**APPROVED**

 **Director of Laboratory**

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**REPORT ON THEME**

**1. General information on the Theme**

**1.1. Theme code** **01-3-1136-2019**

**1.2. Laboratory** BLTP

**1.3. Scientific field Theoretical Physics**

**1.4. Title of the Theme Theory of Nuclear System**

**1.5. Theme Leader Antonenko N. V., Dzhioev A. A., Ershov S. N.**

**1.6. Projects in the Theme**

1. Microscopic models for exotic nuclei and nuclear astrophysics

Voronov V. V., Dzhioev A. A.

2. Low-energy nuclear dynamics and properties of nuclear systems

Ershov S. N., Antonenko N. V.

3. Quantum few-body systems

Motovilov A. K., Melezhik V. S.

4. Relativistic nuclear dynamics and nonlinear quantum processes

Bondarenko S. G.

**2. Scientific report on the Theme**

**2.1. Annotation**

In the framework of the theme "Theory of nuclear systems", topical problems of nuclear physics, nuclear astrophysics, few-body systems, and relativistic nuclear physics were solved. The properties and mechanism of formation of superheavy nuclei, mechanisms of nuclear reactions for obtaining certain isotopes and states of nuclei, nuclear processes under astrophysical conditions, exotic nuclear decays, the relationship between the distribution of nucleons in the nucleus and its states, properties of nuclei at high densities and temperatures, states of few-body systems, nonequilibrium processes in open quantum systems were studied. New theoretical methods are proposed to consider nuclear fission, sub-barrier processes, thermal effects in astrophysical reactions, scattering of light nuclei, atomic states. A comparative analysis of the scattering length of a vector meson on a proton was carried out, a theory of nonlinear quantum processes in strong electromagnetic fields was developed, and a new effective method of sympathetic ion cooling was proposed. Research within the theme was coordinated with work programs at experimental facilities using high-intensity beams of stable and/or radioactive nuclei at JINR and in the world. Studies of high-energy heavy ion collisions are related to the NICA project.

**2.2. A detailed scientific report**

It is shown that at core-collapse supernova conditions neutrinos exhibit exo- and endoenergetic scattering on hot nuclear mater. From the analysis energy transfer due to neutrino-nucleus scattering, it was demonstrated that the average energy transfer changes from positive to negative values when the neutrino energy is about four times the temperature. Similar features were found for neutrino scattering on magnetized nucleon gas.

Electron-capture rates were calculated for neutron-rich semi-magic *N*=50 nuclei (78Ni, 82Ge, 86Kr, 88Sr) at temperatures *T*=0 corresponding to the capture to the ground state and at *T* = 1010 K (0.86 MeV), which is a typical temperature at which the *N*=50 nuclei are abundant during a supernova collapse. It was shown that at astrophysical relevant temperatures, this Pauli blocking of the Gamow-Teller (GT+) strength is overcome by thermal excitations leading to a sizable GT contribution to the electron capture. Therefore, the neutron-rich *N*=50 nuclei do not serve as an obstacle of electron capture during a supernova collapse.

The quasiparticle random phase approximation and the cluster model were applied to explain the mystery of a drastic reduction, by two orders of magnitude, of the $B(E1;3\_{1}^{-}\rightarrow 2\_{1}^{+})$ strength along the Mo isotopic chain. Both models reproduce the trend and predict that this sharp drop is due to the interference effect between the neutron and proton contributions to the matrix element of the *E*1 transition.

The 1+ spectrum of 130In populated in the *β* decay of 130Cd was studied. The coupling between one- and two-phonon terms in the wave functions of 1+ states was taken into account within the microscopic model based on the Skyrme interaction. It was shown that the dominant contribution to the additional 1+ states comes from the [3+⊗2+] two-phonon configurations constructed from the charge-exchange 3+ phonons. A correlation was found between the low-lying *E*2 transition strengths of the parent 126,128,130In and daughter 126,128,130Cd isobaric companions.

The model was developed for the description of the dipole decay widths, in which the energy-dependent shift of the one-phonon states arising due to the coupling of the one-phonon states with complex configurations can be analytically estimated. The obtained results are in good agreement with those of the microscopic calculations for nuclei around 208Pb.

The self-consistent approach based on the quasiparticle random-phase approximation implemented with Skyrme interaction and taking into account coupling to complex configurations was generalized for describing the process of double γ-decay in an even-even nucleus. For the first time, the γγ-decay of the first quadrupole state of the doubly-magic nucleus 48Ca was studied which could proceed in competition with a single γ-decay. It was shown that the γγ-decay width is sensitive to the mixing of simple and complex configurations in the giant dipole resonance region. The obtained estimate of the γγ-decay probability, 3×10-8, can be tested experimentally.

The recent (α,α′) data on the Isoscalar Giant Monopole Resonance and Isoscalar Giant Quadrupole Resonance (ISGQR) in 92,94,96,98,100Mo were analyzed within a fully self-consistent Quasiparticle Random Phase Approximation approach (QRPA) with Skyrme interactions. It was found that in the ground state the inclusion of pairing correlations and axial deformations play important roles. Comparison between ISGMR and ISGQR distributions confirmed that even at modest deformations there is a deformation-induced coupling of the monopole and quadrupole modes.

The two-step scheme was suggested to search for vortical toroidal states in (*e,e’*) reaction. In the firststep, QRPA calculations are used to determine promising candidates for toroidal states. These states should have a distinctive toroidal distribution of the convective nuclear current and significant *B*(*M*2) and *B*(*E1*) values. In the second step, these states are checked to reproduce a pattern of experimental data for *E*1 and *M*2 transversal form factors in electron scattering to back angles. A description of the interference between spin and orbital currents indicates that a vortical toroidal flow in the chosen state actually takes place.

As shown, the structure of 96Zr indicates that the shape of this nucleus can change dramatically with increasing excitation energy. The structure of 96Zr based on the collective quadrupole Bohr Hamiltonian was studied. This approach allows one to describe all the peculiarities of the structure of 96Zr at low excitation energies. The nucleus 96Zr is spherical in the ground state with a 100% probability but becomes deformed if the excitation energy reaches 1.6 MeV. This result indicates the possibility of radical changes in the shape of the nucleus upon its excitation.

A microscopic interpretation of vortex-free nuclear dynamics is given within the proton-neutron symplectic model.

Based on the collective nuclear Hamiltonian and the microscopic approach to the description of the structure of low-lying states of nuclei, the relationship between excitation energy and the probability of the *E*2 transition to the first 2+ state was theoretically derived.

Using the improved scission-point model, the mass and charge distributions of fragments resulting from the fission of Cf isotopes were calculated and compared with the available experimental data. The change of the shape of mass and charge distributions with increasing excitation energy was predicted for future experiments. The coexistence of symmetric mass and asymmetric charge distributions of fission fragments was examined. The first predictions for superheavy elements were made.

The possibility of application of the dinuclear system model to the simultaneous description of α-decay, cluster radioactivity, and spontaneous fission was investigated. The half-lives of cluster decay and spontaneous fission for the nuclei 232,234,236U, 236,238Pu, 242Cm, and 248Cf were calculated within the same approach and compared with the existing experimental data. The cluster radioactivity in the 248Cf nucleus was predicted.

It was found that taking into account the non-diagonal matrix elements of the coupling matrix, traditionally neglected in the conventional coupled-channels approaches, allows one to explain the difficulties arising in various models in the interpretation of experimental data for the *S*-factor of the fusion reaction of two colliding heavy nuclei.

Based on the energy density functional theory, the nucleus 288Fl was predicted as the next double magic nucleus after 208Pb, and 304120 was identified as the most likely candidate for the next-to-next double magic nucleus.

The possibilities for production of yet unknown neutron-rich isotopes 261–265Md were explored in the multinucleon transfer reactions with stable beams bombarding Cf and Es targets. The production of a given isotope of neutron-rich Md was optimized by appropriate choices of projectile-target combinations and bombarding energies. The production cross sections of neutron-rich Md isotopes in the 0*n-* and 1*n-*evaporation channels of multinucleon transfer reactions were compared. Prospects for the use of radioactive beams in the production of new Md isotopes were discussed.

The production cross sections of the heaviest isotopes of superheavy nuclei with charge numbers 112–118 were predicted in the *xn*–, *pxn*–, and *αxn*–evaporation channels of the 48Ca-induced complete fusion reactions for future experiments. A way was shown to produce currently unknown superheavy isotopes in the 1*n*– or 2*n*–evaporation channels.

For future experiments, the production cross sections of superheavy nuclei with charge numbers 114–117 were predicted in the (5–9)*n* evaporation channels of the 48Ca-induced complete fusion reactions. The structure and the *α-*decay spectra of superheavy nuclei have been studied.

Partial cross-sections of the *nα* and *dt* collisions in the quantum state *Jπ* = 3/2+ near the *dt*-threshold, taken from the available *R*-matrix analysis, were fitted using the semianalytic multi-channel Jost matrix with a proper analytic structure and some adjustable parameters. As a result of such an analytic continuation, the previously established 3/2+ resonance (at 47 keV) and its shadow pole (at 80 keV) were both split in overlapping pairs. Apart from studying the properties of a specific nuclear state, it was also proved for a general multi-channel problem that the Coulomb forces change the topology of the Riemann surface as well as destroy the so-called mirror symmetry of the *S*-matrix.

A family of analytically solvable potential models for the one- and two-channel problems was considered within the Jost matrix approach. The migration of the *S*-matrix poles on the Riemann surface of the energy caused by variations of the potential strength was studied. It was demonstrated that the long-range (~1/*r*2) tails and Coulomb potential (1/*r*) cause unusual behavior of the *S*-matrix poles. The Coulomb tail not only changes the topology of the Riemann surface but also breaks down the so-called mirror symmetry of the poles in both the single-channel and two-channel problems.

For the fermionic or bosonic oscillator fully coupled to several heat baths with mixed statistics, the analytical expressions for the occupation numbers were derived within the non-Markovian quantum Langevin approach. The role of statistics of the system and heat baths in the dynamics of the system was studied. The full coupling of a quantum system to a heat bath usually induces its evolution towards asymptotic equilibrium. It was shown that such equilibrium might never be reached when the system is coupled simultaneously to bosonic and fermionic heat baths unless different thermal reservoirs are related with each other. The conditions under which asymptotic equilibrium can be reached were discussed.

Confinement-induced resonances (CIRs) in atom-ion quantum mixtures in hybrid traps were studied for small atom-ion mass ratios. Specifically, we considered an ion confined in a time-dependent radio-frequency Paul trap with linear geometry, while the atom is constrained to move into a quasi-one-dimensional optical waveguide within the ion trap. We evaluated the impact of the ion intrinsic micromotion on the resonance position. We found that the energy of ion provided by the oscillating radio-frequency fields can affect the resonance position substantially. Notwithstanding, the peculiar phenomenology of those resonances regarding perfect transmission and reflection is still observable. These findings indicate that the intrinsic micromotion of the ion is not detrimental for the occurrence of a resonance and that its position can be controlled by the radio-frequency fields. This provides an additional means for tuning atom-ion interactions in low spatial dimensions.

A new efficient method was proposed for sympathetic cooling of ions: the use for this purpose of cold buffer atoms in the region of atom-ion CIRs. It was shown that the destructive effect of ion micromotion on its sympathetic cooling can be suppressed in the vicinity of the atom-ion CIR. The effect of sympathetic cooling around CIRs in atom-ion and atom-atom confined collisions was investigated within the quantum-quasiclassical approach using the Li-Yb+ and Li-Yb confined systems as an example. The region was found near the atom-ion CIR where the sympathetic cooling of the ion by cold atoms is possible in a hybrid atom-ion trap. It was shown that one can improve the efficiency of sympathetic cooling in atomic traps by using atomic CIRs.

Among various understandings of the term “resonance” in quantum mechanics, the two most common interpretations are as follows. (1) Resonance is a complex energy value producing a pole to the scattering matrix analytically continued to the so-called unphysical energy sheet(s). (2) Resonance is a complex eigenvalue of the complexly deformed Hamiltonian under consideration. In the case of the Friedrichs-Faddeev model, it is proven that the resonances understood in the senses (1) and (2) are equivalent. Notice that the Friedrichs-Faddeev model is quite universal. Various concrete quantum-mechanical Hamiltonians, in particular, the two-particle ones with short-range interactions, admit a reduction just to the Friedrichs-Faddeev model.

For the first time, analytical formulas were obtained for calculating amplitudes of the population of atomic levels as a result of interactions of the atom with the EM field of the laser. The interaction potential of the atom with the field is recorded in the dipole approximation. The mathematical apparatus of the model was based on complex scaling of the Stark Hamiltonian and on a number of mathematical theorems that accompany such a description. For the first time, a series was proposed that describes well the amplitude of the probability of populating the atomic level.

The two-dimensional movement of a slow quantum particle was studied in the field of a central long-range potential decreasing as a power function *r-β* with the exponent $β\in (1,2)$ and *β*>2. For this particle, low-energy asymptotics of the scattering phase shifts and differential cross section were found. A simple approximation for the energies of weakly-bound states was established.

It is shown that the binding of two heavy fermions interacting with a light particle through contact interaction is possible only with a sufficiently large mass ratio of heavy and light particles.

A non-direct product discrete variable representation (npDVR) was developed for treating quantum dynamical problems which involve non-separable angular variables. The npDVR basis was constructed on spherical functions orthogonalized on the grids of the Lebedev or Popov 2D quadratures for the unit sphere instead of the direct product of 1D quadratures. The use of the npDVR based on the Lebedev or Popov 2D quadratures substantially accelerates the convergence of the computational scheme.

In the framework of the kinetic models of the Monte Carlo type Quark-Gluon-String-Model (QGSM) and Partons-Hadrons-String-Dynamics (PHSD), the transverse and global polarization of Λ hyperons in interactions of heavy ions in the energy range of the NICA collider was studied. The analysis of the spatial structure of the transverse and diagonal vorticity components relative to the reaction plane was carried out, and the spatial separation of hydrodynamic helicity was revealed. The results of theoretical calculations show satisfactory agreement with the experimental results of the STAR collaboration. In the MPD experiment performed using Monte Carlo simulations, the transverse polarization Λ of hyperons was studied to analyze the detector's sensitivity to this observable.

The structure in the K+/π+ ratio was studied, which appears in the heavy ion collisions (Au+Au and Pb+Pb) at energies √sNN ∼ 7-10 GeV. The Polyakov loop extended Nambu-Jona-Lasinio model was used as it describes both chiral phase transition and deconfinement. It was shown that the splitting of multiplet mass in dense matter is responsible for the difference in the behavior of the *K+/π+* and *K-/π-* ratios; the “peak” structure was interpreted as a sequence of the chiral symmetry restoration and subsequent deconfinement effect; the “horn” is more sensitive to the curvature of the phase diagram at high *μB* than the order of the chiral phase transition; the peak depends on the strangeness neutrality or chemical baryon potential of a strange quark.

The combined approach based on solution of the Dyson-Schwinger equations for quark propagators and the Bethe-Salpeter equation for bound states was employed at non-zero temperature. A competition of bound states and quasi-free two-quark states was found at *T≈*100 MeV.

The Bethe-Salpeter-Faddeev formalism was generalized to the case of a nonzero orbital moment of particles in a nucleon pair. The binding energy of the triton and the amplitudes for the states 1S0, 3S1, 3D1, 3P0, 1P1, and 3P1 were calculated. The contribution of the relativistic P and D states to the binding energy of the triton were estimated.

The masses of the ground and excited states of pseudo-scalar glueballs were calculated based on the rainbow approximation to the Dyson-Schwinger and Bethe-Salpeter equations with effective parameters adjusted to lattice QCD data. The structure of the truncated Bethe-Salpeter equation with the gluon and ghost propagators as solutions of the truncated Dyson-Schwinger equations was analyzed in the Landau gauge. Both the Bethe-Salpeter and Dyson-Schwinger equations were solved numerically within the same rainbow-ladder truncation with the same effective parameters which ensure the consistency of the approach. With a set of parameters that provides a good description of the lattice data within the Dyson-Schwinger approach, solutions of the Bethe-Salpeter equation for pseudo-scalar glueballs exhibit a rich mass spectrum that also includes the ground and excited states predicted by lattice calculations.

It was found that in the case of momentum being an independent variable in the Hamiltonian, the Lorentz transformations of the thermodynamic quantities belong to the Planck formalism. However, if velocity is supposed to be the independent variable in the Hamiltonian (though it is not correct from the point of view of the relativistic dynamics), the Lorentz transformations of the thermodynamic quantities belong to the Ott formalism. This demonstrates that the Ott formalism cannot be appropriate. Moreover, it was proven that in the Planck description the first law of thermodynamics was covariant and the Legendre transform of the Lagrangian was preserved. Thus, it was demonstrated that only the Planck formulation of relativistic thermodynamics of a moving body is properly defined and the Ott formalism should be discarded.

A theoretical analysis of elastic scattering and momentum distributions of clusters in breakup reactions of exotic halo-nuclei 8Be, 8,12,14Be was performed. The decisive role of periphery of these nuclei was revealed to describe their scattering and breakup into clusters. It was found that the parameters of the pion-nucleon amplitude differ essentially from those for the pion scattering on free nucleons (“in-medium effect”).

The electromagnetic form factors of three-nucleon systems in the static approximation were calculated for various models of the electromagnetic nucleon form factors at the momentum transfer squared up to 10 GeV2. The calculation of the relativistic corrections to the form factors of three nucleon nuclei associated with Lorentz transformations was also performed.

It was found that in terms of the scaled variables the quark-hadron duality of the lattice QCD and the hadron resonance gas (HRG) model disappears. However, the scaled variables lead to the quark-hadron duality of the lattice QCD and the quantum ideal gas of kaons and antikaons, namely, the ideal gas of those hadrons that contain all the three quarks u, d, s and their antiquarks. Despite the fact that there is no phase transition in an ideal kaon gas, in the present calculations the scaled thermodynamic quantities of the ideal gas and the lattice QCD follow the same qualitative behavior and are consistent with each other.

The hard proton knock-out by the proton from the deuteron at relativistic energies is considered with a focus on the color transparency (CT) effect which influences the initial- and final-state interactions. A well-known behavior of the transparency is mainly preserved up to plab ~ 50 GeV/c, but changes significantly at higher beam momenta due to the interference of valence quark configurations of small and large sizes. As a result, the transparency at small pst exhibits oscillations as a function of the beam momentum (the nuclear filtering effect). The tensor analyzing power due to the longitudinal polarization of the deuteron is calculated. The event rate at NICA is estimated.

The effect of temperature on the bound states of quark-antiquark pairs was studied. The presence of a phase transition was shown. For the first time, a comparative analysis of the scattering length of vector meson (ω, φ, J/ψ) – proton interactions was performed. A non-trivial exponentially strong dependence of the scattering length on the quark content of interacting hadrons was found.

The theory of nonlinear quantum processes in strong electromagnetic fields was developed. For the first time, this method was used to predict the production probabilities of hard Compton photons and electron-positron pairs in interaction of ultra-relativistic electrons with intense laser pulses in a wide range of electron energies and laser beam intensities at the largest European laser project (XFEL, DESY), which is under construction.

2.2.1. List of bibliographic references

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The results of the work are presented in 102 reports at various scientific events.

4 habilitation and 3 PhD dissertations have been defended.

Lectures were given at the University of Dubna, UC JINR, and Tomsk Polytechnic University.

3 JINR awards were granted for the best scientific works.

1 patent was obtained (R.G.Nazmitdinov et al. "Solar thermal collector for heat removal from solar photovoltaic panel" RU 210191).

**3. International scientific and technical cooperation**

The countries, institutions and organizations actually involved.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Country or International Organization** | **City** | **Institute or****laboratory** |  |  |  |  |  |
| Armenia | Yerevan | RAU |  |  |  |  |  |
|   |   | YSU |  |  |  |  |  |
| Belarus | Gomel | GSU |  |  |  |  |  |
|   | Minsk | IP NASB |  |  |  |  |  |
| Belgium | Brussels | ULB |  |  |  |  |  |
|   | Louvain-la-Neuve | UCL |  |  |  |  |  |
| Brazil | Florianopolis, SC | UFSC |  |  |  |  |  |
|   | Niteroi, RJ | UFF |  |  |  |  |  |
|   | Sao Jose dos Campos, SP | ITA |  |  |  |  |  |
|   | Sao Paulo, SP | UEP |  |  |  |  |  |
| Bulgaria | Sofia | INRNE BAS |  |  |  |  |  |
|   |   | NBU |  |  |  |  |  |
| China | Beijing | CIAE |  |  |  |  |  |
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|   | Lanzhou | IMP CAS |  |  |  |  |  |
| Czech Republic | Prague | CU |  |  |  |  |  |
| Egypt | Giza | CU |  |  |  |  |  |
| France | Caen | GANIL |  |  |  |  |  |
|   | Orsay | IJCLab |  |  |  |  |  |
| Germany | Berlin | HZB |  |  |  |  |  |
|   | Bielefeld | Univ. |  |  |  |  |  |
|   | Bonn | UniBonn |  |  |  |  |  |
|   | Cologne | Univ. |  |  |  |  |  |
|   | Darmstadt | GSI |  |  |  |  |  |
|   |   | TU Darmstadt |  |  |  |  |  |
|   | Dresden | HZDR |  |  |  |  |  |
|   |   | TU Dresden |  |  |  |  |  |
|   | Erlangen | FAU |  |  |  |  |  |
|   | Frankfurt/Main | Univ. |  |  |  |  |  |
|   | Giessen | JLU |  |  |  |  |  |
|   | Hamburg | Univ. |  |  |  |  |  |
|   | Leipzig | UoC |  |  |  |  |  |
|   | Mainz | JGU |  |  |  |  |  |
|   | Rostock | Univ. |  |  |  |  |  |
|   | Siegen | Univ. |  |  |  |  |  |
| Greece | Athens | INP NCSR "Demokritos" |  |  |  |  |  |
| Hungary | Budapest | Wigner RCP |  |  |  |  |  |
|   | Debrecen | Atomki |  |  |  |  |  |
| India | Chandigarh | PU |  |  |  |  |  |
|   | Kasaragod | CUK |  |  |  |  |  |
|   | New Delhi | IUAC |  |  |  |  |  |
| Iran | Zanjan | IASBS |  |  |  |  |  |
| Italy | Catania | INFN LNS |  |  |  |  |  |
|   | Messina | UniMe |  |  |  |  |  |
|   | Naples | INFN |  |  |  |  |  |
|   | Turin | UniTo |  |  |  |  |  |
| Japan | Kobe | Kobe Univ. |  |  |  |  |  |
|   | Morioka | Iwate Univ. |  |  |  |  |  |
|   | Osaka | Osaka Univ. |  |  |  |  |  |
|   |   | RCNP |  |  |  |  |  |
| Kazakhstan | Almaty | INP |  |  |  |  |  |
|   |   | KazNU |  |  |  |  |  |
| Lithuania | Kaunas | VMU |  |  |  |  |  |
| Mexico | Mexico City | UNAM |  |  |  |  |  |
| Moldova | Chisinau | IAP |  |  |  |  |  |
| Norway | Bergen | UiB |  |  |  |  |  |
|   | Oslo | UiO |  |  |  |  |  |
| Poland | Krakow | INP PAS |  |  |  |  |  |
|   | Lublin | UMCS |  |  |  |  |  |
|   | Otwock (Swierk) | NCBJ |  |  |  |  |  |
|   | Warsaw | UW |  |  |  |  |  |
| Republic of Korea | Daegu | KNU |  |  |  |  |  |
|   | Daejeon | IBS |  |  |  |  |  |
|   | Jeonju | JBNU |  |  |  |  |  |
|   | Seoul | SNU |  |  |  |  |  |
| Romania | Bucharest | IFIN-HH |  |  |  |  |  |
|   |   | UB |  |  |  |  |  |
|   | Cluj-Napoca | UBB |  |  |  |  |  |
| Russia | Dolgoprudny | MIPT |  |  |  |  |  |
|   | Gatchina | NRC KI PNPI |  |  |  |  |  |
|   | Khabarovsk | PNU |  |  |  |  |  |
|   | Moscow | MSU |  |  |  |  |  |
|   |   | NNRU "MEPhI" |  |  |  |  |  |
|   |   | NRC KI |  |  |  |  |  |
|   |   | PFUR |  |  |  |  |  |
|   |   | SINP MSU |  |  |  |  |  |
|   | Moscow, Troitsk | INR RAS |  |  |  |  |  |
|   | Omsk | OmSU |  |  |  |  |  |
|   | Saratov | SSU |  |  |  |  |  |
|   | St. Petersburg | SPbSU |  |  |  |  |  |
|   | Tomsk | TPU |  |  |  |  |  |
|   | Vladivostok | FEFU |  |  |  |  |  |
| Serbia | Belgrade | IPB |  |  |  |  |  |
| Slovakia | Bratislava | CU |  |  |  |  |  |
|   |   | IP SAS |  |  |  |  |  |
| South Africa | Johannesburg | WITS |  |  |  |  |  |
|   | Pretoria | UP |  |  |  |  |  |
|   | Somerset West | iThemba LABS |  |  |  |  |  |
|   | Stellenbosch | SU |  |  |  |  |  |
| Spain | Palma | UiB |  |  |  |  |  |
| Sweden | Goteborg | Chalmers |  |  |  |  |  |
|   | Lund | LU |  |  |  |  |  |
| Ukraine | Kiev | KINR NASU |  |  |  |  |  |
|   |   | NUK |  |  |  |  |  |
| United Kingdom | Guildford | Univ. |  |  |  |  |  |
| USA | Notre Dame, IN | ND |  |  |  |  |  |
|   | University Park, PA | Penn State |  |  |  |  |  |
| Uzbekistan | Namangan | NamMTI |  |  |  |  |  |
|   | Tashkent | Assoc. P.-S. PTI |  |  |  |  |  |
|   |   | IAP NUU |  |  |  |  |  |
|   |   | INP AS RUz |  |  |  |  |  |
|  |  |  |   |   |   |  |  |

**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,****FTE amount** | **JINR associated personnel,****FTE amount** |
| 1. | research scientists | **54** | **1** |
| 2. | engineers |  |  |
| 3. | specialists |  |  |
|  | **Total:** | **54** | **1** |

**4.2. Actual cost of the Theme / LRIP**

|  |  |  |  |
| --- | --- | --- | --- |
| **No.** | **Items of expenditure** | **Full cost****(thousands of US** **dollars)** | **Expenditure for the last year,****(thousands of US dollars)** |
| 1. | International cooperation |  | **74.8** |
| 2. | Materials  |  |  |
| 3. | Equipment, Third-party company services |  |  |
| 4. | Commissioning |  |  |
| 5. | R&D contracts with other research organizations  |  |  |
| 6. | Software purchasing |  |  |
| 7. | Design/construction |  |  |
| 8. | Service costs (*planned in case of direct project affiliation)* |  |  |
| **TOTAL:** |  |  |

**4.3. Other resources**

**5. Conclusion**

**The planned work has been completed.**

**Theme leader**

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**Project leader**

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**Project leader**

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**Project leader**

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**Laboratory Economist**

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