0) possess the so called HKT (hyper-Kahler with torsion) geometry in 4n dimensional bosonic sector and are described in terms of the appropriate unconstrained potentials, so actually giving rise to the possibility of explicit constructions of new metrics of this type and consideration of new versions of N=4 supersymmetric quantum merchanics on HKT manifolds (and their important HK particular case) [F. Delduc, E. Ivanov, Nucl. Phys. B855 (2012) 815; E. Ivanov, S. Fedoruk, A. Smilga, J. Math. Phys. 59 (2018) 083501]. Generalizing the models just mentioned to the case of N=8 supersymmetry requires considering the relevant root multiplets (8,8,0) and unusual 8n dimensional bosonic geometries [G.W. Gibbons, G. Papadopoulos, K.S. Stelle, Nucl.Phys. B508 (1997) 623] (a number of steps toward constructing and studying the particular models were undertaken in works of the participants, e.g., in [E. Ivanov, O. Lechtenfeld, A. Sutulin, Nucl. Phys. B790 (2008) 493; S. Fedoruk, E. Ivanov, Nucl. Phys. B938 (2019) 714]). The issues of possible integrability of such geometrical models and of their relationships (via various compctifications) with supersymmetric gauge theories in higher-dimension (e.g., with 8-dimensional supersymmetric gauge theories) and, finally, with string theories were not properly investigated to date, so they certainly deserve a careful attention. The deformed versions of N=8 mechanics based on semi-simple supergroups like SU(2|2) and SU(4|1) ([E. Ivanov, O. Lechtenfeld, S. Sidorov, JHEP 1808 (2018) 193, JHEP 1808 (2015) 193 ], are closely related with matrix models ([D. Berenstein, J. Maldacena, H. Nastase, JHEP 0204 (2002) 013]), and, hence, with the integrable systems of the Calogero-Moser type. For classifying diverse variants of N=8 mechanics (both standard nd deformed), as well as for constructing their invariant superfield actions it is highly desirable to generalize to this case the methods of the superfild gauging of isometries by non-propagating gauge supermultiplets which revealed its efficiency in N=4 case [F. Delduc, E. Ivanov, Nucl. Phys. B753 (2006) 211]. This circle of problems encompasses as well the new type of supersymmetric mechanics, possessing local worldline N=4 and N=8 supersymmetries and having, as their bosonic target manifolds, the quaternion-Kahler (QK) 4n dimensional spaces, as well as some their consistent reductions and further generalizations like quaternion-Kahler manifolds with torsion (QKT) [E.Ivanov, L.Mezincescu, JHEP 1712 (2017) 016]. This new class of 1D theories as a generalization of the stnadrad N=4 and N=8 mechanics with flat supersymmetry admits application of the whole arsenal of mthods worked out for standard models, including the gauging of the relevant isometries and consideration of various deformations of local 1D supersymmetries (that implies the use of non-equivalent and non-minimal N=4 и N=8 1D “supergravities”), as well as an extension to other off-shell N=4, 1D multiplets.

N=4, 1D supersymmetry, as its special feature, involves two different classes of supermultiplets that are "mirror" to each other [E. Ivanov, J. Niederle, Phys. Rev. D 80 (2009) 065027]. They are equivalent and differ only in the mutual replacement of two independent SU(2) of the full automorphism group SO(4) ~ SU(2) x SU(2). On the other hand, multiplets and their mirror counterparts cease to be equivalent after deformation to SU(2|1), 1D supersymmetry [E. Ivanov, S. Sidorov, Class. Quant. Grav. 33 (2016) 055001]. It also turned out to be an important property that some mirror multiplets are described by chiral superfields and, as a result, they can interact with the chiral multiplet (2,4,2) in chiral superspace [S. Sidorov, J. Phys. A 54 (2021) 035205].

An impressive example of specific features of one-dimensional supersymmetry is the existence of

(2.4.2) and (3.4.1) nonlinear supermultiplets found two decades ago in [E. Ivanov, O. Lechtenfeld,

JHEP 0309 (2003) 073; E. Ivanov, S. Krivonos, O. Lechtenfeld, Class. Quant. Grav. 21 (2004) 1031].

They made possible to essentially enlarge the class of N=4 supersymmetric mechanical systems. In

particular, oon their basis there were constructed N= 4 supersymmetric extensions of the Landau problem [S. Bellucci, A. Beylin, S. Krivonos, A. Nersessian, E Orazi Phys. Lett. B **616** (3-4), 228].

Moreover, it was found that N= 4 supersymmetric mechanics constructed by the use of a nonlinear

chiral multiplet can be generalized to a very wide class of two-dimensional systems parameterized by

an arbitrary holomorphic function [S. Bellucci, A. Nersessian, Phys. Rev. D **73** (10), 107701]. In the

study of systems induced by nonlinear supermultiplets there remained a wide range of unexplored

problems. We plan to attack them during 2024-2028.

Recently we initiated the study of integrable system with Kahler phase space given by noncompact

analog of complex projective space [E.Khastyan, A.Nersessian, H.Shmavonyan *,*Int. J.Mod. Phys. A

**36** (2021) 08n09 2150055], as well as their supersymmetric extensions whose phase spaces are non-

compact analogs of complex projective superspace [E.Khastyan, S.Krivonos, A.Nersessian, Phys.Rev.

D **105** (2022) 025007]. In 2024-2028 we plan to continue these studies by considering the integrable

systems with other Kahler phase spaces, and to construct their supersymmetric extensions.

The main attention will be paid to phase spaces given by complex projective spaces,

Grassmannians,and SU(N) flag manifolds, as well as by their non-compact analogs.

In particular, we plan to construct, generalizations of (compactified) Ruijsenaars-Schneider

model including its integrable spin extensions. For the systems with phase spaces given

by non-compact analogs of of Grassmannians and SU(N) flag manifolds, we expect to establish

their connection with the known integrable systems on cotangent bundles. An essential part of the

project will be devoted to the construction of the (deformed) 2k-supersymmetric extensions of the

constructed systems. For this purpose, we plan to construct and study, by the use of the Hamiltonian

reduction method, the appropriate Kahler supermanifolds with 2k fermionic degrees of freedom,

which generalize complex projective spaces, Grassmannians, and related flag manifolds. These

supermanifolds will play the role of phase superspaces of the corresponding supersymmetric systems.

Special attention will be paid to the study of 2k-superconformal systems. These systems will be

defined on non-compact super-analogs of complex projective spaces and Grassmannians constructed

by the use of the Hamiltonian reduction method, in the spirit of ref.

[O.M.Khudaverdian,A.P.Nersessian, J. Math. Phys. **34** (1993) 5533]. We expect to find, in this way,

the general construction for the deformed 2k-supersymmetric extensions of the systems with Kahler

phase space, and thus, extend preliminary results obtained two decades ago [S.Bellucci, A.Nersessian,

Phys. Rev. D **64** (2001) 021702 ].

Currently, there remains a number of unresolved problems in superconformal field theories in different dimensions. On the other hand, in recent years, in the works [V. P. Spiridonov, Adv. Math. 331 (2018), 830—873; G. A. Sarkissian and V.P.Spiridonov,vProc. Steklov Inst. Math 309 (2020), 251—270; G. Sarkissian and V. P. Spiridonov, JHEP 1810 (2018), 097; E.Apresyan, G.Sarkissian and V.P.Spiridonov, arXiv:2205.10276], a significant progress has been made in understanding the properties of rarefied elliptic and hyperbolic functions that could allow to solve these problems.A natural continuation of these studies is two cycles of problems planned for the next five years. The first circle of problems concerns the calculation of the superconformal index in four-dimensional superconformal theories [C.Romelsberger, arXiv:0707.3702] on products of special lens spaces with a circle. The secobd cycle is related to exploring several aspects of N=1 superconformal two-dimensional Liouville theory [G.W.Moore and N.Seiberg, Commun. Math. Phys. 123 (1989), 177; L.Hadasz, JHEP 12 (2007), 071].

One of the most interesting modern directions of research is related with study of possible extentions of General Relativity. This direction attracts a lot of attention related with recent rapid development of gravitational-wave astronomy [LIGO Scientific Collaboration and Virgo Collaboration, Phys. Rev. Lett. 116 (2019) 241103]. New instruments allow to obtain a lot of new results in physics of neutron stars and black holes. It also open a lot of opportunities to study very massive compact objects. The numerical modelling of collisions of neutron stars and massive black holes makes possibly a direct confronting the OTO predictions with various experimental data.

Black holes, boson stars and other cosmological objects are at the focus of research activity of many

groups. One of the most interesting directions here is related with study of relations between self-gravitating soliton-like field configurations and so-called „hairy“ black holes [M.S. Volkov and D.V. Galtsov, JETP Lett. 50 (1989) 346]. It is well known that the vacuum solutions of the Einstein equations in asymptotically flat 3+1dimensional spacetime admit family of solutions with an event horizon, it includes the Schwarzshild solution, the Reissner-Nordstem solution and the stationary Kerr solution. On the other hand, the very concept of black holes naturally arises in supersymmetric theories and models of supergravity [E. Witten, Adv. Theor. Math. Phys. 2 (1998) 253; J.M. Maldacena, Adv. Theor. Math. Phys. 2 (1998) 231]. Study of the self-gravitating non-Abelian matter fields reveals very interesting results, as for example, existence of non-trivial static solutions with matter fields localized on the event horizon [M.S. Volkov and D.V. Galtsov, Phys Rept. 319 (1999) 1]. Solutions of that type were obtained also in the Einstein-Skyrme theory [H. Luckock and I. Moss, Phys. Lett. B 176 (1986) 341], they can be thought of as a bound state of the Skyrmion and a small Schwarzshild black holelocated in the core of the configuration [P. Bizon, Phys.Rev.Lett. 64 (1990) 2844]. Hairy black holes with non-Abelian fields can be considered as a limiting case of the Bartnik-McKinnon solutions [R. Bartnik and J. McKinnon, Phys. Rev. Lett. 61 (1988) 141]. Recently, it was shown that these spherically symmetric solutions can be generalized to the case of stationary rotating Kerr-Newman hairy black holes [B. Kleihaus and J. Kunz, Phys. Rev. Lett. 86 (2001) 3704].

In 2014 a new type of spinning solutions has been founded, it represents spinning hairy black holes continiously linked to the Kerr solution [C Herdeiro and E. Radu, Phys. Rev. Lett. 112 (2014) 221101)]. Such solutions can be considered as a cloud of scalar particles localized in the ergosphere of the black hole. Here the angular velocity of rotation of the event horizon must be synchronized with the internal frequency of the complex scalar field, then there is not fluy of the matter field through the event horizon and the configuration remains stable [C. L. Benone, L. C. B. Crispino, C. Herdeiro and E. Radu, Phys. Rev. D 90 (2014) 10, 104024]. Another generalization of this system represents electrically charged scalar field synchronized with the Kerr-Newman black hole [C. Herdeiro, I. Perapechka, E. Radu and Y. Shnir, JHEP 1902 (2019) 111]. It was also shown that self-interaction of the scalar fields allows for existence of non-linear clouds in the space-time with Kerr geometry. It was shown in 2020 that another type of charged non-linear scalar clouds may exist in the vicinity of the spherically symmetric Reissner-Nordstem black hole [J. P. Hong, M. Suzuki and M. Yamada, Phys. Rev. Lett. 125 (2020) 111104]. Multicomponent systems of boson stars in the Einstein-Klein-Gordon theory have been constructed in 2021 [C.Herdeiro, J.Kunz, I.Perapechka, E.Radu, Ya.Shnir, Phys. Lett. B812 (2021) 136027].

**During performing the project it is planned to obtain the following results:**

- Constructing the one-loop induced effective action in the theory of hypermultiplet interacting with N=2 supergravity in the harmonic superspace approach, working out the superfield proper time method and finding out the divergences in terms of N=2 super geometrical invariants.

- Development of the methods of calculation of the one-loop induced effective action in the theory of hypermultiplet coupled to external fields of N=2 harmonic gauge superfields of the bosonic higher spins and calculating the divergent contributions to the effective action in terms of invariants composed out of the higher-spin superfields.

- Derivation of 4D, N=2 harmonic superfield formulation for N=2 supersymmetric gauge fermionic higher spin fields. Construction of the free action and defining the relevant gauge transformations. Constructing the cubic vertices of the interaction of such superfields with hypermultiplet.

- Working out 4D, N=2 superfield gauge theory of higher spin fields in the AdS space, defining the corresponding gauge superfields, deriving their free action and the algebra of their gauge transformations.

- Finding out superfield harmonic Lagrangians of sigma models obtained by T-duality from 2D, N=(4,4) supersymmetric hyperkahler and quaternion-kahler sigma models, analysis of classical and quantum target geometries of such new models and generalizing them to non-abelian T-duality.

- Calculating all leading and subleading in the dimensional regularization parameter two-loop counterterms in 6D, N=(1,0) and N=(1,1) supersymmetric gauge theories in the framework of the harmonic background superfield method.

- Development of effective methods for describing gauge fields and superfields of infinite spin in an an arbitrary space-time dimension. Using the twistor approach and BRST methods to find Lagrangians describing free infinite spin (super)fields.

- Finding the Lagrangians describing the interactions of infinite spin fields and higher spin fields with fields of fixed spin. Calculation by the background field method of quantum loop corrections obtained from these interactions. Application of the approach found in the supercase.

- Building the superfield matrix formulation of new N=4 and N=8 supersymmetric extensions of integrable many-particle systems and their quantization. Construction of supersymmetric matrix systems with extended deformed supersymmetry and matrix systems of superconformal mechanics in harmonic N=4, 1D superspace. Finding applications of such systems in cosmological models, in black hole physics and nuclear physics.

- Construction of new models of N-extended supersymmetric quantum mechanics by using the superfield gauging method, which describe the interaction of dynamic and semidynamic multiplets of various types, including mirror multiplets. Finding quantum generators of symmetry and quantum spectrum in the constructed supersymmetric models.

- Construction and study of N=4 models of supersymmetric mechanics based on the interaction of linear and nonlinear supermultiplets with the component content (4,4,0), (3,4,1) and (2,4,2). Generalizing the models for mirror multiplets to SU(2|1) supersymmetric mechanics. Quantization and analysis of the structure of wave functions in the framework of the SU(2|1) representation theory.

- Constructing the Hamiltonian formulation and performing quantization of the generalizations of systems with the nonlinear (2.4.2) supermultiplet.

- Constructing an extension of N= 4 supersymmetric mechanics with (3.4.1) supermultiplet to the class of systems parametrized by an arbitrary holomorphic function, similar to the generalization of systems with the multiplet (2.4.2).

- Construction and study of many-particle systems with nonlinear supermultiplets, as well as their further generalization.

- Construction of a superfield description of Calogero-type models with extended N≥4 supersymmetries in the framework of the matrix approach.

- Analysis of the integrability of N-extended supersymmetric systems of the Euler–Calogero–Moser and Calogero–Moser–Sutherland types for the A(n-1) series of the Coxeter group by constructing the Lax representation, as well as the generalization of all models from the A(n−1) series to other Coxeter groups.

- Finding an explicit form of the functionally independent conserved Liouville currents, as well as an additional set of conserved currents, in N=2 supersymmetric Calogero models for all root systems of Coxeter groups.

- Two new exactly calculated rarefied elliptic beta integrals associated with special lens spaces and a special subgroup of modular transformations group SL(2,Z) will be constructed. We plan to prove that the superconformal index of the chiral multiplet in N=1 superconformal theory over products of special lens spaces with a circle coincides with a new generalized rarefied elliptic gamma function.

- We plan to compute a matrix of modular transformations of one-point conformal blocks on a torus in the Neveu-Schwarz sector of N=1 superconformal Liouville field theory, based on the expression of this matrix as an integral of the product of certain elements of the fusion matrix.

- We also plan to obtain the difference equations for the fusion matrix in the Neveu-Schwarz sector of N=1 superconformal Liouville field theory [8] and show their connection with the corresponding difference equations for the rarefied hyperbolic hypergeometric functions.

- Fiinding a new class of solutions of GR with gauge multicomponent matter fields in models with spontaneous symmetry breaking, which correspond to stationary rotating multicomponent ultracompact self-gravitating boson stars with several long-range fields, and to the new types of hairy black holes with a cloud of charged scalar fields located in ergosphere of the black hole. Studying a new class of solutions with the event horizon and magnetic field generated by stationary supercurrents on the black-hole horizon.

- Constructing and exploring a new class of solutions of extenged Einstein gravity with Chern-Simons term, which represents stationary rotating black holes dynamically connected to the scalar matter fields via gravitational topological term. The presence of the gravitational Chern-Simons term should manifest itself in various PT-symmetry violation effects, related with deformation of the geometry of the horizon and localizing potentials.

Setting the problems and all expected results are new and surpass the world level. The planned results are on the level of all leading world scientific groups in the area of the quantum field theory, gauge theories, supersymmetry and integrable system theory. The results will be published in International journals and reported on the seminars and International Conferences.

The project participants are proficient in all the methods necessary to solve these problems and are actively involved in modern research. In particular, the project manager E. Ivanov is one of the creators of the harmonic superspace method, which will be widely used in the project. The project participant I. Buchbinder was one of the pioneers of employing this method for studying the quantum structure of gauge theories with extended supersymmetry.

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**2.3 Estimated completion date 2024 - 2028**

**2.4 Participating JINR laboratories BLTP**

**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** |
| UWA | Australia | Perth | Kuzenko S.  Buchbinder E. | Visits exchange  Collaborations |
| Yerevan Physics Institute | Armenia | Yerevan | Hakobian Т.  Манвелян Р.  Mkrttchyan R.  Demirchian H.  Khastyan E.  Avetisyan M. | Visits exchange  Collaborations |
| INRNE BAS | Bulgaria | Sofia | Dobrev V.  Iliev B.  Todorov I.T. | Visits exchange |
| UFES | Brazil | Juiz de Fora | Shapiro I.  Deriglazov A. | Collaborations |
| University | Brazil | Sao Paulo | Ferreyra L. | Collaborations |
| University | UK | Glasgow | Feigin M. | Collaborations |
| Imperial College | UK | London | Stelle К.  Tseytlin А. | Visits exchange |
| University | Germany | Hanover | Lechtenfeld O.  Dragon N. | Collaborations |
| IPO | Germany | Oldenburg | Grunau S.  Kleihaus B.  Kunz J.  Azad B. | Collaborations |
| University | Greece | Athens | Zoupanos G. | Collaborations |
| IPM | Iran | Tehran | Sabejan S.  Sheikh-Jabbari M. | Agreement |
| School of theoretical physics | Ireland | Dublin | Tchrakian D. | Visits exchange |
| UPV/EHU | Spain | Bilbao | Bandos I. | Visits exchange Collaborations |
| University | Italy | Padova | Basseto A.  Sorokin D. | Agreement |
| SISSA/ISAS | Italy | Trieste | Bonora L. | Agreement |
| University | Poland | Wroclaw | Popowicz Z.  Borowiec A.  Lukierski J.  Frydryszak A. | Visits exchange Collaborations |
| University of Aveiro | Portugal | Aveiro | Radu E.  Herdeiro C. | Visits exchange Collaborations |
| ITEP | Russian Federation | Moscow | Morozov A.  Mironov A.  Rosly A.  Olshanetsky M. | Visits exchange |
| MSU | Russian Federation | Moscow | Galtsov D.  Sveshnikov K.  Talalaev D.  Shafarevich А.  Stepanyantz К. | Visits exchange Collaborations |
| MIRAS | Russian Federation | Moscow | Arefeva I.  Orlov D.  Slavnov N.  Volovich I.  Katanaev M. | Visits exchange |
| Lebedev Physical Institute | Russian Federation | Moscow | Barvinsky А.  Vasiliev М.  Metsaev R. | Visits exchange |
| MIPT | Р Russian Federation Ф | Долгопрудный | Musaev E.  Bondal А. | Collaborations |
| IHEP | Russian Federation | Protvino | Zinoviev Yu. | Collaborations |
| St. Petersburg Department of Steklov Mathematical Institute | Russian Federation | St. Petersburg | Derkachev S. | Collaborations |
| Sobolev Mathematical Institute | Russian Federation | Novosibirsk | Mironov А. | Visits exchange |
| Tomsk Polytechnic University | Russian Federation | Tomsk | Galajinsky А. | Collaborations |
| Tomsk State Pedagogical University | Russian Federation | Tomsk | Lavrov P.  Krykhtin V.  Snegirev Т.  Merzlikin B.  Reshetnyak A. | Collaborations |
| Landau Institute for Theoretical Physics | Russian Federation | Chernogolovka | Belavin А.  Sokolov V.  Starobinsky А. | Visits exchange |
| University of Maryland | USA | College Park | Gates J.  Koutrolikos К. | Visits exchange |
| University of Miami | USA | Coral Gables | Mezincescu L. | Collaborations |
| University of Pennsylvania | USA | Philsdelphia | Ovrut B. | Collaborations |
| CUNY | USA | New York | Akulov V.  Korepin V.  Shuryak Е.  Catto S. | Visits exchange |
| Institute of theoretical physics | USA | New York | Zamolodchikov A. | Visits exchange |
| Technical University | Czech Republic | Prague | Burdik Ch. | Visits exchange Collaborations |
| LAPTH | France | Annecy-le-Vieux | Ragoucy E.  Sokatchev E. | Visits exchange Collaborations |
| CPT | France | Marseille | Кокоро Р.  Ogievetsky O. | Collaborations |
| University | France | Tours | Volkov M.S.  Garaud J. | Collaborations |
| SUBATECH | France | Nant | Smilga A. | Collaborations |
| CERN | Switzerland | Geneva | Alvarez-Gaume L.  Antoniadis I.  Ferrara S. | Agreement |
| Institute of Science and Technology | Japan | Okinawa | Tsulaia M. | Visits exchange Collaborations |
| Tokyo University  of Science | Japan | Tokyo | Sawado N.  Yuki A. | Visits exchange  Collaborations |

**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 | 8.5 |  |
| 2. | engineers |  |  |
| 3. | specialists |  |  |
| 4. | office workers |  |  |
| 5. | technicians |  |  |
|  | **Total:** | **8.5** |  |

**3.2. Available manpower**

**3.2.1. JINR staff**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No.** | **Category of personnel** | **Full name** | **Division** | **Position** | **Amount**  **of FTE** |
| 1. | research scientists | Ivanov E.A.  Fedoruk S.A.  Buchbinder I.L.  Nersessian A.P.  Shnir Ya.M.  Sidorov S.S.  Sutulin A.O.  Sarkissian G.A.  Zaigraev N.M. | BLTP  BLTP  BLTP  BLTP  BLTP  BLTP  BLTP  BLTP  BLTP | Head of Sector  Leading Scientist  Leading Scientist  Leading Scientist  Leading Scientist  Senior Scientist  Senior Scientist  Senior Scientist  Junior Scientist | 1  1  1  0.5  1  1  1  1  1 |
| 2. | engineers | 0 |  |  |  |
| 3. | specialists | 0 |  |  |  |
| 4. | technicians | 0 |  |  |  |
|  | **Total: 9** | **9** | **BLTP** |  | **8.5** |

**3.2.2. JINR associated personnel**

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Category of personnel** | **Partner organization** | **Amount of FTE** |
| 1. | research scientists | Nersessian A., Yerevan Physics Institute | 0.5 |
| 2. | engineers |  |  |
| 3. | specialists |  |  |
| 4. | technicians |  |  |
|  | **Total:** | **1** | **0.5** |

**4. Financing**

The project will be financed in the framework of the Theme ``Modern mathematical physics: integrability, gravity and supersymmetry’’

**4.1 Total estimated cost of the project/LRIP subproject**

The total cost estimate of the project (for the whole period, excluding salary).

The details are given in a separate table below.

**4.2 Extra funding sources**

Expected funding from partners/customers – a total estimate.

**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: \_\_\_\_\_\_\_\_\_ document number: \_\_\_\_\_\_\_\_\_

Year of the project (LRIP subproject) start: \_\_\_2024\_\_\_\_\_\_\_\_\_\_\_\_\_

(for extended projects) – Project start year: \_\_\_\_\_\_\_

**Proposed schedule and resource request for the Project / LRIP subproject**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **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 |  |  |  |  |  |  |
| Materials |  |  |  |  |  |  |
| Equipment, Third-party company services |  |  |  |  |  |  |
| Commissioning |  |  |  |  |  |  |
| R&D contracts with other research organizations |  |  |  |  |  |  |
| Software purchasing |  |  |  |  |  |  |
| Design/construction |  |  |  |  |  |  |
| Service costs (*planned in case of direct project affiliation)* |  |  |  |  |  |  |
| **Resources required** | **Standard hours** | Resources |  |  |  |  |  |  |
| * the amount of FTE, |  |  |  |  |  |  |
| * 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 |  |  |  |  |  |  |

Project (LRIP subproject) Leader\_\_\_\_\_\_\_\_\_/\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_/

Laboratory Economist \_\_\_\_\_\_\_\_\_/\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_/

**APPROVAL SHEET FOR PROJECT / LRIP SUBPROJECT**

TITLE OF THE PROJECT/LRIP SUBPROJECT

Supersymmetry, Higfher Spins, Gravity

SHORT DESIGNATION OF THE PROJECT / SUBPROJECT OF THE LRIP

PROJECT/LRIP SUBPROJECT CODE

THEME / LRIP CODE

NAME OF THE PROJECT/ LRIP SUBPROJECT LEADER Ivanov E.A.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  | |
| 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  THEME / LRIP LEADER | \_\_\_\_\_\_\_\_\_\_\_  SIGNATURE | \_\_\_\_\_\_\_\_\_  NAME | \_\_\_\_\_\_\_  DATE |  |
| PROJECT / LRIP SUBPROJECT LEADER | \_\_\_\_\_\_\_\_\_\_  SIGNATURE | \_\_\_\_\_\_\_\_\_  NAME | \_\_\_\_\_\_\_\_\_  DATE |  |
|  |  |  |  |  |
| APPROVED BY THE PAC | \_\_\_\_\_\_\_\_\_\_\_  SIGNATURE | \_\_\_\_\_\_\_\_\_  NAME | \_\_\_\_\_\_\_\_\_  DATE | |

**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**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Names of costs, resources, funding sources** | | | **Cost (thousands**  **of US dollars) / Resource request** | **Proposal from**  **the laboratory for allocation of funding and resources** | | | | |
| 1  year | 2  year | 3  year | 4  year | 5 year |
|  | | International cooperation |  |  |  |  |  |  |
| Materials |  |  |  |  |  |  |
| Equipment, Third-party company services |  |  |  |  |  |  |
| Commissioning |  |  |  |  |  |  |
| R&D contracts with other research organizations |  |  |  |  |  |  |
| Software purchasing |  |  |  |  |  |  |
| Design/construction |  |  |  |  |  |  |
| Service costs (*planned in case of direct project affiliation)* |  |  |  |  |  |  |
| **Resources required** | **Standard hours** | Resources |  |  |  |  |  |  |
| * the amount of FTE, |  |  |  |  |  |  |
| * 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\_ г.**