BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

ANNUAL REPORT 2016

At the Bogoliubov Laboratory of Theoretical Physics (BLTP) studies were carried out on the following four themes: Theory of Fundamental Interactions; Theory of Nuclear Structure and Nuclear Reactions; Theory of Condensed Matter; Modern Mathematical Physics: Strings and Gravity, Supersymmetry, Integrability. Two new sectors were organized at BLTP for enhancement of theoretical research in neutrino physics and phenomenology of relativistic heavy ion physics. An important component of the BLTP activities is theoretical support of experimental research to be carried out within major international projects with the participation of JINR as well as Dubna based experimental programs of JINR Laboratories. The research resulted in about 500 publications in peer-reviewed journals and proceedings of international conferences. Most of the results were obtained in cooperation with scientists from the JINR Member States, Brazil, China, Egypt, Germany, India, Italy, France, South Africa, and other countries. The Laboratory has become a site for organization of international conferences, workshops, schools for young scientists in various fields of theoretical physics. In 2016, more than 600 scientists participated in 11 international conferences, workshops and schools organized at the Laboratory. The international collaboration was supported by grants of the Plenipotentiaries of Bulgaria, the Czech Republic, Hungary, Poland, the Slovak Republic, Romania, and the JINR Directorate; the collaboration with German theorists was based on the Heisenberg-Landau Program; with Armenia, on Smorodinsky-Ter-Martirosyan Program; with Polish theorists, on the Bogoliubov-Infeld Program; with Czech theorists, on the Blokhintsev-Votruba Program; and with Romanian theorists, on the Titeica-Markov Program. Collaboration with scientists from Western Europe was carried out in the framework of the JINR-INFN, JINR-IN2P3 agreements. The agreements for collaboration between the Bogoliubov Laboratory and APCTP (South Korea), ITP CAN (Beijing) are functioning, as well as the active cooperation with theorists from CERN. 19 research projects and 4 conferences and schools were supported by the RFBR grants. Much attention was paid to recruiting young researchers, students, and post-graduate students to the Laboratory within the Research and Education Project "Dubna International Advanced School of Theoretical Physics (DIAS-TH), in particular. More than 130 PhD students and young scientists from the JINR Member States participated in the DIAS-TH schools. The Laboratory plays the role of the training center for young scientists and students from many countries. Currently, about one third of the scientific personnel are young scientists and PhD students. Within the JINR fellowship program for nonmember states several researchers from Argentina, India, Japan, Mexico, and Tajikistan have been working at BLTP on the long-term basis.

1. SCIENTIFIC RESEARCH

1.1 Theory of Fundamental Interactions

Theoretical investigations were continued in the framework of the following projects:

- Standard Model and Its Extensions;
- QCD Parton Distributions for Modern and Future Colliders;
- Physics of Heavy and Exotic Hadrons;
- Hadron Matter under Extreme Conditions.

A systematic study of the leading ultraviolet divergences for the on-shellscattering amplitudes in gauge field theories with maximal supersymmetry in dimensions D = 6, 8 and 10 is performed. The all loop summation of the leadingdivergences is performed with the help of the differentialequations which are the generalization of the RG equations for non-renormalizable theories. Numerical solutions of these equations in the general case are obtainedin D=6, 8 and 10 dimensions. The key issue is that the summation of infinite seriesfor the leading and the subleading divergences does improve the situation and doesnot allow one to remove the regularization and obtain the finite answer. This meansthat despite numerous cancellations of divergent diagrams these theories remain non-renormalizable [1].

Dynamical chiral symmetry breaking is studied within (2+1)-dimensional QED with N four-component fermions. The leading and next-to-leading orders of the $1/N$ expansion are computed exactly. The analysis is carried out in arbitrary non-local gauge. Resummation of the wave-function renormalization constant at the level of the gap equation yields a strong suppression of the gauge dependence of the critical fermion flavour number, $Nc(\xi)$. Here ξ is the gauge fixing parameter, which is such that chiral symmetry breaking takes place for $N<Nc(\xi)$. Obtained results show that chiral symmetry breaking should take place for integer values $N\leq 3$. Acorrespondence between reduced QED4,3 and QED3 allows us to derive also the corresponding results in graphene at the infra-red Lorentz-invariant fixed point where the system is described by an effective relativistic-like field theory. The results are in good agreement with ones found in models with instantaneous Coulomb interaction [2].

A Grassmannian integral representation is obtained for tree-level gauge invariant off-shell amplitudes (reggeon amplitudes) with an arbitrary number of external legs, one of which is being off-shell both for the case of maximally supersymmetric Yang-Mills theory and pure gluodynamics. A further generalization of this result to the case of arbitrary number of off-shell legs was obtained. It is shown that the (deformed) off-shell amplitude expressions could be also obtained using quantum inverse scattering method for auxiliary gl(4|4) super spin chain [3].

Finite size corrections are obtained for ground and exited states of generalized Dicke model [4].

Leading SM contribution to the strong coupling beta-function is obtained at thefour-loop level. In addition to well-known pure QCD corrections, the Yukawa interactions of topquarks are taken into account together with self-interactions of the Higgs boson. Numericanalysis of the new contribution shows that above the electroweak scale it turns out to be anorder of magnitude larger that recent five-loop pure QCD result by other authors [5].

The four-quark structure of the recently discovered charged $Z_c(3900)$, $Z(4430)$ and $X_b(5568)$ exotic states has been examinedwithin a covariant quark model. It was found that the tetraquark-type current widely used in the literature for the Zc(3900) leads to a significant suppression of the DD^*-modes. Contrary to this a molecular-type current provides an enhancement by a factor of 6-7 for the DD^*-modes compared with the $J/\psi\pi$ and $\eta_c\rho$ modes in agreement with recent experimental data from the BESIII Collaboration [6].

The possible new physics (NP) effects in the exclusive decays $B\to D(D^*) + \tau^- + \nu_\tau$ have been studied in some extension of the Standard Model by taking into account right-handed vector (axial), left- and right-handed (pseudo)scalar, and tensor current contributions. We provide constraints on NP operators based on measurements of the ratios of branching fractions of the tau and muon modes and consider the effects of these operators on physical observables in different NP scenarios [7].

For hydrogen molecular ionscontributions to the energy in orders $m\alpha^6$ and $m\alpha^7$are obtained, which take into consideration vibrational motion of nuclei [8].

Energies of ionization of H_2^+, HD^+и D_2^+, which are required for determination of masses of light nuclei from precision spectroscopy of H_2, HD, etc., were calculated. Improved values for fundamental transitions in the hydrogen ions, which allow to determine with a significant precision such fundamental physical quantity as the Rydberg constant, proton charge radius, and proton-to-electron mass ratio, were calculated [9].

A thorough statistical analysis of all available reactor data was performed in order to test one of the predictions of the quantum-field theoretical approach to neutrino oscillations – violation of the classical inverse square law (ISL) for the antineutrino count rate as a function of distance. The value of the ISL violation $L_0$is found to be 1.5–3.5 m that corresponds to the spectrum-weighted value of the mean momentum spread of the external in and out wave packets of the order of 0.5–0.8 eV [10].

A theoretical approach is proposed to calculate the nucleon axial form factor for large virtualities in the Q^2=1-10 GeV^2 range using the next-to-leading order light-cone sum rules, which is important due to emerging possibilities to study threshold pion electroproduction at large momentum transfers [11].

The specific toroidal structures of vorticity field in heavy-ion collisions were found, named as femto-vortex sheets. Their relation to polarization of hyperons, recently discovered experimentally, is established [12].

By using QCD analysis of the HERMES data on the multiplicity production of the positively and negatively charged pions in the semi-inclusive unpolarized processes, the fragmentation functions of the u and anti-u quarks into the pions are determined. It is shown that the HERMES data presented in different representations, (x,z) and (Q^2,z), are probably inconsistent [13].

The width of the decay $\tau\to K^-\pi^0\nu_\tau$ is calculated in the framework of the Nambu-Jona-Lasinio model, taking into account the contributions of the intermediate vector $K^*(892)$ and scalar $K^*_0(800)$ mesons. It is shown that the main contribution to the width of this decay is given by the subprocesses with the intermediate W-boson and vector $K^*(892)$ meson. The scalar channel with the intermediate $K^*_0(800)$ meson gives an insignificant contribution. It is shown that the contribution of the subprocess with the intermediate $K^{*\prime}(1410)$ meson is negligible as well [14].

The glueball contribution to the equation of state (EoS) of hot gluon matter below and above T_c is invetigated. It is shown that the strong changing of the masses of the scalar and pseudoscalarglueballs near T_c is determining the thermodynamics of the SU(3) gauge theory. The arguments a provided to justify that these glueballs become massless at $T_G\approx 1.1T_c$, which is crucial to understand the behavior of the trace anomaly found in lattice calculations [15].

Radiaitve mechanism of spontaneous conformal symmetry breakingin a conformal-invariant version of the Standard Model (SM)is suggested. The Coleman-Weinberg mechanism of dimensionaltransmutation in the SM gives rise to finite vacuumexpectation values and, consequently, masses of scalar andspinor fields. A natural bootstrap between the energyscales of the top quark and Higgs boson is suggested.The Coleman-Weinberg mechanism was also studied for the case of a supersymmetric system of scalar and fermion fields [16].

The Three-fluid Hydrodynamics-based Event Simulator Extended by UrQMD final State interactions (THESEUS) has been constructed and its performance with basic results is described in a collaborative publication. The program is the first and only (so far) that can provide event simulation in the energy range of NICA and FAIR with the equation of state of matter as an input, so that inparticular the question of typical signatures for a first order phase transition, as opposed to a crossover transition, can be investigated with it. As examples are given: the proton rapidity distribution and flow observables [17].

Results for the topological susceptibility at nonzero temperature obtained from lattice QCD with four dynamical quark flavours are presented. Different smoothing methods, including gradient Wilson flow and over-improved cooling, are applied before calculating the susceptibility. It is shown that the considered smoothing techniques basically agree among each other, and that there are simple scaling relations between flow time and the number of cooling/smearing steps. The topological susceptibility exhibits a surprisingly slow decrease at high temperature [18].

An approach to QCD vacuum as a medium describable in terms of a statistical ensemble of almost everywhere homogeneous Abelian (anti-)self-dual gluon fields was refined. These fields play the role of the confining medium for color charged fields as well as underline the mechanism of realization of chiral $SU_L(N_f)\times SU_R(N_f)$ and $U_A(1)$ symmetries. Hadronization formalism based on this ensemble leads to manifestly defined quantum effective meson action. Strong, electromagnetic, and weak interactions of mesons are represented in the action in terms of nonlocal *n*-point interaction vertices given by the quark-gluon loops averaged over the background ensemble. New systematic results for the mass spectrum and decay constants of radially excited light, heavy-light mesons, and heavy quarkonia were presented. Transition form factors $F_{P\gamma^*\gamma(^*)}$ of pseudoscalar mesons were studied consistently with mass spectra. It is found that $Q^2F_{\pi\gamma^*\gamma}(Q^2)$ approaches a constant value at asymptotically large Q^2, which complies with Belle data more likely than with BaBar ones. At the same time the generally accepted factorization bound is shown to be satisfied for the case of the symmetric kinematics, $Q^2F_{P\gamma^*\gamma^*}(Q^2)$ [19].

1.2 Theory of Nuclear Structure and Nuclear Reactions

In 2016, investigations were carried out in accordance with four projects:

- Nuclear Properties at the Border of Stability;
- Low-Energy Dynamics and Nuclear System Properties;
- Quantum Few-Body Systems;
- Processes with Nuclei at Relativistic Energies and Extreme States of Matter.

The *g*-factors for the $2^+_{1,2}$ states of ^{132,134,136}Te are studied by performing self-consistent calculations with the Skyrme force *f*- and taking into account the coupling between one- and two-phonon configurations. Available experimental data are well described. It is shown that the negative *g*-factor (-0.18) predicted for the 2^+_1 state in ^{136}Te indicates significant neutron character of this state. In contrast, a large positive *g*-factor (+0.64) is predicted for the 2^+_2 state in ^{136}Te, which reveals a dominant proton character, corresponding to a mixed-symmetry state with severe breaking of *F*-spin symmetry [20].

The random phase approximation with Skyrme forces is extended to finite temperatures to obtain the strength function of Gamow–Teller transitions in neutral channel for nuclei embedded in a hot supernova medium. Different Skyrme parametrizations are used to analyze thermal effects on the strength distribution of charge-neutral Gamow-Teller (GT) transitions in ^{56}Fe and ^{82}Ge. It is shown that cross sections and rates for weak-interaction processes involving hot nuclei demonstrate robustness against the variation of the Skyrme force parameters.

However, due to a larger strength of thermally unblocked low- and negative-energy GT transitions, the calculated low-energy cross-sections for inelastic neutrino scattering off hot nuclei are larger than those obtained within other approaches [21].

A two-dimensional collective Hamiltonian on both azimuthal and polar motion in triaxial nuclei is proposed to investigate chiral and wobbling modes. The broken chiral and signature splittings in the mean field approximation are restored by this Hamiltonian. This newly developed model is applied to a triaxial rotor coupled with one proton particle and one neutron hole on $h_{11/2}$ orbital. By diagonalizing the Hamiltonian, the angular momenta and energy spectra are obtained. The results agree with the exact solutions of the particle rotor model at high rotational frequencies [22].

Using the improved scission-point model, the isotopic trends of the charge distribution of fission fragments are studied in induced fission of even-even Th isotopes. The calculated results are in a good agreement with available experimental data. With increasing neutron number the tran- sition from symmetric to asymmetric fission mode is shown to be related to the change of the potential energy surface. The change of the shape of mass distribution with increasing excitation energy is discussed for fissioning ^{A}Th nuclei. At high excitation energies, there is unexpected large asymmetric modes in the fission of neutron-deficient Th isotopes considered [23].

The possibilities of direct production of the isotopes of transfermium nuclides ^{259,260}Md, ^{260,261}No, $^{261\text{-}264}$Lr, ^{264,265}Rf, $^{264\text{-}268}$Db, $^{266\text{-}269}$Sg, $^{266\text{-}271}$Bh, $^{267\text{-}274}$Hs, and $^{270\text{-}274}$Mt in various asymmetric hot fusion-evaporation reactions are studied. The excitation functions of the formation of these isotopes in the α*xn* and *pxn* evaporation channels are predicted for the first time [24].

A new method is suggested to extract pure transfer probabilities P_{tr} and $P_{1n,2n}$ from the transfer and capture (fusion) experimental data. The almost exponential dependence of the extracted pure one- and two-neutron transfer probabilities at backward angle on the minimal distance of approach is shown for the ^{40}Ca + ^{96}Zr system. As found, at energy slightly below the Coulomb barrier the ratio P_{1n}/P_{2n} becomes close to unity [25].

The probability of the formation and decay of a dinuclear system is investigated for a wide range of relative orbital angular momentum values. The mass and angular distributions of the quasifission fragments are studied for the collision ^{78}Kr (10A·MeV) + ^{40}Ca within dinuclear system model. The analysis shows the possibility of the 180° rotation of the system so that projectile-like products can be observed in the forward hemisphere with large cross sections, which can explain the phenomenon observed recently in the ISODEC experiment [26].

A three-body system consisting of two identical fermions of mass m and a distinct particle of mass m_1, with zero-range interactions between different particles, was studied in the universal limit of low energies. It was shown that for an unambiguous definition of the (Hermitian) three-body Hamiltonian in the interval $8.619 < m/m_1 \leq 13.607$ one needs to introduce an additional parameter constraining the wave function near the triple-collision point. The dependence of the three-body bound-state energies on m/m_1 and the three-body parameter for the most important case $L^P=1^-$ was calculated and analyzed with the aid of a simple model. The same problem was discussed for different L^P. The states of odd L and P for two identical fermions and states of even L and P for two identical bosons were considered. It is established that an additional three-body parameter is needed for definition of the (Hermitian) three-body Hamiltonian for m/m_1 above a critical value specific for each L^P sector [27].

Geometric (confinement-induced) resonances were predicted in atom-ion systems, dependence of their positions on the atomic mass and the colliding energy was calculated, analytic and semi-analytic formulae for the position of a geometric resonance were obtained in the “long-wavelength and zero-energy limit”. Possible applications of the phenomenon were

discussed, e.g., to determining the atom-ion scattering length, to determining the temperature of the atomic ensemble in the presence of an ion impurity etc. It was found that a slight anisotropy of the confining trap considerably enhances the reactive rate constants in the scattering of cold atoms [28].

Assuming the Hamiltonian *H* reads as a *J*-self-adjoint 2x2 block-operator matrix, conditions are established ensuring the analytic continuability of one of the Schur complements of the operator 2x2-matrix *H-E* to the unphysical sheets of the energy *E* plane. Theorems on factorization of the continued complement in the sense of Markus and Matsaev are prooven. In the Feshbach spectral case, it is established that the operator root of the Schur complement analytically continued to the respective unphysical sheet, generates for *H* a pair of *J*-orthogonal invariant subspaces [29].

The nature of phase transition in hot and dense nuclear matter is discussed in the framework of the effective SU(2) Nambu-Iona-Lasinio (PNJL) model with a Polyakov loop with two quark flavors – one of a few models describing the properties of chiral and confinement-deconfinement phase transitions. The parameters of the models are considered and the additional interactions are examined that influence the structure of phase diagram and the positions of critical points in it. The effect of meson correlations of the thermodynamic properties of the quark-meson system is examined. The evolution of the model with changes in the understanding of the phase diagram structure is discussed [30].

1.3 Theory of Condensed Matter

Theoretical investigations within the theme "Theory of Condensed Matter" were continued in the framework of the following projects:

- Complex Materials and Nanostructures;
- Contemporary Problems of Statistical Physics.

Iridium oxides with a honeycomb lattice have been identified as platforms for the much anticipated Kitaev topological spin liquid. A new type of magnetic ground state that was called "the structure of triplet dimers on an effective triangle lattice" has been predicted. The prediction can be verified by means of neutron diffraction and neutron magnetic spectroscopy [31].

A new theoretical model is developed to describe the structural properties of low viscosity sodium alginate from small-angle neutron scattering data. It is found that addition of salt accelerates the gelation process, induces a collapse which shorten sodium alginate chains, and a transition from a rough surface fractal-like structure to a mass fractal structure occurs [32].

A distribution function of relaxation times was investigated in a new group of materials $Sr_{14-x}Ca_xCu_{24}O_{41}$. It has been found that a commonly used description based on the relaxation rate does not give the proper distribution function even in the case of a broad distribution. For this reason, our original data processing procedure was developed. It was revealed that the observed thermal relaxation at x = 12 clearly indicates the formation of the spin density wave (SDW) ground state at low temperatures [33].

The microscopic theory of high-temperature superconductivity in cuprates was formulated within the extended Hubbard model in the limit of strong correlations [34]. The spin-wave excitation spectrum, magnetization, susceptibility and the Neel temperature were calculated for the quasi-two-dimensional compass-Heisenberg model for iridates, for the Kitaev-Heisenberg model on the honeycomb lattice [35].

The suppression of the long-range antiferromagnetic order in the strongly correlated systems has been studied in the framework of the Kondo-Heisenberg model. The spin-spin correlation functions at different doping levels and Kondo-coupling λ have been calculated

within the quantum Monte-Carlo method. The critical doping level has been found. The restoration of the long-range order with decreasing λ has been shown [36].

The influence of both the concentration and different location of edge vacancy defects on the stability of edge states in zigzag-type semi-infinite graphene sheet was studied. Three types of distributions have been considered: normal, uniform, and periodic. When vacancies are located at a distance of one or two atoms, their mutual influence leads to the appearance of subpeaks in the local density of electronic states. The edge state turns out to be destroyed most effectively when vacancies are located at a distance not exceeding the characteristic range of mutual influence [37].

It is shown that the experimentally observed increase of Young's modulus in single-layer graphene with low density of point defects leads to a noticeable enhancement of the thermal conductivity in a wide temperature range [38].

The phase dynamics of SQUID consisting of Josephson junctions with topologically nontrivial barriers is investigated, and its comparative analysis with simple SQUID is performed. It is shown that in case of SQUID with nontrivial barrier the branch of IV-characteristic corresponding to the resonance frequency shifts in $\sqrt{2}$ along the voltage [39].

The von-Neumann entanglement entropy and Schmidt gap in the vortex free ground state of the Kitaev model considering different geometries for the sub-system were investigated. It was found that for square/rectangular and cylindrical geometries of the subsystems entanglement entropy shows signature of phase transition from gapless to gapped phase. The results show that though the gapless and gapped phase of the Kitaev model is topologically distinct, exact nature of entanglement entropy and Schmidt gap depends on the geometry of the subsystem with respect to the full system [40].

Statistical systems composed of atoms interacting with each other through nonintegrable interaction potentials are considered. A novel iterative procedure for describing such systems is developed, starting from a correlated mean-field approximation, allowing for a systematic derivation of higher orders [41].

A unifying picture that extends the semiclassical perspective of Heller, which relates the localization measure to the probability of return, is introduced. The dependence of the localization measure on the initial state and on the strength of the many-body interactions is explored using a novel recursive projection method [42].

A matrix-product representation for the stationary states of the totally asymmetric simple exclusion process (TASEP) on a finite ring in the case of a generalized discrete-time dynamics with two hopping probabilities was constructed. Exact finite-size expressions for the probability normalization factor, the current of particles, and the correlation function were obtained and analyzed in the regimes of dynamic attraction and repulsion. An explicit analytic expression for the pair correlation function in the limit of irreversible aggregation was derived [43].

The quantum Yang-Baxter equation (YBE) and star-triangle relation define exactly solvable models in statistical mechanics. The most complicated solution of YBE (R-matrix) is defined by an integral operator with an elliptic hypergeometric kernel and it defines models with the continuous values of spins. A principally new class of finite-dimensional R-matrices has been found, which is built from elliptic theta functions with two different modular parameters. It is connected to finite-dimensional representations of the elliptic modular double and determined by two-dimensional lattices of discrete values of the spins. This yields new discrete integrable systems in statistical mechanics whose physical properties have not been determined yet, except of the cases of Baxter's 8-vertex model and its higher spin generalization due to Sklyanin. These YBE solutions were obtained with the help of the operator intertwining equivalent representations of the relevant symmetry algebra. For special spin values, this operator has finite-dimensional invariant spaces which were described explicitly [44].

The internal structure of rotor-router walk on a semi-infinite cylinder and growth of the cluster of visited sites by rotors are considered. It is shown that the average width of the surface region of the cluster evolves to the stationary value by a scaling law whose parameters are close to the standard Kardar-Parisi-Zhang (KPZ) exponents. The sequence of characteristic labels corresponding to closed clockwise contours formed by rotors is in average an ordered helix structure [45].

1.4 Modern Mathematical Physics: Strings and Gravity, Supersymmetry, Integrability

The topics of main focus in the theme were:

- Supersymmetry and Superstrings,
- Quantum Groups and Integrable Systems;
- Supersymmetry;
- Quantum Gravity, Cosmology and Strings.

Actions of N=4 superparticles in the AdS3 space were constructed, including ones with higher derivatives. It was proved that idea of using the method of nonlinear realizations is applicable to the construction of actions in curved spaces, provided that one can choose coordinates and fields in such a way that fermionic coordinates of superspace transform homogeneously under broken supersymmetry. Nonrelativistic limit of these systems was also considered [46].

A new generalization of the special lagrangian geometry on Calabi-Yau manifolds, which has been exploited in SYZ-construction for the explanation of Mirror Symmetry, to the case of arbitrar algebraic varieties is proposed. It is proven that the moduli space of our Special Bohr-Sommerfeld lagrangian submanifolds is finite; certain examples of the moduli spaces are presented [47].

The six-dimensional N=(1,0) supersymmetric model of abelian gauge multiplet coupled to a hypermultiplet is considered in the harmonic superspace approach. The divergent part of the one-loop effective action is computed. It is shown that the corresponding counterterms contain the purely gauge multiplet contribution together with the mixed contributions of the gauge multiplet and hypermultiplet. The theory is on-shell one-loop finite in the gauge multiplet sector and contains unremovable divergences in the mixed sector [48].

A new kind of non-relativistic N=8 supersymmetric mechanics is introduced, associated with worldline realizations of the supergroup SU(2|2) treated as a deformation of flat N=8, d=1 supersymmetry. Various worldline SU(2|2) superspaces are constructed and the corresponding superfield techniques are developed. For the off-shell SU(2|2) multiplets (3,8,5), (4,8,4), and (5,8,3), the most general superfield and component actions are constructed and analyzed. For the simplest (5,8,3) model the quantization is performed [49].

The existence of hairy black holes is studied in the generalized Einstein-Skyrme model. It is proven that in the BPS model limit there are no hairy black hole solutions, although the model admits gravitating (and flat space) solitons. As an example, it is shown that there are no hairy black holes in the L_2+L_6+L_0 model [50].

The Schroedinger eigenvalue problems for the Whittaker-Hill potential and the periodic complex potential Q_i are studied using their realizations in two-dimensional conformal field theory. It is shown that the hamiltonian H_1 is PT-symmetric for some special choice of parameters and has a real spectrum in the weak coupling region. Thus, H_1 can serve as yet another new model for testing postulates of PT-symmetric quantum mechanics [51].

New models of the SU(2|1) supersymmetric mechanics based on gauging the systems with dynamical (1,4,3) and semi-dynamical (4,4,0) supermultiplets are presented. A new N=4

extension of d=1 Calogero-Moser multiparticle system is obtained by gauging the $U(n)$ isometry of matrix SU(2|1) harmonic superfield model [52].

A new mechanism for inflation is proposed which uses the Horndeski prescription to couple gravity with classical homogeneous and isotropic SU(2) Yang–Mills field. This generally and gauge covariant YM theory with a curvature-dependent action is ghost-free. It is shown that the action leads to second-order gravity and Yang–Mills field equations. The respective solution space contains the de Sitter boundary, which after some finite time attracts trajectories, thus a robust inflation with a graceful exit is ensured. A two-step inflationary scenario is obtained when the Higgs is included in the theory. In this case the Planck-scale YM-generated inflation naturally prepares the desired initial conditions for the GUT-scale Higgs inflation [53].

Modified teleparallel gravity with a function $f(T,T_G)$ in action is investigated. The function depends on a torsion scalar T and an analogue of Gauss-Bonnet invariant T_G. As distinct from the usual teleparallel gravity with $f(T)$ in the action, this theory contains higher derivative terms, which may produce different instabilities. It is explicitly demonstrated that the Minkowski stability in such kind of theories demands that $f_T(0,0)<0$, $f_{T_G T_G}(0,0)>0$. It is checked whether these restrictions are fulfilled for various types of functions discussed by other authors [54].

Explicit compact formulae for the ponderomotive forces in the macroscopic electrodynamics of moving media are derived in the Minkowski and Abraham approaches. The expression for the Abraham force is obtained for arbitrary dependence of the medium velocity on spatial coordinates and time and for nonstationary external electromagnetic field. The Lorentz force is found which is exerted by external electromagnetic field on the conduction current in a medium [55].

The influence of temperature on the surface plasmons in graphene was investigated using the recently developed polarization tensor for the electronic exitations in (2+1) dimensions. A model with non-zero mass gap, but zero chemical potential was considered. It is shown that the plasmons may exist for both polarizations of the electromagnetic field, transverse electric (TE) and transverse magnetic (TM). For TE, the momentum region, where the dispersion function is real, appears bounded from below, whereas for TM it is bounded from above. The influence of the temperature on plasmons is compared with the respective effect of the chemical potential [56].

It is demonstrated that solutions to the Beltrami 3-dimensional hydrodynamics equation can be viewed as instantons of an N=2 supersymmetric nonlinear sigma model on 4-dimensional locally Hyper-Kahler worldvolume with a 4-dimensional Hyper-Kahler target space, so that they are triholomophic maps between the worldvolume and the target space. Consequently, the classification of the solutions to the 3-dimensional Beltrami equation is reduced to enumeration of the triholomorphic maps, which is represented in terms of a topological sigma model [57].

2. DUBNA INTERNATIONAL ADVANCED SCHOOL OF THEORETICAL PHYSICS (DIAS-TH)

In 2016, the research and education project DIAS-TH was successfully continued. There were the following activities in the framework of DIAS-TH:

- XXth Research Workshop “Nucleation Theory and Applications”, April 1-30, Dubna;
- Helmholtz International Summer School “Quantum Field Theory at the Limits: from Strong Fields to Heavy Quarks”, July 18-30, Dubna;
- International School “Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems”, July 30 - August 6, Dubna;

- Helmholtz International Summer School “Cosmology, Strings and New Physics”, August 28 - September 10, Dubna;
- Regular seminars for students and postgraduates were organized;
- Computer processing of video records of lectures was continued;
- Web-site of DIAS-TH was supported.

3. CONFERENCES AND MEETINGS

11 conferences, workshops and schools were organized in 2016:

- XXth Research Workshop “Nucleation Theory and Applications”, April 1-30, Dubna;
- International Session-Conference SNP PSD RAS “Physics of Fundamental Interactions”, April 12-15, Dubna;
- XXIVth International Colloquium “Intagrable Systems and Quantum Symmetries”, June 14-18, Dubna;
- BLTP/JINR-KLTP/CAS Joint Workshop “Physics of Strong Interaction”, June 28 - July 3, Dubna;
- International Workshop “Few-Body Systems”, July 4-7, Dubna;
- Helmholtz International Summer School “Quantum Field Theory at the Limits: from Strong Fields to Heavy Quarks”, July 18-30, Dubna;
- International School “Advanced Methods of Modern Theoretical Physics: Integrable and Stochastic Systems”, July 30 - August 6, Dubna;
- Helmholtz International Summer School “Cosmology, Strings and New Physics”, August 28 - September 10, Dubna;
- International Workshop “Classical and quantum integrable systems and supersymmetry”, September 19-24, Tianjin, China;
- XXIIIth International Baldin Seminar "Relativistic Nuclear Physics and Quantum Chromodynamics", September 19-24, Dubna;
- Meeting of the working group "Theory of Hadronic Matter under Extreme Conditions", October 31 - November 3, Dubna.

4. COMPUTER FACILITIES

In year 2016 new faster processors were installed and memory was extended to 512 GB on main computational server theor2.jinr.ru. The upgrade of network links to speed 1 Gbit/s for all PCs in BLTP has been completed with the installation of several high-performance switches. Main BLTP switches and servers now communicate via 10 Gbit/s lines. The video-broadcast server in conference hall has been moved to more powerful equipment. This allows for better quality of video-broadcasts and better service of more watchers. To improve video-broadcasts from 4-th floor auditorium new Full HD PTZ camera has been installed. Software packages like Mathematica, Maple, Intel Parallel Studio, Origin Pro running on BLTP servers and used on PCs via network licenses has been upgraded to latest releases. One more network licenses were purchased for Maple and Origin Pro.

5. REFERENCES

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