JOINT INSTITUTE FOR NUCLEAR RESEARCH

2000-312

A. T. Filippov

ANNUAL REPORT

BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

Report to the 89th Session
of the JINR Scientific Council
January 18–19, 2001

Dubna 2000

A. T. Filippov

ANNUAL REPORT

BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

Report to the 89th Session
of the JINR Scientific Council
January 18–19, 2001

Dubna 2000

1 SCIENTIFIC RESEARCH

1.1 Fields and Particles

The theme includes a wide range of researches on modern topics in quantum field theory and particle physics. The following fields of studies were of main importance:

- Quantum symmetries, integrable models, supersymmetries with application to strings, gravity, and cosmology;
- Nonperturbative approaches to QCD;
- Standard Model and its extension;
- QCD: spin effects, sum rules and vacuum structure;
- Low energy quark models.

Integrable models continue to play an essential role in present-day investigations in string and M-theories, in gauge theories, and in quantum gravity.

A new insight into the nature of symmetries and, as a consequence, into the origin of complete integrability of the supersymmetric Toda lattice equations is achieved. The conjecture concerning the possibility of a superfield formulation of the $N = (2|2)$ supersymmetric Toda lattice hierarchy, proposed earlier, is proved, and the algebras of corresponding symmetries are exactly derived. An infinite class of new two-dimensional supersymmetric Toda-type hierarchies is considered. [V.G. Kadyshesky, A.S. Sorin, Preprint JINR E2-2000-270, nlin. SI/0011009; to be published in Proceedings of the NATO ARW "Integrable Hierarchies and Modern Physical Theories"(Chicago, USA, July 22 - 26, 2000), Kluwer Academic Publishers].

A universal functional equation is derived for the eigenvalues of integrals of motion for a wide class of discrete three-dimensional quantum integrable models, associated with the Weyl algebra at the root of unity. In the most simple cases, this equation is equivalent to the Baxter's $T - Q$ equation and, in general, to the complete "nested Bethe ansatz" chain of equations. [S.M. Sergeev, Theor. Math. Phys. **124** (2000) 1187-1201].

Till now the supersymmetry remains the most appealing idea in the theory of elementary particles. A series of interesting results were obtained in this area. The worldvolume superfield equations of motion for the $N = 1, D = 4$ supermembrane as well as for the space-filling D2- and D3-branes are derived from nonlinear realizations of supersymmetries. A new polynomial representation for the $d = 3, 4$ Born-Infeld equations, with merely a cubic nonlinearity, was proposed [S. Bellucci, E. Ivanov, S. Krivonos, Phys. Lett. **B482** (2000) 233-240].

A most complete version of conformal $N = (4, 4)$, 2D supergravity was for the first time constructed, by using the $N = (4, 4)$, 2D harmonic superspace. This

supergravity theory is important to know for unambigous construction of the superstrings with the worldvolume $N = (4,4)$ supersymmetry [S. Bellucci, E. Ivanov, Nucl. Phys. **B587** (2000) 445-480].

The dynamics of an $N = 4$ spinning particle in a curved background is described by using the N=4 superfield formalism. The anti-de-Sitter spaces are shown to belong to the class of admissible manifolds [E.E. Donets, A. Pashnev, V.O. Rivelles, D. Sorokin, M. Tsulaia, Phys. Lett. **B 484** (2000) 337].

Contractions play a significant role in the theory of finite-dimensional integrable systems providing relating such systems in curved and flat spaces. By using the Inönü–Wigner contractions from the rotation group $O(n)$ into the Euclidean group $E(n)$, asymptotic relations are derived for the matrix elements between eigeenfunctions of the Laplace–Beltrami operator corresponding to the separation of variables in the coordinates of subgroups on an n-dimensional sphere of arbitrary n [A.A.Izmest'ev, G.S. Pogosyan, A.N. Sissakian and P. Winternitz, accepted J. Phys.A].

In the framework of solving an inverse problem for reducing polynomial Hamiltonians to the normal form, the method of construction of a class of integrable models is formulated on the basis of symbolic computational algebra package of REDUCE [N.A. Chekanov, V.A. Rostovtsev, Y. Uwano, S.I. Vinitsky, Comput. Physics. Commun. **126** (2000) 47].

Noncommutative gauge field theories play an important role in the nonperturbative string dynamics. The dynamics of excitations along brane vacuum realised by noncommutative solitons was studied. These excitations are described by a nonlinear sigma-model, for which classical solutions and statistical behaviour in the limit of small noncommutativity were found [E.E. Donets, A.P. Isaev, C. Sochichiu and M. Tsulaia, hep-th/0011090, accepted to JHEP].

The quantum gravity remains a challenge to theoreticians. A new method for describing quantum field effects near rotating black holes and, more generally, on any stationary space-time was developed. The idea of the method is to go to an equivalent problem where the background itself is static, but there is an additional gauge connection corresponding to the rotation. This transition from one problem to another is similar to the Kaluza-Klein approach. The new method has a number of important applications. For instance, it enables one to derive the thermal part of the stress-energy tensor of quantum fields near the horizon of the Kerr-Newman black hole. Analogous derivation by other methods is extremely difficult because of complexity of the corresponding geometry [D.V. Fursaev, hep-th/0006217, Nucl. Phys. B, to appear].

The effective method was developed for constructing the spectral zeta functions in quantum field theories and quantum gravity with allowance for boundary conditions possessing spherical or cylindrical symmetries. For this purpose, the contour integration is used in the complex frequency plane as well as the uniform asymptotic expansions and the addition theorems for the Bessel functions. In this approach, the renormalization procedure is elaborated which leads to a finite value of the vacuum

energy in the problems under consideration [V.V. Nesterenko and I.G. Pirozhenko, J. Math. Phys. **41** (2000) 4521].

The reparametrization-invariant description of relativistic strings is developed by resolving the energy constraints. The method leads to a new continual representation of the causal Green functions and gives a new algebra of local constraints [B.M. Barbashov, V.N. Pervushin, JINR preprint E2-2000-100, submitted to J. of Phys. A; M. Pawlowski, V.N. Pervushin, hep-th/0006116, submitted to Int. J. Mod. Phys. A].

The lattice simulations remain the most powerful nonperturbative method in QCD and other gauge theories. The special effect of zero-momentum modes (ZMM) of the gauge field on the gauge dependent fermion correlators was studied. It was found that the standard Lorentz gauge fixing prescription in lattice theory provides gauge copies with ZMM. The Lorentz gauge employing nonperiodic gauge transformations in order to suppress the ZMM (the ZML gauge) allows one to reach the global maximum of the Lorentz gauge functional. Furthermore, it provides a reliable fermion mass determination, at least, if the hopping parameter κ is chosen not too close to the chiral critical line $\kappa_c(\beta)$. In this approach, a complete solution to the Gribov copy problem in the quenched lattice QED was proposed in the Coulomb (i.e., physical) phase [V.K. Mitrjushkin, Pis'ma v ZheTF, **72** (2000) 45; Nucl. Phys. Proc. Suppl. **83** (2000) 515; I.L. Bogolubsky, V.K. Mitrjushkin, M. Muller-Preussker, P. Peter and N.V. Zverev, Phys. Lett. **B476** (2000) 448].

A self-consistent scheme — Analytic Perturbation Theory (APT) — is devised that relates a renorm-invariant, effective coupling functions $\tilde{\alpha}(s)$ and $\alpha_{an}(Q^2)$. Non-power perturbation expansions are constructed for observables in Minkowskian (time-like) and Euclidean domains, that are free of extra singularities and obey better convergence in the infrared region. The basic tool is the "double spectral representation", similar to the representation for Adler function, that stems from first principles of local QFT. A global APT scheme is constructed for the real QCD case in the whole space-like and time-like domain with various numbers of active quarks. The effect of π^2–terms in the APT expansions for the s–channel QCD effective coupling and observables and its influence on the numerical values of $\bar{\alpha}_s$ extracted from experiments are analyzed. The main result is that the common two-loop (NLO, NLLA) approximation widely used in the five-quark ($\sqrt{s} \gtrsim 10$ GeV) region for a shape analysis contains a systematic negative 1–3 per cent error for the extracted $\bar{\alpha}_s^{(2)}$ values. The physical conclusion is that the $\bar{\alpha}_s(M_Z^2)$ value averaged over the $f = 5$ data $< \bar{\alpha}_s(M_Z^2) >_{f=5} \simeq 0.124$ appreciably differs from the currently accepted "world average" ($= 0.118$). [D.V. Shirkov, JINR preprint E2-2000-46, hep-ph/0003242; JINR preprint E2-2000-211, hep-ph/0009106, submitted to *Europ.J.Phys.*; JINR preprint E2-2000-298, submitted to TMPh].

Analytic perturbation theory was applied to describe the inclusive decay of the τ-lepton. It was argued that this method gives not only a self-consistent description of the process in the timelike region (by using the initial expression for R_τ) and in the spacelike domain (by using the analytic properties of the hadronic correlator), but

also makes it possible to essentially reduce theoretical uncertainties associated with unknown higher-loop contributions and renormalization scheme dependence [K.A. Milton, I.L. Solovtsov, O.P. Solovtsova, V.I. Yasnov, Eur. Phys. J. **C14** (2000) 495].

Studies were continued on the minimal supersymmetric standard model (MSSM). Soft supersymmetry breaking was examined in the superfield formalism. It is shown that it initiates soft masses for the auxiliary fields which enter into the renormalization group equations for scalar superpartners. Explicit solutions for masses of nonphysical particles are obtained up to three-loop order in the general case and in the MSSM. An arbitrariness in the choice of initial conditions is discussed [D.I. Kazakov, V.N. Velizhanin, Phys. Lett. **B485** (2000) 393, hep-ph/0005185].

The role of higher orders in the $b \to s\gamma$ decay rate in the MSSM was discussed. It is shown that, if higher orders are taken into account, one can enlarge the allowed region in the MSSM parameter space. The range of possible values of the Higgs boson mass in the MSSM is found to be $m_h = 115 \pm 3(stop\ mass) \pm 1.5(stop\ mixing) \pm 2(theory) \pm 5(top\ mass)$ GeV. This is valid for any value of $\tan\beta$ greater than 20. The values of $\tan\beta$ smaller than 3.3 are eliminated by the direct Higgs boson non-observation [W. de Boer, M. Huber, A. Gladyshev, D.I. Kazakov, hep-ph/0007078, submitted to Proceedings of the ICHEP'00, Osaka, 2000].

Studies in QCD proceed to supply theoretical description of new, more subtle properties of hadronic processes. The spin azimuthal asymmetries recently observed in semi-inclusive hadron production on longitudinally (HERMES) and transversely (SMC) polarized targets were explained *without using any free parameters.* This explanation is based on preliminary experimental data from DELPHI on the left-right asymmetry in the fragmentation of transversely polarized quarks ("Collins effect") and the theoretical calculation of the proton transversity distribution in the effective chiral quark soliton model.

On this basis, one can state that the proton transversity distribution could be successfully measured in future DIS experiments with *a longitudinally* polarized target, simultaneously with measuring the spin gluon distribution $\Delta g(x)$, for example, in the COMPASS experiment [A.V. Efremov, K. Goeke, M.V. Polyakov, and D. Urbano, Phys. Lett. **B478** (2000) 94; hep-ph/0001119].

The basic hard exclusive processes: $\pi\gamma * \gamma$ - transition, pion and nucleon electromagnetic form factors were analyzed, and the analytic continuation of QCD formulas from the spacelike to the timelike region of the relevant momentum transfers was performed. It was shown that for the hard perturbative QCD contribution to the hadronic form factors, there are no K-factor-type enhancements. The soft part of the pion electromagnetic form factor was studied in a QCD sum rule inspired model, and it was shown that there exist noncanceling Sudakov double logarithms which result in a K-factor-type enhancement in the timelike region. Such an enhancement is supported by experimental data, thus providing another evidence that at present energies the hadronic form factors are dominated by the soft mechanism [A.P. Bakulev, A.V. Radyushkin and N.G. Stefanis, Phys. Rev. **D62** (2000) 113001].

The twist-3 contribution to Deeply Virtual Compton Scattering was investigated. As a result, the manifestly gauge invariant amplitude at the order $1/Q$ was obtained, and the respective contributions to the spin asymmetries were calculated. The result is further developed in several papers (Polyakov et al. Belitsky and Muller, Radyushkin and Weiss) and may be important for a simultaneous description of spin asymmetries recently reported by HERMES and CLAS/E1 [I.V. Anikin, B. Pire and O.V. Teryaev, Phys. Rev. **D62** (2000) 071501].

Principles and physics on photon-photon colliders were reviewed. Main attention was paid to the nonlinear effects in the process of backward Compton scattering of circularly polarized laser beams focused on the bunch of high-energy longitudinally polarized electrons. The photon-photon luminosity and polarization characteristics are obtained. Also, the calibration processes were reviewed. The physical program on photon colliders is discussed in a conspective form [M. Galynski, E. Kuraev, and M. Levchuk, Part. & Nuc. **31** (2000) 157].

A detailed next-to-next-to-leading order (NNLO) QCD analysis was performed for the experimental data of the CCFR collaboration for the xF_3 structure function. It was found that the amplitude of the x-shape of the twist-4 factor decreases in NLO and NNLO, though some remaining twist-4 structure seems to retain in NNLO in the case when statistical uncertainties are taken into account. The NNLO results for $\alpha_s(M_Z)$ values, extracted from the CCFR xF_3 data, are $\alpha_s(M_Z) = 0.118 \pm 0.002(stat) \pm 0.005(syst) \pm 0.003(theory)$ provided the twist-4 contributions are fixed through the infrared renormalon model and $\alpha_s(M_Z) = 0.121^{+0.007}_{0.010}(stat) \pm 0.005(syst) \pm 0.003(theory)$ provided the twist-4 terms are considered as free parameters [A.L. Kataev, G. Parente and A.V. Sidorov, Nucl. Phys. **A666** (2000) 184].

The phenomenology approach successfully combines rigorous formalism with additional theoretical ideas and experimental facts. In a chiral $U(3) \times U(3)$ quark model, if radial excitations of quarkonia are taken into account, it is shown that the experimentally observed scalar meson states in the energy interval from 0.4 to 1.7 GeV can be interpreted as members of two scalar meson nonets: the ground state and radially excited, and a glueball ($f_0(1500)$). In a $U(3) \times U(3)$ quark model without radially excited quarkonia, the glueball is introduced into the effective meson Lagrangian, by using the dilaton model. Masses and main strong decay modes of the scalar mesons were described [M.K. Volkov, V.L. Yudichev, Yad. Fiz. **63** (2000) 1924; D. Ebert, M. Nagy, M.K. Volkov, V.L. Yudichev, Eur. Phys. J. **A8** 567 (2000)].

It was shown that the absolute normalization of the pion form factor asymptotics predicted by perturbative QCD is expressed in terms of the fundamental QCD vacuum parameter, the quark nonlocal condensate [I.V. Anikin, A.E. Dorokhov, Lauro Tomio, Phys. Lett. **B475** (2000) 361].

In the linear sigma model, the chromo-electic abd chromo-magnetic polarizabilities of pions by the gluon field were found, and on that basis, the $\pi J/\Psi$ cross section was estimated in the scattering length approximation to be $\sigma(\pi J/\Psi) \approx 1.9\ \mu b$

[S.B. Gerasimov, in Hadron Physics: Effective theories of low-energy QCD, Coimbra, Portugal, 1999, ed. A.H. Blin et al., AIP Conf. Proc. N508, 2000].

The so-called relativistic three-quark model (RTQM) was elaborated to study the properties of heavy baryons containing a single heavy quark (bottom or charm). Physical observables for the semileptonic and nonleptonic decays as well as for the one-pion and one-photon transitions were successfully described in this approach. It was found that the semileptonic decay rates are clearly affected by the choice of currents, whereas the asymmetry parameters show only a very weak dependence on the choice of currents. The RTQM was also extended to include the effects of finite quark masses [M.A. Ivanov, J.G. Körner, V.E. Lyubovitskij, M.A. Pisarev, A.G. Rusetsky, Phys. Rev. **D61** (2000) 114010].

* * *

In the nearest future, the investigations will be continued along the following directions:

in "Pure theory":

Nonperturbative methods in quantum field theories (duality, lattice simulations in gauge theories, instanton effects,....); nature of the symmetries of classical and quantum field theories (gauge symmetries, supersymmetries, quantum symmetries, ...); gauge theories on non-commutative spaces; integrable dynamical systems; superstring and brane models - unification of all interactions; classical and quantum gravity.

in Particle physics:

The Standard Model application and higher order calculations of physical processes; spin and polarization phenomena, hadron dynamics in QCD, structure of QCD vacuum, low x physics in deep inelastic scattering; nonforward deep inelastic scattering, heavy quark dynamics and B-physics; physics beyond the Standard Model; unification models and low energy supersymmetery; CP violation, neutrino physics; physics at hadron colliders.

1.2 Theory of Nuclei and Other Finite Systems

In 2000, investigations within the area "Theory of Nuclei and Other Finite Systems" were carried out in accordance with four projects. Namely,

- Nuclear Structure under Extreme Conditions
- 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.

A systematic microscopic study of the anharmonic properties of the double giant dipole resonance (DGDR) was carried out, for the first time, for nuclei with mass number A spanning the whole mass table. It was concluded that the corrections to the energy centroid of the $J^\pi = 0^+$ and 2^+ components of the DGDR from its harmonic limit are negative, have a value of an order of a few hundred keV and follow an A^{-1} dependence [V.Yu. Ponomarev, P.-F. Bortignon, R.A. Broglia, and V.V. Voronov, Phys. Rev. Lett. **85** (2000) 1400]. A self-consistent random phase approximation for finite Fermi systems was extended to finite temperatures within the framework of the thermo field dynamics. A nonlinear coupling of the thermal Hartree-Fock equations with the equations of motion for the collective variables appearing due to a nonvanishing amount of thermal quasiparticles in the thermal phonon vacuum state was taken into account explicitly. The thermal occupation numbers were also calculated in a consistent way with the energies of the Hartree-Fock quasiparticles. Numerical calculations for the two-level exactly solvable Lipkin model demonstrated that within the thermal SCRPA a statistical behaviour of the system is described with appropriate accuracy at any temperature even if the Hartree-Fock field is fixed at its "spherical" configuration [A.I. Vdovin, A.N. Storozhenko, BgNS Transactions **5** (2000) 157]. It is observed experimentally that an isomeric ratio (IR) for ^{137}Ba and ^{139}Ce equals about 0.13 while in ^{141}Nd and ^{143}Sm it is less than half the size. To explain this effect, the structure of the excited states in the energy region up to 6.5 MeV was calculated within the quasiparticle - phonon model. The single-particle component of the wave function is responsible for the large values of the transitions. The calculated value of IR is in very good agreement with the experimental data for all the four nuclei. A slightly different value of maximum energy with which the nuclei rest after a neutron decay of the giant dipole resonance is responsible for the reported effect of the A dependence of the IR [N. Tsoneva, Ch. Stoyanov, Yu.P. Gangrsky, V.Yu. Ponomarev, et al., Phys. Rev. **C61** (2000) 044303 (9 pages)]. Nuclear structure model based on the U(6/12) graded algebra describes a nuclear system with collective quadrupole excitations and odd particle occupying single - particle states with angular momenta j=1/2,3/2 and 5/2. It was shown that although in the general case the model Hamiltonian does not obey a dynamic symmetry, part of the eigenstates of even–even and odd neighboring nuclei form supersymmetric multiplets [R.V. Jolos and P. von Brentano, Phys.Rev. **C62** (2000) 034310 (7 pages)]. The self-consistent harmonic oscillator model including the three-dimensional cranking term was extended to describe collective excitations in the random phase approximation. It was found that quadrupole collective excitations associated with the wobbling motion in rotating nuclei led to the appearance of two- or three-dimensional rotation [W.D. Heiss and R.G. Nazmitdinov, Pis'ma ZhETP, **72** (2000) 157] Global properties of dinuclear systems treated as two touching nuclear clusters were compared with the corresponding quantities of super- and hyperdeformed nuclei. It was found that the hyperdeformed states of nuclei were close to those of nearly symmetric nuclear systems, whereas the superdeformed states could be considered as the states of asymmetric dinuclear sys-

tems. The super- and hyperdeformed states constructed from two touching clusters have large octupole deformations [T.M. Schneidman, G.G. Adamian, N.V. Antonenko, S.P. Ivanova, W. Scheid, Nucl. Phys. **A671** (2000) 119]. The nuclear theory methods were also applied in theoretical studies of metallic clusters.

An orbital quadrupole magnetic resonance (twist mode) was predicted in alkali metal clusters where it was represented by $I^\pi = 2^-$ low-energy excitations of valence electrons with strong M2 transitions to the ground state. The shell structure of clusters was fully exploited, which is crucial for the considered region of sizes ($8 \leq N_e \leq 1314$). In medium and heavy spherical clusters the twist mode dominates over its spin-dipole counterpart and becomes the strongest multipole magnetic mode [V.O. Nesterenko, J.R. Marinelli, F.F. de Souza Cruz, W. Kleinig and P.-G. Reinhard, Phys. Rev. Lett., **85** (2000) 3141]. Various problems were investigated within the project Few-Body Physics

The resonance transparency of repulsive barriers for bounded pairs of particles was studied. It was shown that a local minimum of the total potential generates metastable bound states, and their spectrum determines the positions of maxima in the penetration probability. Another conclusion is that the probability of tunnelling of two interacting particles from a false vacuum can be considerably larger than it was assumed before [F.M. Pen'kov, JETP **118** (2000) 806]. The mechanism of formation of the Efimov states of the helium ^{4}He trimer was studied when the force of the interatomic interaction was changed. It was shown that the Efimov levels arised from virtual levels which were in turn formed from (quasi)resonances settled on the real energy axis. The resonances including virtual levels are calculated by the method based on solving the boundary value problem, at complex energies, for the Faddeev differential equations describing the scattering processes ($2+1 \to 2+1; 1+1+1$). Moreover, it was shown that the excited state of the trimer was indeed a Efimov state [E.A. Kolganova, A.K. Motovilov, Computer Phys. Commun. **126** (2000) 88]. Effect of a drastic change of the Auger decay rate due to the wave-function mixture was predicted for long-lived states of the antiprotonic helium. The effect takes place for the states whose energy is close to that of the specific short-lived ones. In the fall of 2000, after revival of the experimental programme in CERN, this prediction has been confirmed by the ASACUSA collaboration [O.I. Kartavtsev, D.E. Monakhov, S.I. Fedotov, Phys. Rev. **A61** (2000) 062507]. Elastic ηd scattering was considered within the AGS formalism for various ηN input data. A three-body resonant state was found close to the ηd threshold. This resonance is sustained for different choices of the two-body ηN scattering length $a_{\eta N}$. The position of the resonance moves towards the ηd threshold when $\mathrm{Re}\, a_{\eta N}$ is increased and it turns into a quasibound state at $\mathrm{Re}\, a_{\eta N} = 0.733$ fm [N.V. Shevchenko, V.B. Belyaev, S.A. Rakityansky, S.A. Sofianos, W. Sandhas, Eur. Phys.J. **A9** (2000) 143]. From the analysis of the recent JLab data for the reaction $p(e,e'p)\pi^0$ it was found that up to $Q^2 = 4.0(\mathrm{GeV/c})^2$ the extracted $\Delta(1232)$ resonance helicity amplitudes $A_{3/2}$ and $A_{1/2}$ remained comparable with each other. This implies that the hadronic helicity is not conserved and that the pQCD limit is not yet reached at the above range of

Q^2 [S.S. Kamalov, S.N. Yang, Nucl. Phys. **A663** (2000) 405].

At the end, let us enumerate the main results of the project Relativistic Nuclear Dynamics.

An analytic expression for the eikonal phase for the typical nuclear potential of the symmetrized Woods-Saxon shape was obtained. This expression can be widely applied in the analysis of intermediate energy nucleus-nucleus collisions at dozens of MeV/nucleon, thus permitting one to analyze the mechanism of scattering and perform fast numerical calculations [V. Lukyanov, E. Zemlyanaya, J. Phys.G: Nucl. Part. Phys., **26** (2000) 357]. A production of ϕ mesons in the near-threshold region using throughout the conventional "non-strange" dynamics was analyzed. The occurrence ϕNN interaction may show up in different unpolarized and polarization observables in the $\pi N \to N\phi$ reaction. A strong nontrivial difference between observables in the reactions $pp \to pp\phi$ and $pn \to pn\phi$ caused by the different role of the spin-singlet and triplet in the entrance channel was found. A series of predictions for the experimental study of this effect was presented [A.I. Titov, B. Kaempfer and B.L. Reznik, Eur. Phys.J. **A7** (2000) 543]. A quantum statistical model of nuclear multifragmentation was proposed. The model exhibits the first order phase transition. Quantum statistics effects are clearly seen on the microscopic level of occupation numbers but are almost washed out for global thermodynamic variables and the averaged observables studied. In the latter case, the recurrence relations for multiplicity distributions of both intermediate-mass and all fragments were derived and the specific changes in the shape of multiplicity distributions in the narrow region of the transition temperature was stressed [A.S. Parvan, V.D. Toneev and M. Ploszajczak, Nucl. Phys. **A676** (2000) 409].

* * *

In the nearest future the studies within the area will be concentrated on nonlinear models of nuclear structure in cold and hot nuclei; manifestation of sypersymmetry in nuclear spectra; mechanisms of nucleus- nucleus collisions at intermediate energies; resonance effects in various few-body physics; properties of η-nuclei; nuclear multifragmentation at high energies; investigation of fingerprints of "hidden" strangeness in proton.

1.3 Theory of Condensed Matter

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

- Strongly correlated systems;
- Dynamic systems: chaos, integrability and self-organization;
- Disordered structures: glasses, topological defects, nanostractures and Josephson junction;

- Mesoscopic and coherent phenomena in quantum systems.

In the studies of **strongly correlated systems** models with strong electron correlations were investigated to elucidate physical properties of materials with complicated metal-insulator, magnetic and superconducting phase transitions like manganites, vanadates and cuprates.

An explanation of a "giant" oxygen isotope effect is suggested for the Curie temperature T_c recently observed in (La-Pr-Ca)MnO_3 manganites. The proximity of the ferromagnetic transition to the dielectric antiferromagnetic phase enables one to explain the experimental data by considering only weak electron-phonon interaction for the charge carriers [N.M. Plakida, JETP Letters, **71** (2000) 491-493].

The theory of magnetic superexchange is developed for a cuprate family member $Ba_3Cu_2O_4Cl_2$ and the quater-filled two-leg ladder system NaV_2O_5. By formulating the multiorbital Hubbard model and reducing it to the effective spin Hamiltonian the ground-state magnetic properties of the cuprate compound were analysed and additional noncollinear modulation of the antiferromagnetic structure was predicted [V. Yushankhai, M. Wolf, K.-H. Muller, et al., Phys.Rev. **B62** (2000) 14229-14236].

It is found numerical evidence for the coexistence of metallic and insulating dynamical mean field theory solutions in a half-filled single-band Hubbard model in the Bethe lattice [V. Oudovenko et al., Phys. Rev. Lett. (submitted)].

Superconducting pairing in the periodic Anderson model for d- and f-electrons was investigated. The singlet superconductivity was suggested due to interplay of Kondo coupling, interorbital tunneling, nonlinear correlations and on-site Coulomb repulsion [V.A. Moskalenko, P. Entel, et al., Phys. Rev. **B** (submitted)].

A phenomenological approach determining the critical temperatures for homologous series of mercuro-cuprates depending of number of copper-oxygen layers was proposed which provided a quantitative explanation of the experiments [A.L. Kuzemsky, I.G. Kuzemskaya, A.A. Cheglokov, J. Low Temp. Phys.**118** 147 (2000)].

In the field of the theory of **dynamical systems: chaos, integrability and self-organization** the following results should be mentioned.

By an inversion symmetry, it was shown that in the Abelian sandpile model the probability distribution of dissipating waves of topplings that touch the boundary of the system shows a power-law relationship with critical exponent 5/8. The probability distribution of those dissipating waves that are also last in an avalanche has an exponent of 1. Extensive numerical simulations not only support these predictions, but also show that inversion symmetry is useful for the analysis of the two-wave probability distributions [Chin-Kun Hu, E.V. Ivashkevich, Chai-Yu Lin and V.B. Priezzhev, Phys. Rev. Lett., **85** (2000) 4048].

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

A field-theory model was formulated to describe electronic states of a fullerene-like molecule. An existence of exactly one zero-energy mode due to a disclination was predicted. For 60° disclination the normalized electron density at zero energy

was found to behave as $R^{-5/3}$ with R being the fullerene radius [V.A. Osipov and E.A. Kochetov, JETP Letters **72** (2000) 199].

The asymptotical behaviour of the vortex-like solutions was studied in the framework of the gauge model of disclinations in elastic continuum. For 2π vortices, an important role of two characteristic lengths appearing in the gauge theory of defects was established [M. Pudlak and V.A. Osipov, Nonlinearity **13** (2000) 459].

The pronounced crossover in the thermal conductivity from T to T^2 due to phonon scattering by biaxial wedge disclination dipoles of finite length was found at low temperatures. [S.E. Krasavin and V.A. Osipov, Phys. Letters **A277** (2000) 245].

Low-frequency magnetic noise spectrum of a granular superconductor was calculated within the model of $3D$ random overdamped Josephson junction arrays. The existence of both white noise and flicker-like noise contributions was predicted [S.A. Sergeenkov, Journal of Superconductivity **13** (2000) 895].

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

Concerning the Bose-condensation theory, T_c for Bose-condensation of trapped atoms was found to depend on the deformation of the trap by the gravitational field due to the barrier cut-off and the re-definition of the atomic spectrum. The $2D$ Bose-condensation T_c shift caused by the gravity increases from $\sim 5 \cdot 10^{-7}$K in the initial trap up to $\sim 2 \cdot 10^{-6} K$ in the deformed trap for the same number of atoms and the trap volume. This example predicts the probable nonstability of properties for mesoscopic devices planned to be used in the outer space [D. Baranov, V. Yarunin, JETP Lett. **71** (2000) 384].

The short-range particle correlations were considered for a dilute Bose gas with an arbitrary strong repulsion within the thermodynamically consistent model proposed earlier. This allowed for deriving correct values of the kinetic and interaction energies of the system involved. Found results are in agreement with the data of the Monte-Carlo calculations for the hard-sphere Bose gas [A.Yu. Cherny, A.A. Shanenko, Phys. Rev. **E62** (2000) 1646].

The polaron energy and the effective mass are calculated for an electron confined in a symmetrical finite quantum well constructed of $GaAs/Al_xGa_{1-x}As$ layers. To simplify the study an approximate model is developed in which parameters of a medium are averaged over the ground-state wave function. The authors obtained a rather monotonous behavior of the polaron energy as a function of the confining potential width and found a peak of the effective mass [M.A. Smondyrev, B. Gerlach, M.O. Dzero, Phys. Rev. **B62**, 15 December issue (2000)].

A complicated electrodynamics for strongly correlated systems of atoms, phonons and nuclears was elaborated [V.I. Yukalov, Phys. Elementary Particle and Nucleus, **31** (2000) No 5].

Methods were developed for classical and quantum spin systems with toroid polarization in addition to the magnetic one. The generalized Maxwell equations for media with two toroid electric and magnetic polarizations were proposed, and

patents were taken out for some mesoscopic setups based on the proposed theory. Dynamic description of the electromagnetics in mesoscopic, low-dimensional systems, and cyclic molecules were performed. The applications were found in the most fundamental fields of physics related to the problems of quantum gravity [V.M. Dubovik, M.A. Martsenyuk, B. Saha, Phys. Rev. **E61** (2000) 7087].

* * *

In the nearest future investigations in the field of Condensed Matter will continue according to the lines described above.

In particular, it is planned to study: quasiparticle dynamics and phase transitions in the basic models with strong electron correlations; dynamic systems and self-organized criticality, one-dimensional stochastic transport; structural, spin and superconductive glasses, topological defects in membranes and nanostructures; quasiparticle spectra in quantum wells, wires and dots, Bose-Einstein condensation in quantum liquids and in magnetic traps.

2 COMPUTER FACILITIES

For the first time at the BLTP, the server with two processors Alpha with the clock rate 750 MHz was installed (*http : //thsun1.jinr.ru/guide/alpha*) Peak productivity of 3 GFlops and 2 GB of the RAM allows one to solve, with the new computer, the most complicated problems with the use of Fortran, C, C ++, Reduce, Form.

With the purpose of improving the performance of the computer network at BLTP, the first stage of a new cabling system based on a twisted pair (UTP) was developed. The high-speed Fast Ethernet switch was installed. The first stage of the UTP network covers about 100 rooms at BLTP and provides connection to the switches for more than 200 computers. Now, the new cabling system allows to connect, via Fast Ethernet, all of BLTP servers and about 30 most powerful PCs (*http : //thsun1.jinr.ru/guide/lan/lan*$_2$*000.png*).

During 2000, there were purchased and installed 13 modern personal computers based on the Pentium-III. On the cluster of workstations, the transition to the Solaris 7 operating system was completed, and some packages of the applied software were refreshed. The object-oriented system ROOT developed at CERN for the numerical calculations and graphical representations of results was installed. Creation of the guide to computer resources of BLTP was started (*http : //thsun1.jinr.ru/guide*).

The resources of the JHEP server (*http : //jhep.jinr.ru*), the accelerator of access to *xxx.itep.ru*(*http : //thsun1.jinr.ru* : 1081) and a file archive (*http : //thsun1.jinr.ru/file − archive.html*) were extended. The search engine for the keyword-based document retrieval from the archive was installed. The caching proxy-server was started (the configuration file - *http : //thsun1.jinr.ru/proxy.pac*). This development became possible due to funding from RFBR (The Russian Foundation for Basic Research).

3 CONFERENCES AND MEETINGS

1. IV-th Research Workshop "Nucleation Theory and Applications", (April, 3–28, Dubna).
2. V-th International Workshop on Heavy Quark Physics, (April, 6–8, Dubna).
3. International Conference "Nuclear Structure and Related Topics", (June 6–10, Dubna).
4. IX-th International Colloquium "Quantum Groups and Integrable Systems", (June 22–24, Prague, Czech Republic), jointly organized by BLTP, Czech Technical University, Charles University and LPTMC, University Paris 7.
5. Research Workshop "Calculations for Modern and Future Colliders", (July 9–23, Dubna).
6. International Workshop "Symmetries and Spin", (July 17–22, Prague, Czech Republic), jointly organized by BLTP and Charles University.
7. International Seminar "Supersymmetry and Quantum Field Theory", (July 25-29, Kharkov, Ukraine, jointly organized by BLTP and NSC KIPT).
8. XXIII-rd International Colloquium "Group Theoretical Methods in Physics", (July 31 – August 5, Dubna).
9. Research Workshop "Hot points in Astrophysics", (August 22–26, Dubna).
10. Research Workshop "Quantum Gravity and Superstrings", (August 28 – September 8, Dubna).
11. XV-th International Seminar "Relativistic Nuclear Physics and Quantum Chromodynamics", (September 25–29, Dubna), jointly organized by LHE and BLTP.

Preliminary Plans for 2001

1. V-th Research Workshop "Nucleation Theory and Applications", (April 2–28, Dubna).
2. IX-th International Conference "Supersymmetry and Unification of Fundamental Interactions", (June 11–17, Dubna), to be jointly organized by BLTP and LNP.
3. X-th International Colloquium "Quantum Groups and Integrable Systems", (June 21–23, Prague, Czechia), to be jointly organized by BLTP, Czech Technical University, Charles University and LPTMC, University Paris 7.
4. Research Workshop "Quantum Gravity and Superstrings", (June 18–28, Dubna).

5. IX-th International Conference "Symmetry Methods in Physics", (July 3–8, Yerevan, Armenia), to be jointly organized by BLTP and Univ. Yerevan.
6. VIII-th International Workshop on High Energy Spin Physics, (July 9–14, Dubna).
7. International Conference "New Trends in High Energy Physics", (September 8–15, Yalta, Crimea, Ukraine), to be jointly organized by BLTP and ITP NASU.
8. International Workshop "Supersymmetries and Quantum Symmetries", (September 17–22, Karpacz, Poland), to be jointly organized by BLTP and ITP Wroclaw.

4 SUMMARY

- In 2000, about 600 papers were published in the leading scientific journals, Proceedings of conferences and as preprints.
- A wide scientific collaboration is continued and expanded with scientific centres of Member States and other countries.

  In 2000, the international collaboration was supported by grants of the plenipotentiaries of the Czech Republic, Poland, the Slovak Republic, and Hungary; the collaboration with Polish theorists was based on the Bogoliubov–Infeld Programme. A new programme of collaboration with Czech theorists, the Blokhintsev–Votruba Programme, was established.

  Within the Heisenberg–Landau Programme more than 70 papers were published jointly with the colleagues from German scientific centres, 45 joint projects and 7 meetings obtained financial support from the HLP. Collaboration with the INFN sections (Italy), IN2P3 Institutes (France) and the CERN TH is continued.
- In 2000, 7 meetings organized by BLTP were supported by UNESCO.
- Grants of the scientific Funds: Programme of supporting the leading scientific school, National Programme of RF, RFBR–DFG (joint project), RFBR–INTAS (joint project), INTAS, RFBR, State Committee of the RF for Education.

Received by Publishing Department
on December 25, 2000.