BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

At the Bogoliubov Laboratory of Theoretical Physics (BLTP), studies are carried out on the following four themes: Fields and Particles, Modern Mathematical Physics, Nuclear Theory, and Theory of Condensed Matter. *Important components of BLTP's activities are theoretical support of experimental research to be carried out with JINR's participation and recruiting of young researchers, students, and postgraduate students to the Laboratory*. In 2004 a new theme, Dubna International Advanced School of Theoretical Physics (DIAS-TH), was started at BLTP.

FIELDS AND PARTICLES

Theoretical research in the *Fields and Particles* division of BLTP covers a wide field of activity in *quantum field theory* (QFT) and *phenomenology of particle physics*.

Phenomenology of particle physics includes the Standard Model of fundamental interactions and its extension, as well as high- and low-energy hadron physics. The main topics were:

- Nonperturbative methods and QCD phenomenology;
- Studies of Standard Model and its extensions.

In 2004, considerable progress was achieved in several directions. Below one can find a brief description of selected results obtained at BLTP during the year.

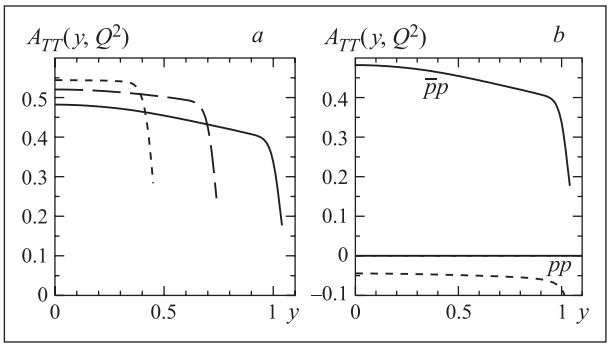
The three-loop corrections to the anomalous dimension matrix for the Wilson twist-2 operators in the $N = 4$ supersymmetric Yang–Mills model were calculated for polarized and unpolarized cases. In the first three orders of perturbation theory, the eigenvalues of this matrix are expressed in terms of a universal function with arguments shifted by integer numbers. Singularities of this universal function, with its argument $j \to 1$, agree with the predictions obtained from the BFKL equation at the next-to-leading order. The asymptotics at large j are in agreement with the expectations based on interpolation between week and strong coupling regimes in the framework of the AdS/CFT correspondence [1].

Development of analytical field theoretical methods suitable for studying the infrared behaviour of Green functions in QCD is of great importance for understanding the long-standing problem of quark confinement. It was shown how, in general, the infrared momentum structure of Green functions can be extracted within the method of so-called exact renormalization group equations, which opens new perspectives in investigation of QCD beyond perturbation theory. The infrared behaviour of gluon and ghost propagators, particularly sensitive to physics of confinement Green functions, was investigated in this approach. The gluon propagator was found to be suppressed in the infrared limit, while the singularity of the ghost propagator was enhanced. This result supports the Kugo–Ojima confinement scenario and is in agreement with the results obtained in the Dyson–Schwinger equation approach, as well as with very recent lattice studies [2].

A new criterion for existence of heavy quarkonia based on the effect of Higgs boson exchange was established which takes into account the quarks of 4th generation. The calculations of the related processes were performed which are important for future experiments at LHC [3].

The size of cross sections of charmonia on light hadrons is of great relevance to the interpretation of heavy-ion collision physics studied intensively in experiments at RHIC. Much attention is attracted to these cross sections because suppression of charmonium production could be used as a signature of a quark–gluon plasma. The amplitudes and the cross sections of the charm dissociation processes $(c\bar{c}) + \pi$ into two mesons with open charm ($D\bar{D}$, etc.) were calculated within a relativistic constituent quark model. The contributions coming from both the box and triangle diagrams that contribute to the dissociation processes were consistently taken into account. Summing up the four channels gives a maximum total cross section of about 2.3 mb at $\sqrt{s} \approx 4.1$ GeV [4].

It was shown that the problem of the Dark Matter in our galaxy could be solved within the Minimal Supersymmetric Standard Model. SUSY provides an excellent candidate for the Dark Matter and, assuming that the Dark Matter consists of SUSY WIMPs, one can reproduce the profile of the Dark Matter and simultaneously describe the rotation curves of the stars. The consideration of the astrophysical information from recent EGRET (Energetic Gamma-Ray Telescope) diffuse galactic gamma-ray data limits the WIMP mass to the 50–100 GeV range, while the sky maps are used to determine the halo structure. The total mass of the halo is determined to be $3 \cdot 10^{12}\ M_{\odot}$. These signals of Dark Matter annihilation are compatible with supersymmetry and, combined with all features mentioned above, provide an intriguing hint that the EGRET excess is indeed a signal from Dark Matter annihilation [5].



a) The asymmetry $A_{TT}(y, M^2)$ at PAX as a function of the rapidity y for $Q^2 = 5$ (solid), 9 (dashed) and 16 GeV^2 (dotted line) for $s = 45$ GeV^2. *b)* Comparison of $A_{TT}(y, M^2)$ from proton–antiproton (solid) and proton–proton (dotted line) collisions for $Q^2 = 5$ GeV^2

The Drell–Yan process remains up to now the theoretically cleanest and safest way to access the nucleon transversity $h_1^a(x)$. The first attempt to study $h_1^a(x)$ by means of the Drell–Yan process is planned at RHIC. Dedicated estimates, however, indicate that at RHIC the access of $h_1^a(x)$ is very difficult since the observable double-spin asymmetry A_{TT} is proportional to a product of transversity quark and antiquark. The latter are small even if they saturate the Soffer bound. This problem can be circumvented by using an antiproton beam. The challenging promising programme how to polarize an antiproton beam was recently suggested in the PAX experiment at GSI. The quantitative estimates for the A_{TT} in the kinematics of the PAX experiment were given by Bochum–Dubna group on the basis of predictions for the transversity distribution from the chiral quark soliton model (figure, *a*).

The advantage of using antiprotons is evident from figure, *b*. The corresponding asymmetry from proton–proton collisions is an order of magnitude smaller. Even if this advantage is compensated by a small antiproton polarization $(5{-}10\%)$, the counting rates and accuracy are more sizeable [6].

The current boom of the hadron spectroscopy makes interesting the observation of exotic states in hard reactions where application of QCD is most reliable. In this connection the hard electroproduction of exotic hybrid quark–gluon mesons was investigated. It was shown that in the case of their longitudinal polarization this process receives the contribution from the leading twist amplitude due to the gluons from the string produced by the nonlocal quark–antiquark source. The corresponding cross section is only one order of magnitude smaller than the dominant cross section of ρ-meson production, opening a possibility of hybrids study at COMPASS, HERMES and CLAS [7].

A new model for exotic multiquark state pentaquark was suggested. This model is based on the triquark and diquark correlation inside a pentaquark induced by strong fluctuations of vacuum gluon fields, instantons. It is shown that small mass and width of the Θ^+ pentaquark have a natural explanation as a bound state of triquark and diquark configurations in a relative $L = 1$ state [8].

Generic formulae for the polarization density matrix of leptons produced in νN and $\overline{\nu} N$ collisions were derived. The formalism was employed to the most important particular cases of quasi-elastic, deep inelastic and resonance scattering [9]. An extension of the popular model by Rein and Sehgal for single-pion neutrinoproduction was developed in order to include the final lepton mass and spin. A numerical analysis of the production cross section and polarization vector of τ's produced through quasi-elastic ν_τ and $\overline{\nu}_\tau$ interactions with nucleons was given within two models for the vector electromagnetic form factors of proton and neutron. The impact of G parity-violating axial and vector second-class currents is investigated by applying a simple heuristic model for the induced scalar and tensor form factors [10].

The role of positivity constraints for τ's polarization, which is rather important due to poor knowledge of parity-violating DIS structure functions at low Q^2, was also investigated [11].

Different methods to extract the polarized parton densities from the world polarized DIS data were con-

sidered. The higher twist corrections $h^N(x)/Q^2$ to the spin-dependent proton and neutron g_1 structure functions were taken into account and found to be nonnegligible and important in the QCD analysis of the present experimental data. Their role in determining the polarized parton densities in the framework of the different approaches was discussed [12].

The semi-inclusive deep inelastic scattering (SIDIS) process was considered. A new theoretical method was proposed which allows a direct extraction from the SIDIS data of the first moments of the polarized valence distributions and of the first moment difference of the light sea quark polarized distributions in the next-to-leading (NLO) QCD order. The validity of the method was confirmed by the respective simulations [13].

The leading-order contribution from the hadronic part of the photon vacuum polarization to the anomalous magnetic moment of the muon, $a_\mu^{hvp,1} = 623(40) \times 10^{-10}$, and τ lepton, $a_\tau^{hvp,1} = 3.1(0.2) \cdot 10^{-6}$, were estimated. The calculations were based on the usage of the vector Adler function which was studied in the framework of a covariant chiral quark model with instanton-like quark–quark interaction. This function describes the transition between the high-energy asymptotically free region of almost massless current quarks to the low-energy hadronized regime with massive constituent quarks. The instanton model reproduces the Adler function and the correlators of vector and axial-vector currents extracted from the ALEPH and OPAL data (CERN) on hadronic τ-lepton decays [14].

NLO QCD LCSR processing of the CLEO data reveals that only BMS-like pion distribution amplitudes, extracted earlier from nonlocal condensate QCD sum rules, appear within the 1σ region, while all other known models are excluded at least at 2σ or more. These findings are further backed up by E791 data on diffractive dijet production [15].

NLO QCD analytic perturbation-theory analysis of the pion form factor shows that the same BMS «bunch» of pion distribution amplitudes provides results very close to those obtained with the asymptotic distribution amplitude and to JLab F(pi) data [16]. This agreement proves that double-humped distribution amplitude structure is much less relevant compared to its endpoint behaviour: strong endpoint suppression of the BMS distribution amplitude generates agreement with the CLEO data.

Chiral amplitudes for calibration processes at $\gamma\gamma$, γe and $e^\pm e^-$ colliders were calculated for quasi-peripheral kinematics. In this experiment set-up the QED processes have large cross sections and provide an important background for studying Standard Model predictions, as well as manifestations of the new physics. The processes mentioned above were used as a calibration of luminosity of colliders. The accuracy of obtained results is about 0.1% due to the radiative corrections taken into account [17].

Multiple lepton-pair production in relativistic heavy-ion collisions was analyzed by direct summation of Feynman amplitude contributions of all orders of PT. The Poisson distribution in impact space was confirmed [18].

The multilepton exchanges between ions and the created pair components were investigated; namely, the case when two photons are emitted by each ion was calculated. Some unexpected phenomena were found — the first of them is a nonzero imaginary part of the amplitude and a double-logarithmical enhancement for the case of large-angle pair production. Also the double-logarithmical asymptotic of elastic and inelastic quark form factors in QED and QCD was investigated [19].

The spectrum of diquark excitations over a cold and dense quark matter in the 2SC phase of colour-superconductivity with only u and d flavour contributions to the diquark condensate was investigated. The number of massless Goldstone modes was found to be less than predicted by the Goldstone theorem, but to be in agreement with the Nielsen–Chadha theorem. This phenomenon is explained by the absence of colour and electric charge neutrality of the colour superconducting quark matter when all chemical potentials, except for the baryon number, vanish [20].

The renormalization-group algorithm in mathematical physics (developed earlier for models based on differential equations) was generalized for boundary value problem with integral equations, in particular for models with nonlocal terms in the form of linear functionals of solution. Some illustrations are given [21].

The quasi-potential approach in quantum field theory was used to derive relativistic threshold resummation factors in quantum chromodynamics. A new model expression for $R(s)$ in which threshold singularities are summarized into a main potential contribution was suggested [22].

MODERN MATHEMATICAL PHYSICS

The topics of main focus in the theme were:

- Supersymmetry and superstrings;
- Quantum groups and integrable systems;
- Quantum gravity and cosmology.

Below, we present some results obtained in 2004 on these subjects.

The $SO(4) \times SU(2)$ invariant Q deformation of Euclidean $N = (1,1)$ gauge theories in the harmonic superspace formulation was constructed for the first time. This deformation preserves chirality and Grassmann harmonic analyticity but breaks $N = (1,1)$ to $N = (1,0)$ supersymmetry. The $N = (1,0)$ supersym-

metric action for the gauge groups $U(1)$ and $U(n>1)$ was explicitly given in both superfield and component forms, and the relevant Seiberg–Witten map to undeformed $N=(1,1)$ gauge multiplet was found [23].

A variety of off-shell $N=8$, $d=1$ supermultiplets with finite numbers of component fields were constructed as direct sums of properly constrained $N=4$, $d=1$ superfields. It was shown how these multiplets could be described in $N=8$, $d=1$ superspace where the whole amount of supersymmetry is manifested. Examples of invariant superfield actions for the multiplets were presented, including a few $N=8$ superconformally invariant ones. The results obtained constitute a basis for constructing new models of $N=8$ supersymmetric quantum mechanics [24].

Integrable structures related to the bosonic Toda lattice hierarchy were uncovered recently in many different branches of modern theoretical physics, and its possible supersymmetric generalizations can be important for supersymmetric theories. In this connection, new integrable supersymmetric generalizations with a different number of supersymmetries of the open and periodic Toda lattice hierarchies, as well as their dispersionless (semiclassical) limits, were constructed in recent years. A new bracket operation on the space of graded operators with an involution which generalizes the graded commutator in superalgebras was proposed, and this bracket was used for constructing the corresponding Lax pair representations (including spectral parameters) [25].

In view of immense complexity of the string theory and the lack of appropriate mathematical tools for concrete calculations in its framework, it is important to reveal the relation of the string approach and usual local field theory. By making use of twistor technique it was shown that the topological strings of type B, considered on weighted projective spaces, were equivalent to the holomorphic Chern–Simons theory on the same spaces. In turn, the latter theory is equivalent to field models which are self-dual truncations of $N=4$ Super–Yang–Mills theory [26].

A unifying description for the XXZ open spin$=1/2$ chains and for a family of one-dimensional fluctuating interface models is developed in terms of proper extentions of the Temperley–Lieb algebras. Combinatorial properties of the stationary states for these models were analyzed and compared in detail, and explicit formulae for the weights of various stationary configurations were given. It was shown that these weights satisfied a series of bilinear recurrent equalities — the Pascal hexagon relations which also give solutions to Hirota's difference equation [27].

New types of integral transformations for functions of many complex variables were introduced. They were naturally related to a pair of root systems and to the corresponding elliptic beta integrals. As a consequence, a completely new multivariable beta-type integral for the A_n root system was discovered. A simple method of proving all known elliptic beta integrals of type I was proposed. Warnaar's elliptic extension of a Macdonald multiparameter summation formula was generalized to Riemann surfaces of arbitrary genus. Poisson algebras related to self-dual generalized eigenvalue problems for two tridiagonal matrices were described. These results should have important applications in classical and quantum integrable multiparticle systems [28].

Multi-instanton solutions were investigated in the framework of field theory with noncommutative coordinates. It was proposed to make the translational instanton moduli noncommutative as well. This enables one to overcome the difficulties in constructing explicit nonsingular instanton configurations with a topological charge greater than one [29].

Interaction of rotating higher dimensional black holes with a brane in space-times with large extra dimensions was investigated. A rotating black hole attached to a brane was demonstrated to be stationary only if the null Killing vector generating the black hole horizon was tangent to the brane world-sheet. The characteristic time when a rotating black hole with the gravitational radius r_0 reaches this final stationary state is $T\sim r_0^{p-1}/(G\sigma)$, where G is the higher dimensional gravitational coupling constant, σ is the brane tension, and p is the number of extra dimensions [30].

There exist two alternative approaches to construct general-relativistic quantum mechanics of a particle. The first one is quantization of a scalar field and construction of the one-particle subspace of the Fock space, in which quantum mechanics is realized. The second is quantization of geodesic dynamics in the Riemannian space-time. A mysterious fact is found in the n-dimensional space-time, these two approaches lead to different constants of nonminimal coupling of the scalar field to external gravitational field, except when $n=4$, that is the dimension of the observed Universe. The result may be interesting in relation to the brane cosmological models [31].

NUCLEAR THEORY

In 2004, investigations within the area «Nuclear Theory» were carried out in accordance with the four projects:

- Theory of nuclear excitations;
- Dynamics and manifestation of structure in nuclear and mesoscopic systems;
- Few-body physics;
- Relativistic nuclear dynamics.

The following main results were obtained in the field of *nuclear structure theory*:

Based on the Q-phonon representation of the wave functions of low-lying collective states, the properties of the lowest dipole two-phonon states and $E1$ transitions between low-lying levels in spherical nuclei were analyzed. Several relations between different reduced matrix elements of $E1$ transition operator were derived. These relations qualitatively explain correlations between experimentally measured data on $E1$ transitions [32].

A «decay-out» phenomenon of the yrast superdeformed states in nuclei ^{190,192,194}Hg and ^{192,194,196}Pb was studied in a cluster model. The model was based on the assumption that highly deformed cluster-type shapes were produced by a collective motion of the nuclear system in the charge asymmetry coordinate. As follows from the analysis, a sudden transition from the superdeformed minimum to the normal deformed minimum occurs because of the crossing of superdeformed band with the nearest neighbouring excited normal deformed band and spreading of collective states among the compound states [33].

A temperature dependence of the spreading width of a giant dipole resonance was studied in the microscopic approach combining the quasiparticle–phonon model and the formalism of the thermofield dynamics. Numerical calculations were made for ^{120}Sn and ^{208}Pb compound nuclei at temperatures of up to 3 MeV. The spreading width was found to increase with temperature following the experimental observation. The reason for this effect is the coupling of collective dipole states with the very low lying particle–particle and hole–hole states appearing only at finite temperatures [34].

Average yrast moments of inertia at high spins, where the pairing correlations are expected to be largely absent, were found to deviate from the rigid-body values. The gross dependence of moments of inertia and shell energies on the neutron number in terms of both the semiclassical periodic orbit theory and the level bunching in the calculated single-partical spectra in the rotating Woods–Saxon potential was interpreted. It was shown that the ground-state shell energies, nuclear deformations and deviations from rigid-body moments of inertia were all due to the same periodic orbits [35].

Moreover, new results were obtained in theoretical investigations of *nuclear reactions*.

The production cross section for the heaviest nuclei $Z = 108-118$ in the ^{48}Ca-induced hot fusion–evaporation reactions was shown to depend on the neutron number of actinide target. In the actinide-based reactions, the most neutron-rich targets available for the experiment lead to smaller cross sections. New optimal reactions for the synthesis of superheavy nuclei were suggested. The production of superheavies in hot fusion reactions on targets with a smaller neutron number would be important as additional confirmation of superheavy nuclei with charge numbers $Z = 112-116$ synthesized in hot fusion reactions, because the alpha-decay chains end in the region of known nuclei [36].

A direct derivation of the structure of a two-body operator for spin-$1/2$ particles in the framework of nonrelativistic dynamics was carried out. The two-body operator, compatible with invariance under basic symmetries and Galilean frame transformations, splits into two parts that are even and odd with respect to the space reflection. The partial wave decomposition for coefficient functions, valid on and off shell, was explicitly deduced. The momentum transfer representation and angular momentum decomposition for general spin-dependent potentials were obtained [37].

An expression was obtained for the complex nucleus–nucleus scattering potential which fully reproduces the high-energy scattering amplitude of the Glauber–Sitenko theory. Moreover, for the real part, the double-folding potential was calculated including the exchange term. The potentials were used for composing the microscopic nucleus–nucleus optical potentials. The method was successfully applied in calculations of the total reaction cross sections of the light exotic nuclei $^{6,8}\mathrm{He} + {}^{28}\mathrm{Si}$ which were compared with the recent data from the Flerov Laboratory of Nuclear Reactions at JINR [38].

A variety of problems were under study within the project *Few-Body Physics*. The corresponding results are:

Properties of weakly bound small helium clusters attract considerable attention, in particular because of the booming interest in Bose–Einstein condensation of ultracold gases. Advanced calculations were performed for the scattering length of collisions of ^{3}He and ^{4}He atoms with $^4\mathrm{He}_2$ dimers. These investigations were based on the hard-core version of the Faddeev differential equations. As compared to the previous calculations of the same quantity, much more refined grids were employed, providing an improvement of about 10% [39].

A new adiabatic approach for the description of three charged particles in the continuum was suggested. This approach is based on the Coulomb–Fourier transformation of a three-body Hamiltonian which allows one to develop a scheme alternative to the Born–Oppenheimer one. The approach appeared as an expansion of the kernels of the corresponding integral transformations in terms of a small mass-ratio parameter. The results were presented for the system ppe in the continuum. The wave function of the system was compared with the one which is used for the estimation of the rate for a triple reaction $p+p+e \to d+\nu$, which takes place as a step of the pp cycle in the centre of the Sun [40].

By using the dynamical model DMT (Dubna–Mainz–Taipei) and the unitary isobar model MAID, a new partial wave analysis of pion photo- and electroproduction from threshold up to total energy $W < 2$ GeV was carried out. In addition, the older data from the world data base and recent experimental results from

JLab for $Q^2 = 1$ (GeV/c)^2 were analyzed. As a result, the new Q^2 dependence of the e.m. helicity amplitudes was extracted for the most important nucleon resonances. It was found that the contributions from the pion degrees of freedom to the e.m. resonance amplitudes had to be subtracted in comparison with the quark models results [41].

A time-dependent approach to the study of the Coulomb breakup in two clusters in scattering on a charged target was developed. It allowed one to perform, for the first time, a «direct» calculation of the muon stripping at the deceleration of the muonic helium atom in deuterium. With this approach, the stripping and excitation cross sections were also calculated for collisions of an atomic helium atom ($n < 4$) with a proton [42].

The main results of the project *Relativistic Nuclear Dynamics* were:

A 3-fluid hydrodynamic model was developed for simulating heavy-ion collisions at incident energies between a few and about 200 $A \cdot$GeV. In addition to two baryon-rich fluids, the new model incorporates evolution of a third, retarded baryon-free fluid created by this decelerated baryonic matter. Different equations of state, including those with the deconfinement phase transition, were treated. A reasonable agreement with experiment was illustrated by proton rapidity spectra, their dependence on collision centrality and beam energy [43].

It was shown that the cross sections of the Θ^+-pentaquark production in different processes decrease with energy faster than the cross sections of production of conventional three-quark hyperons. Therefore, the threshold region with an initial energy of a few GeV or less seems to be more favourable for the production and experimental study of the Θ^+ pentaquark [44].

Within an effective meson–nucleon theory, the Okubo–Zweig–Iisuka rule was analyzed in processes of vector meson production in threshold-near elementary nucleon–nucleon collisions $pp \to ppV$, $pn \to pnV$ and $pn \to dV$ ($V = \omega, \phi$). It was shown that a set of effective parameters could be established to explain fairly well the available experimental data on angular distributions and the energy dependence of the total cross sections without explicit implementation of the Okubo–Zweig–Iisuka rule violation. Isospin effects were considered in detail and compared with experimental data [45].

In theoretical studies of metallic clusters the following result was obtained:

Infrared quadrupole modes of the valence electrons in light deformed sodium clusters were studied by means of the time-dependent local-density approximation. The modes are unambiguously related to specific electron-hole excitations and provide a direct access to the single-electron spectra near the Fermi surface. Most of the modes are determined by cluster deformation and can serve as a sensitive probe of the deformation effects in the mean field. It was shown that some two-photon processes, e.g., Raman scattering, stimulated emission pumping, and stimulated adiabatic Raman passage, could be implemented to atomic clusters to populate the infrared electron modes [46].

THEORY OF CONDENSED MATTER

Theoretical investigations in the *Theory of Condensed Matter* were continued in the framework of the following projects:

- Strongly correlated systems;
- Dynamical systems: chaos, integrability, and self-organization;
- Disordered structures: glasses, topological defects, nanostructures and the Josephson junction;
- Mesoscopic and coherent phenomena in quantum systems.

Main results in the field of *strongly correlated systems* were obtained in studies of electronic spectrum and magnetic properties of materials with strong electron correlations like transition metal oxides. A number of important new results were obtained, among which are the following:

A valence bond crystal was considered within an effective spin-orbital Hamiltonian for threefold-orbitally-degenerate spin one-half pyrochlore lattices. It was shown that the orbital degrees of freedom could modulate the spin exchange removing the infinite spin-degeneracy of the ground state characteristic of pyrochlore structures. The theory provides an explanation for the helical spin-singlet pattern observed in the B-spinel $MgTi_2O_4$. It was proposed to use the resonant X-ray spectroscopy for experimental observation of the orbital ordering in a phase like this [47].

A new method based on the dynamical mean-field theory for calculation of optical and transport properties of Ce, CrO_2, $LaTiO_3$ materials was proposed and implemented. In Ce calculations the old question of the physical origin of the $\alpha \to \gamma$ transition in Ce was addressed. It was found that the Kondo collapse model described the optical data better than a Mott transition picture. The full temperature dependence of the optical spectra was predicted [48].

A superexchange theory was developed for a three-dimensional spin one-half antiferromagnet to explain a competition between «vertical» and «diagonal» interplane magnetic bonds in manganese oxide Sr_2GaMno_{5+x}. Based on this theory, a natural explanation was obtained for a transition, observed in neutron scattering experiments, between two magnetic structures generated by a chemical substitution in $Sr_2GaMn(O,F)_6$ compound [49].

In the field of the theory of *dynamical systems: chaos, integrability, and self-organization*, the Bethe ansatz solution for discrete time zero-range and symmetric exclusion processes with fully parallel dynamics was presented. The model depends on two parameters: p, the probability of single particle hopping, and q, the deformation parameter, which in a general case obeys $|q| < 1$ and is responsible for the long-range interaction between particles. The particular case $q = 0$ corresponds to the popular Nagel–Schreckenberg traffic model. The largest eigenvalue of the equation for the generating function of the distance travelled by particles was evaluated. For the case $q = 0$ the result was obtained for an arbitrary size of the lattice and a number of particles. In the general case, $|q| < 1$, the model in the scaling limit was considered and the universal form specific of the Karadar–Parizi–Zhang universality class was obtained. The phase transition occurring in the limit $p \to 1$ when $q < 0$ was described [50].

The normalization identity for the totally asymmetric exclusion process on an infinite lattice and on a ring was derived. The sum of conditional probabilities over all possible final positions of particles at time t, given arbitrary initial positions at time $t = 0$, was calculated. A method of derivation of the normalization identity can be used for the evaluation of correlation functions of the exclusion process [51].

In the investigations of *disordered structures* the following main results were obtained:

The effect of pentagonal defects on the electronic structure at the tip of the carbon nanohorns was investigated within the continuum gauge field-theory model. It was found that the existence of a localized electron state at the Fermi level (a true zero-mode state) resulted in the enhanced charge density near the tip [52].

It was shown that the transformation properties of the mean-field slave boson/fermion order parameter under an action of the global $SU(2)$ group impose certain restrictions on their applications to describe the phase diagram of the t–J model [53].

Using a single-plaquette approximation of the overdamped two-dimensional Josephson Junction Arrays (2D-JJA) model, a pronounced step-like structure observed in the temperature dependence of AC susceptibility in artificially prepared 2D-JJA of unshunted Nb–AlO_x–Nb junctions was explained by assuming that steps were related to the geometric properties of the plaquette [54].

The main topics of *mesoscopic and coherent phenomena in quantum systems* covered the expansion of basic quantum effects to the cases of finite (mesoscopic) systems.

The comprehensive description of coherent spin relaxation was given. The theory of nuclear spin superradiance was developed and the experimental observations of this phenomenon were considered. The intriguing problem of how coherence develops from initially incoherent quantum fluctuations was analyzed. All main types of coherent radiation by nuclear spins were discussed, which are: free nuclear induction, collective induction, maser generation, pure superradiance, triggered superradiance, pulsing superradiance, punctuated superradiance, and induced emission. The influence of electron-nuclear hyperfine interactions and the role of magnetic anisotropy were studied. Conditions for realizing spin superradiance by magnetic molecules were investigated [55].

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

In 2004, a new scientific-educational project, DIAS-TH, was successfully launched. The main goal of DIAS-TH is organization and supervision of all educational programmes for students, postgraduates, and young researchers at BLTP; support of the JINR experimental programmes by organizing lecture courses and review lectures on new trends in modern physics. The following activities in the framework of DIAS-TH were:

• 2nd Winter School on Theoretical Physics (30 January — 7 February), supported by RFBR;

• Advanced Summer School on Modern Mathematical Physics (4–18 July), jointly organized with ITEP; supported by RFBR, the Heisenberg–Landau programme (HLP), Grant of the Plenipotentiary of Ukraine;

• International summer school and workshop «Hot Points in Astrophysics and Cosmology» (2–13 August), supported by RFBR, HLP, Helmholtz Association;

• International school «Selected Topics in Nuclear Theory» (20–29 July), jointly organized with the JINR University Centre; supported by RFBR, HLP and the Votruba–Blokhintsev programme;

• VIII research workshop «Nucleation Theory and Applications» (1–31 October), supported by RFBR, HLP, UNESCO (ROSTE);

• VI International Physical Competition for Schoolchildren (19–22 December), jointly with ITEP and Moscow Centre for Continuous Mathematical Education;

• Lecture course on Quantum Chromodynamics was given at the Laboratory of Particle Physics;

• Lecture course «Contemporary Problems in Quantum Field Theory of Dense Nuclear/Quark Matter» was given at the JINR University Centre;

• Web-site of DIAS-TH was created (http://thsun1.jinr.ru/dias/).

COMPUTER FACILITIES

The stack of network switches was extended by installation of 48-port Gigabit Ethernet switch. This made it possible to connect all Linux servers via Gigabit Ethernet and to connect PC at Gigabit speed. Hardware of servers THEOR, THPROXY and UNAMP was upgraded. User's home directories, e-mail, WWW-server were moved to THEOR. The WWW access to e-mail was arranged: https://theor.jinr.ru/mail/. RFBR funded purchase of two dual-processor servers based on 64-bit AMD Opteron. These servers are equipped with 8 and 6 GB of RAM. Nineteen personal computers based on Pentium 4 were acquired for work places upgrades. The color laser printer HP Color LaserJet 2550 was purchased.

MEETINGS, SCIENTIFIC COLLABORATION

In 2004, besides of the schools organized in the framework of DIAS-TH, the Laboratory participated in the organization of 6 international conferences held in Dubna, Prague, and Moscow.

The international conference «Problems of Theoretical and Mathematical Physics» dedicated to the 95th anniversary of Nikolai Nikolaevich Bogolyubov was held on 2–6 September in Moscow and Dubna. The conference was organized by JINR and the Russian Academy of Sciences with the support of RFBR and UNESCO Office in Venice — the Regional Bureau for Science in Europe.

The conference opened on 2 September at the Steklov Mathematical Institute of RAS, and on 3 September the conference moved to Dubna, where it continued its work at the Bogoliubov Laboratory of Theoretical Physics. The conference was attended by more than 120 participants from 15 countries. The topics of the reports presented at the conference were related to modern problems of mathematics and nonlinear mechanics, quantum field theory and elementary particle theory, statistical physics and kinetics — exactly those to which N. N. Bogoliubov made a decisive contribution.

In 2004, the Laboratory participated in the organization of the XVII International Baldin Seminar on High Energy Physics Problems (27 September — 2 October, Dubna) and 3 conferences in Prague: «Quantum Groups and Integrable Systems» (17–19 June), «Symmetry Methods in Physics» (21–24 June) and «Symmetries and Spin» (5–10 July).

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The agreements for collaboration between the Bogoliubov Laboratory and CERN TH, ICTP are functioning.

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