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D. V. Shirkov

ANNUAL REPORT

BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

Report to the 83rd Session
of the Scientific Council of JINR
January 15–16, 1998

Dubna 1997

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At the Bogoliubov Laboratory of Theoretical Physics (BLTP), studies are carried out on the following three themes: "Fields and Particles", "Nuclear Theory", "Theory of Condensed Matter ".

Theoretical physicists also participated in realizing a number of the JINR experimental programmes and performed theoretical analysis of the obtained results. Below, we will present main results of studies on these themes in 1997.

1 SCIENTIFIC RESEARCH

1.1 Fields and Particles

The theme includes a wide range of researches on actual problems of quantum field theory and particle physics. At the beginning of 1997 the following fields of studies were defined to be of main importance

- Supersymmetry, quantum symmetries, and integrable models;
- Nonperturbative methods in gauge and gravity theories;
- Heavy flavours and B–physics;
- Spin physics in QCD.

Supersymmetric models continue to attract attention of investigators. Interesting results were obtained in applications of the harmonic superspace approach to studying geometric and quantum structure of supersymmetric gauge theories and sigma models.

The charged hypermultiplet low-energy effective action in the Coulomb branch of the $4D$, $N = 2$ gauge theory was computed by using the harmonic superspace approach. The unique leading contribution was found to be given by the harmonic-analytic Lagrangian of the fourth order in the hypermultiplet superfields, with the induced coupling constant being proportional to central charges of $N = 2$ SUSY algebra [E. Ivanov, A. Sutulin, Clas. Quan. Grav. **14** (1997) 843].

Integrable models play an essential role in recent investigations of superstrings, gauge fields, duality, and quantum gravity. SUSY, quantum and W-algebras provide effective tools for studying integrable systems and constructing new ones. Important results were obtained in elaborating and applying these new mathematical methods.

A matrix generalization of all the known $N = 2$ supersymmetric integrable systems was constructed by exhibiting the corresponding matrix super Lax operators in terms of $N = 2$ superfields [C. Ahn, E. Ivanov, and A. Sorin, Commun. Math. Phys. **18** (1997) 205].

The $N = 2$ supersymmetric matrix Toda lattice hierarchies relevant to constructing supersymmetric matrix models, the $N = 2$ matrix KP hierarchy and an infinite family of its reductions with a finite number of superfields were proposed. Their particular solutions, Hamiltonian structures, recursion operators, discrete symmetries

and Lax-pair representations were constructed [A.N. Leznov and A. Sorin, Phys. Lett. **B402** (1997) 87].

The algebra of observables of chiral Wess–Zumino–Novikov–Witten (WZNW) model (which serves as a building block for conformal field theories) has been investigated. Canonical quantization of the $SU(n)$ invariant chiral WZNW model is performed on the basis of the structural results obtained [L.K. Hadjiivanov, I.T. Todorov, O.V. Ogievetsky, A.P. Isaev, and P.N. Pyatov, Preprints: JINR E2-97-370; CPT-97/P.3570; IC/97/201; submitted to Jour. of Math. Phys.].

Conventional Woronowicz's formalism of bicovariant differential calculus on quantum groups is generalized so that its underlying Hopf algebra structure may be properly taken into account. It results in constructing a noncommutative bicovariant algebra of four basic objects within the calculus – coordinate functions, differential forms, Lie derivatives and inner derivations – as the cross-product algebra of two reciprocally dual graded Hopf algebras. This provides an adequate algebraic setting for earlier results of other authors, and produces several new formulas and the proof of the Cartan identity [O.V. Radko and A.A. Vladimirov, J. Math. Phys. **38** (1997) 5434].

The quantum form of the Birkhoff theorem is proved for the two-dimensional pure dilaton gravity and in particular for spherically symmetric pure gravity in d dimensions. A complete analysis of the corresponding quantum reduction of the field theory to a quantum mechanical system was carried out in the case of the string-inspired dilaton gravity model [M. Cavaglià, V. de Alfaro, A.T. Filippov, hep-th/9704164].

Interesting results were obtained in superintergable quantum mechanics (SIQM) which provides a convenient basis for conducting "experiments" in field theory, condensed matter physics, for combining investigations in quantum mechanics and topology. An important concept of electromagnetic duality was incorporated into the structure of SIQM. This point is of special value because electromagnetic duality plays the central role in gauge theories and may eventually lead to constructing a new nonperturbative approach [A. Maghakian, A.N. Sissakian, V.M. Ter-Antonyan, to be published in Phys. Lett. **A** 1997].

Nonperturbative methods in gauge theories mainly rely on lattice simulations and instanton models.

A new method for calculating the hadron masses in lattice QCD has been developed in collaboration with colleagues from Humboldt University (Berlin), DESY-Zeuten and Bielefeld University. The observables of interest are the π and ρ-meson correlators $\Gamma_{[\pi,\rho]}(\tau)$ and the corresponding masses $m_{[\pi,\rho]}$. All simulations were performed on a $16^3 \times 32$ lattice at $\beta = 6.0$. The method permits one to approach the chiral limit much closer than the standard ones [G. Cella, U.M. Heller, V.K. Mitrjushkin, and A. Vicere, Phys. Rev. **D56** (1997) 3896].

The contribution of the nonperturbative quark-gluon interaction induced by the instantons to the $g_1^p(x,Q^2)$ and $F_2^p(x,Q^2)$ structure functions is estimated. It is shown that nontrivial Q^2 dependence of the instanton contribution to $g_1^p(x,Q^2)$ allows us to explain the observed violation of the Ellis-Jaffe sum rule without involving a large positive gluon polarization [A.E. Dorokhov, S.V. Esaibegyan, N.I. Kochelev, and N.G. Stefanis, J. Phys. **G23** (1997) 643].

In the supersymmetric extension of the Standard Model and in quantum chromodynamics remarkable results were obtained.

The renormalization constants in softly broken supersymmetric gauge theory are investigated. It is shown that they become external superfields depending on the spurion field, their explicit form repeating that of the constants in a rigid theory with the redefinition of the couplings. This allows one to reproduce all the known results on the renormalization of soft couplings and masses in a softly broken theory [L.V. Avdeev, D.I. Kazakov, and I.N. Kondrashuk, hep-ph/9709397].

An analytical approach to the treatment of the ghost singularities in QCD is developed. In this framework an analytical model for the QCD running coupling constant is proposed which is ghost-free, stable with respect to multiloop contributions and also shows a good agreement with experimental data [D.V. Shirkov and I.L. Solovtsov, Phys. Rev. Lett. **79** (1997) 1209]. When applying to the process of e^+e^- annihilation into hadrons this approach enables one to obtain a new expression for the known ratio of the cross-sections $R(s)$ which is ghost-free and remarkably stable (as compared to the conventional perturbative approach) with respect to the renormalization scheme dependence for the whole low-energy region [I.L. Solovtsov and D.V. Shirkov, hep-ph/97011251].

An intriguing relation between the high energy QCD and exactly solvable models is established. Thanks to remarkable property of QCD reggezation, quarks and gluons are very likely to form new collective excitations, reggezied partons or reggeons, and QCD should be replaced by an effective reggeon theory in which reggeons play the role of new elementary fields. Thus the old reggeon field theory is revived at a new level. The first calculations of the reggeon scattering amplitudes revealed integrable structures and duality in high-energy QCD [G.P. Korchemsky, Nucl. Phys. **B498** (1997) 68].

Further insight into the spin dependent processes in the framework of QCD was achieved.

A main problem here is the gluon contribution to the proton spin which should be measured experimentally. It is possible to observe it in the charmonium hadroproduction with nonzero transverse momenta. It is shown that the color octet contribution is dominant in the asymmetries [O. Teryaev and A. Tkabladze, Phys. Rev. **D56** (1997) 7331].

The first observation of transverse handedness in diffractive production of pion triples in the process $\pi^-(40\,GeV) + A \to (\pi^-\pi^+\pi^-) + A$, using the old data of Magnetic Spark Chamber was reported. It was found that the handedness was rather large ($10 \pm 1\%$) and behaved like the transverse polarization, i.e., increases with p_T and x_F of the pion triple. This gives hope of measuring transverse spin distribution for nucleons in semi-inclusive deep inelastic scattering (DIS) with a forward pion triple production (e.g. at COMPASS) [A.V. Efremov, Yu.I. Ivanshin,

L.G. Tkatchev, and R.Ya. Zulkarneev, Rapid JINR Comm. **83** (1997) 5].

Studies of various aspects of hadron spectroscopy were continued.

A detailed description of semileptonic decays of heavy baryons was given within a relativistic quark model. The observables of bottom and charm baryons (Isgur-Wise functions, asymmetry parameters, decay rates and distributions) were calculated. The model-independent Bjorken-Xu inequalities for the Ω_Q baryon Isgur-Wise functions and their derivatives at the zero recoil point were verified. The description of recent experimental data on the $\Lambda_c^+ \to \Lambda^0 e^+ \nu_e$ decay measured recently by the CLEO Collaboration were accomplished [M.A. Ivanov, V.E. Lyubovitskij, J.G. Körner, P. Kroll, Phys. Rev. **D56** (1997) 348].

In the framework of the relativistic potential model, the masses of the lowest hybrid vector mesons composed of the $\bar{Q}Q$-pair ($Q = c, b$) and the valence gluon were calculated. For the first time the effects of mixing the hybrid states with usual $\bar{Q}Q$ - quarkonia in the ground states were taken into account [S.B. Gerasimov, Inv. talk at Int. Workshop "Progress in Heavy Quark Physics", Rostock, Germany, 20–22 Sep. 1997].

The important role of the intermediate sigma meson state at finite temperature and chemical potential is revealed when the threshold condition $M_\sigma = 2M_\pi$ is fulfilled in the decay channel $\sigma \to 2\pi$. This effect should enhance the pion annihilation $2\pi \to 2\gamma$ by a few orders as compared to the vacuum case and could be observed in heavy-ion collisions [E.A. Kuraev and M.K. Volkov, to be published in Yad. Fiz.].

A series of precision calculations of the electro-weak corrections for elastic e^+e^- scattering to small and large angles were carried out.

These processes are important for calibration of the luminosity of meson factories and for taking into account the background in processes with hadron generation. The calculations are done up to the two-loop level in the framework of the electroweak theory. The results were represented in terms of the structure functions with the allowance for the nonleading contributions [A.B. Arbuzov, E.A. Kuraev et al., Nucl. Phys. **B483** (1997) 83].

Interesting predictions were obtained for neutrino physics.

The long-baseline neutrino oscillations were investigated in the framework of the available two spectra. Model independent bounds were obtained on probabilities of neutrino transitions in new long-baseline experiments (CHOOZ, Palo Verde, KEK-Super-Kamiokande, MINOS, ICARUS) [S.M. Bilenky, C. Giunti, W. Grimus, Proc. TAUP97, Sep 7–11, 1997, IASSNS-AST 97/67; hep-ph/9711432].

1.2 Nuclear Theory

Main efforts in the field "Nuclear theory" in 1997 were focused on the following subjects:

- Relativistic nuclear physics
- Exotic nuclei and atoms

- Mechanisms of nucleus-nucleus collisions
- Structure of atomic nuclei at the extremes
- Applications of nuclear theory methods to other Fermi systems.

In the field of relativistic nuclear physics it was shown that some of the double polarization observables of ϕ-meson photoproduction were very sensitive to the hidden strangeness content of the proton. This is because the contributions from the direct knockout and the diffractive processes to these observables have very different spin (helicity) dependence. The optimal range of the initial photon energy to measure the $s\bar{s}$ component of the proton is expected to be around 2-3 GeV [A.I. Titov, Y. Oh, S.N. Yang, Phys. Rev. Lett. **79** (1997) 1634]. The deuteron disintegration reaction near threshold energies is an excellent paradigm to examine non-nucleonic degrees of freedom and relativistic effects. The nonrelativistic reduction of the Bethe-Salpeter amplitude for the deuteron electrodisintegration near threshold energies was investigated. This approach utilizing the first iteration approximation leads to results that exhibit the same analytical structure as the nonrelativistic result plus pair current corrections. [S.G. Bondarenko, V.V. Burov, M. Beyer, S.M. Dorkin, Preprint MPG-VT-UR 118/97, Rostock, 1997].

Methods of the few-body theory were applied to various physical problems. Rates of the Auger transitions for a number of states of antiprotonic helium ^{3,4,6}He$\bar{p}$e were calculated. A difference in the decay rates of the states in ^{3}He$\bar{p}$e and ^{4}He$\bar{p}$e was found to be 2-3 times. The reason of this strong isotopic effect is a dependence of a small component of the wave function of an electron with angular momentum L$\geq$2 on the mass of the helium isotope [O.I.Kartavtsev, S.I.Fedotov, D.E.Monakhov, Hyperfine Interactions **109** (1997) 125]. The knowledge of the production rates of various nuclei in the stellar plasma is very important in understanding the production of energy in stars, explaining the abundance of the elements observed in nature, etc. Burning of hydrogen in the main sequence stars mainly occurs through the pp-chain. A minor role of the nonradiative fusion reaction with the three-body initial state e + p + d $\to^3$He + e for the solar pp-chain has been established, but at the early stage of the Universe this reaction must have been significant [S.A.Rakityansky, S.A.Sofianos, L.L.Howell, M.Braun, V.B.Belyaev, Nucl. Phys. **A613** (1997) 132].

Different aspects of nucleus - nucleus collisions were studied. A restricted number of collective variables is used in the current models of fusion and deep inelastic heavy ion collisions at low energies. These are the distance between the centers of the colliding nuclei, the mass asymmetry and the neck parameter. The evolution of the latter during the initial stage of heavy ion collisions was studied within a dinuclear system concept (DNC). An oscillating behaviour of the neck with the small characteristic time of oscillations was obtained. This makes questionable the inclusion of the neck in the collective variable set [G.G. Adamian, N.V. Antonenko, R.V. Jolos, W. Scheid, Nucl. Phys. **A619** (1997) 241]. DNC was also applied to analyze reactions used for a synthesis of superheavy elements. Minimal excitation energies of compound nuclei with 102$\leq$Z$\leq$114 produced in cold fusion reactions were

calculated. It was shown that a production cross-section goes down with increasing Z mainly due to the quasifission processes [G.G. Adamian, N.V. Antonenko, V.V. Volkov, A.K. Nasirov, E.A. Cherepanov, W. Scheid, JINR Rapid Commun. 6[86]–97 (1997) 12]. The work was accomplished in collaboration with colleagues from FLNR JINR.

A large piece of work was devoted to the theory of nuclear structure at the extreme values of isospin, excitation energy and deformation. By the use of a model which describes ^{6}He as a three-body "α + neutron + neutron" cluster structure the new modes of halo excitation in the ^{6}He nucleus continuum, namely, the second 2^+ resonance, the soft dipole mode and unnatural parity modes were predicted [B.V. Danilin, T. Rogde, S.N. Ershov, ... and M.V. Zhukov, Phys. Rev. **C55** (1997) R577]. The work is a product of Russian – Nordic – British Theory Collaboration. The properties of vibrational states in the second minimum in ^{240}Pu were predicted. Collectivity of vibrational states in the second minimum is quite different from those in the first one. For example, summed E2 and M1 strengths in the 0-3 MeV energy range strongly reduce while the E1 strength increases by an order of magnitude [V.G. Soloviev, A.V. Sushkov, N.Yu. Shirikova, Z. Phys. **A358** (1997) 117]. A finite rank separable approximation for an effective interaction of the Skyrme type was proposed and used to study properties of vibrations in a long chain of the Ar isotopes including ones near the proton and neutron drip lines. It was found that a low-lying dipole component at ~7 MeV appeared in the A=48-52 isotopes due to the single-particle transitions. [N.V. Giai, Ch. Stoyanov, V.V. Voronov, Preprint IPNO/TH 97-33, Orsay 1997]. This work was done within the JINR-IN2P3 agreement. Within the formalism of thermo field dynamics a new approximation was proposed to describe a collective motion of a hot nuclear system. It takes into account the influence of temperature and collective motion parameters on the mean field as well as a nonvanishing number of thermal quasiparticles in a thermal ground state thus going beyond the thermal RPA. [A.I. Vdovin, D.S. Kosov, W. Nawrocka, Teor. Mat. Fiz. **111** (1997) 279].

It was continued to apply the nuclear theory methods in studying metallic clusters and quantum dots. A model for quantum dots was proposed in which the motion of a few electrons in a three - dimensional harmonic oscillator potential under the influence of a homogeneous magnetic field of arbitrary direction was studied. Dependence of the equilibrium shape of the quantum dot on the electron number, the magnetic field parameters, and the slab thickness was found [W.D.Heiss and R.G.Nazmitdinov, Phys. Rev. **B55** (1997) 16310].

A number of works in the field of quantum mechanics and electrodynamics was accomplished. Within a mathematically rigorous theory it was shown that in addition to the bremsstrahlung and Cherenkov shock waves, the electromagnetic shock wave arising from the accelerated (or decelerated) charge overcoming the light velocity barrier in the medium should be observed. The space-time regions where this shock wave exists and the conditions of its appearance were determined [G.N. Afanasiev, S.M. Eliseev, Yu.P. Stepanovski, JINR Rapid Commun. **1[81]–97** (1997) 13].

1.3 Theory of Condensed Matter

Theory of Condensed Matter covers a large field of investigations from purely applied topics to very sophisticated exactly solvable models which are of interest to mathematical physicists. It is also an important ground for quantum field theory and nuclear physics methods playing a role of a unifying field in theoretical physics as a whole.

In particular, in 1997 the major topics of investigation were:

- Strong electron correlations and high temperature superconductivity
- Models of self-organized criticality
- Physics of surfaces

In spite of unprecedented scientific activity there is still no consensus on the theoretical explanation of unusual normal state properties and mechanism of pairing in high temperature superconductors. To elucidate these problems models with strong electron correlations were studied.

In order to look for the competition between magnetism and conductivity one needs an adequate description of electron spin and charge variables in models with strong correlations. By representing these variables in path integrals for the partition functions of the $t-J$ and Anderson lattice models via the $SU(2|1)$ coherent states for Hubbard operators, it was shown that they cannot be, in general, separated in the $t-J$ model [E.A. Kochetov, V.S. Yarunin, Phys. Rev. **B56** (1997) 2703].

A new diagram approach elaborated earlier for strongly correlated systems was used to investigate the Hubbard-Holstein model of electrons which locally interact with a collective mode of optical dispersionless phonons. By using the Lang-Firsov canonical transformation the polaron hopping between lattice sites was discussed and the Dyson equation was established. [V.A. Moskalenko, Theor. Math. Phys. **111** (1997) 439].

A quasiparticle spectrum of doped holes and their superconducting pairing in the CuO_2 plane was studied within the $t-t'-J$ model. Numerical solution of the Eliashberg equations showed d-wave pairing of spin polarons mediated by spin-fluctuation exchange, as well as a strong doping dependence of a quasiparticle bandwidth. [N.M. Plakida, V.S. Oudovenko, P. Horsch, and A. Liechtenstein, Physica **C282–287** (1997) 1739].

A theoretical interpretation of the photoemission experiments in $Ba_2Cu_3O_4Cl_2$ was given with the aid of model calculations. They proved the presence of two different Zhang-Rice – one of which moves in the antiferromagnetically ordered cuprate-like Cu_AO_2 subsystem and the other – on the effectively paramagnetic sublattice formed of extra Cu_B atoms in this copper oxychloride. [M.S. Golden, H.C. Schmeltz, M. Knupfer S. Huffner, G. Krabbes, J. Fink, V. Yushankhai, et al. Phys. Rev. Lett. **78** (1997) 4107].

A weak-link structure of high-T_c superconductors is known to be important in understanding many unusual phenomena in these materials. In particular, some anomalies of magnetization are argued to originate from intrinsic weak links while the spontaneous orbital magnetic moments with the so-called "π junctions" are believed to be responsible for the "paramagnetic Meissner effect" in granular superconductors. An explanation of these phenomena was proposed by taking into account the dipole-dipole interaction between the orbital magnetic moments [S.A. Sergeenkov, Phys. Lett. **A225** (1997) 167]. and the appearance of a non-zero electric polarization and the related change of the charge balance in the system of weakly-coupled superconducting junctions under the influence of an applied magnetic field [S.A. Sergeenkov, J. Phys. I (France) **7** (1997) 1175].

In the field of Self-Organized Criticality a crucial role of exactly solvable models of the type of the Sandpile model was pointed out and relationship between Abelian sandpiles, spanning trees and the conformal field theory was proved.

The minimal recurrent configurations of the Abelian sandpile model on the hexagonal lattice related to the dynamics of a non-conservative sandpile model were investigated. The one-to-one correspondence between these configurations and the set of maximally oriented spanning trees on the triangular sublattice was constructed [D.V. Ktitarev, V.B. Priezzhev, J. Stat. Phys. **88** (1997) 781]. The model of self-organizing Eulerian walkers was numerically investigated on the square lattice. The critical exponents for the distribution of a number of steps (τ_l) and visited sites (τ_s) characterizing the process of transformation from one recurrent configuration to another are calculated using the finite-size scaling analysis. Two different kinds of dynamical rules are considered. The results of simulations show that both the versions of the model belong to the same class of universality with the critical exponents $\tau_l = \tau_s = 1.75 \pm 0.1$. [R.R. Shcherbakov, V.V. Papoyan, A.M. Povolotsky, Phys. Rev. **E55** (1997) 3686].

A striking relation between the critical phenomena and optimal control theory was discovered in investigations of a self–similar approximation theory. The method is based on a power–law algebraic transformation whose powers play the role of control functions governing the fastest convergence of the renormalized series. The critical indices are found to be directly related to limits of control functions at critical points. They were calculated for several difficult problems in good agreement with accurate numerical data. [V.I. Yukalov and S. Gluzman, Phys. Rev. Lett. **79** (1997) 333].

In physics of surfaces investigations of the absorption phenomena were continued. It was proposed for the first time to consider the non-pored surface streaming by the gas or liquid flow as an active one that can adsorb or desorb one of the constituents of the flow. Several problems were studied: the evolution of the activated complexes, the stohastization that appeared in the case of a random force acting in the adsorbate, and various types of non-equilibrium states. The results obtained were applied to the project of industrial plants to refine oil and gas and to analyze their constituents. [V.K. Fedyanin, I.V. Puzynin, and Kh.T. Kholmurodov, J. Phys.

Chem. **4** (1997) 698; **4** (1997) 702; Fluid Phase Equilibria **3365** (1997) 19].

2 COMPUTER FACILITIES

(Project "SPEKTR")

In 1997, implementation of the project SPEKTR was in progress.

20 personal computers on processors Pentium 120 and 133 MHz, 2 computers on processors Pentium Pro 200 MHz and 4 laser printers of personal usage were purchased and installed.

Disk and main memory on the Netware server was increased. Total capacity of disks of the server is 9 Gigabytes. The computer network is being developed and new workplaces are created.

The software on a cluster of the workstation was updated (Servers Sun and Netware server). Package TeX/LaTeX, browsers Netscape and Internet Explorer were acquired and the package Jawa Workshop was installed. On the Sun server the new package of analytical calculations "M" was installed. The known system of analytical calculations MACSYMA was installed too. The mirror servers of electronic magazine JHEP (http: // jhep.jinr.ru) and Few-Body Systems (http: // few-body.jinr.ru) were carried out . The software "Apache" was installed to increase productivity of the laboratory,s WWW servers . The Harvest server was also installed to create database of the JINR web sites resources. The information about the meetings and conferences at BLTP is regularly updated for the current year. It provides also on-line registration.

The information about people at the laboratory is now available from both search engine (search robot) and alphabet list. The information includes name, office, phone, e-mail and URL of personal web page (if any).

3 CONFERENCES AND MEETINGS

- The 5th School–Seminar *"Secrets of Quantum and Mathematical Intuition" (Dubna, June 17–20).* More than 20 scientists and teachers from Russian Universities and Institutes took part in the School.

- 6-th International Colloquium *"Quantum Groups and Integrable Systems" (Prague, Czechia, June 19–21)*, jointly organized by Doppler Inst. of Czech Technical University, BLTP and Universite Paris VII. About 50 participants.

- IV International Symposium *"Dubna Deuteron-97" (Dubna, July 2–5)*, jointly organized by BLTP and LHE. About 100 participants from Russia, JINR and abroad. Supported by the Russian Foundation for Basic Research (RFBR).

- VII Workshop on *High Energy Spin Physics (SPIN 97) (Dubna, July 7–12)*, jointly organized by BLTP and LHE. About 100 participants from Russia,

JINR and abroad. Supported by RFBR and International Committee on High Energy Spin Physics Symposia.

- International Seminar *"Supersymmetries and Quantum Symmetries" (Dubna, July 22–26)* dedicated to V.I. Ogievetskii (6.08.1928–23.03.1996). More than 60 theorists from Russia, JINR and from abroad participated in the seminar. Supported by RFBR, Intrnational Centre of Fundamental Physics in Moscow and the Heisenberg–Landau Programme (HLP).

- VIIIth International Conference *"Symmetry Methods in Physics" (Dubna, 28 July – 2 August)*, dedicated to the 80th anniversary of Professor Smorodinsky's (30.12.1917–16.10.1992) birth. More than 150 participants from many countries and JINR. Supported by RFBR and the Ministry of Science and Technology of the Russian Federation.

- International School *"Strongly Correlated Systems and Critical Phenomena" (Dubna, August 26 – September 5)*. The school was attended by more than 40 young scientists from universities and institutes of Germany, Italy, Japan, Poland, Rumania, Russia, Taiwan, Ukraine and JINR. Work of the school was organized in the form of university's term and lectures by Professors from Georgia, Germany, Italy, Russia, Taiwan, Ukraine and JINR alternated with seminars where students gave their talks.

  Schools of that sort have become a good tradition for BLTP, and in recent years, also the JINR University Centre has participated in their organization. A specific features of the present school is a broad representation of scientists from Taiwan (8 students and 2 Professors) in its work.

  The school was conducted within HLP under support of RFBR and German Foundation "WE-Heraeus-Stiftung".

- International Symposium *"Atomic Nuclei and Metallic Clusters: Finite Many-Fermion Systems", (Prague, Czechia, September 1–5)*, jointly organized by Charles University (Prague, Czechia) and BLTP. About 70 participants.

- The International Conference *"Nuclear Structure and Related Topics" (Dubna, September 9–13)*. More than 100 participants from many countries and JINR. Supported by RFBR.

- IVth Workshop on *Progress in Heavy Quark Physics, Rostock (Germany), September 20–22)*, jointly organized by BLTP and German scientific centres within HLP. Both theorists and experimenters from collaborations ALEPH, ARGUS, ACCMOR, CLEO, and OPAL participated in the Workshop.

- The project "Research Workshops" successfully started in 1997 includes in particular:
  "Nucleation, Cluster Growth and Nuclear Multifragmentation" (Dubna, April

7–18), participants: Bulgaria (2), Czechia (1), Germany (1), Russia (7), Ukraine (2), JINR (5). Supported by JINR and HLP.
"Progress in Current Few–Body Problems" (Dubna, June 8 – July 6), participants: Belgium (1), Germany (3), Russia (7), USA (1), JINR (14). Supported by JINR and HLP.
"Deconfinement at Finite Temperature and Density" (Dubna, October 1–25), participants: Armenia (3), Belgium (1), Brasil (1), Germany (7), Poland (1), Russia (2), USA (2), JINR (10). Supported by JINR, HLP, NSF–DFG Program, Humboldt Foundation, and Volkswagen Foundation.
In addition, the Research Workshops were held in the framework of the International School "Strongly Correlated Systems and Critical Phenomena", the International Seminar "Supersymmetries and Quantum Symmetries", and the International Conference "Symmetry Methods in Physics".

Preliminary plans for 1998

1. *II-nd Research Workshop "Nucleation Theory and Applications", (April, two weeks, Dubna).*
2. *Workshop "Hadronic Atoms and Positronium in the Standard Model", (May 26–31, Dubna).*
3. *Workshop "Finite Quantum Systems", (June 2–11, Dubna).*
4. *7-th International Colloquium "Quantum Groups and Integrable Systems" (June 18–20, Prague, Czechia).*
5. *Workshop "Supersymmetry and Integrable Models", (June 28 – July 2, Dubna).*
6. *Workshop "Classical and Quantum Integrable Systems", (June 29 – July 4, Yerevan, Armenia).*
7. *International Conference "Problems of Quantum Field Theory", dedicated to the 90th anniversary of D.I.Blokhintsev (1908–1979), (July 13–17, Dubna).*
8. *School-Seminar "Self-similar Systems", (August 17–28, Dubna).*
9. *XIV International Seminar on High Energy Physics Problems, (August 24–29, Dubna).*
10. *Research Workshop "Spin Effects in QCD", (September 15–26, Dubna).*
11. *XI Seminar "Gravitational Energy and Gravitational Waves" (December 4–8, Dubna).*

4 SUMMARY

- The research personnel is about 180, half working on fixed-term contracts. The tendency of the last two years is a decrease in the number of permanent researchers and an increase in those working on contracts.

- In 1997, about 600 papers were published in the leading scientific journals, proceedings of conferences and as preprints.

- A wide scientific collaboration. As an example, for 1997, within the Heisenberg–Landau Programme more than 70 papers were published jointly with the colleagues from German scientific centres, 35 joint projects and 9 meetings have obtained financial support of HLP. In addition, collaboration with the INFN sections (Italy), IN2P3 Institutes (France), and the CERN TH is in progress.

  Theorists also participate in experimental programmes of JINR, CERN, DESY, GSI, CEBAF, and some other centers.

- In 1994, the External Council for Theoretical Physics (ECTP) was established under the BLTP Directorate whose members are well-known theorists from the leading centres. Three meetings of the ECTP were held; the third one was held on April 3–5, 1997. The BLTP research is carried out taking into account the analysis and remarks made at these meetings.

- Grants of the scientific Funds in the last two years: Programme of supporting the leading scientific school – 3, National Program of RF – 2, RFBR–DFG (joint project) – 3, RFBR–INTAS (joint project) – 3, INTAS,– 10 RFBR – 40, State Committee of the RF for Education – 4.

General accents for the near future

- Support of research in general aspects of Statistical Mechanics and Mathematical Physics which are of unifying character.

- Favoring of exchange with institutions of Member States. The project "Research Workshops" successfully started in 1997 will be continued; 3–4 workshops are intended to be held in 1998.

- Further efforts for attracting young researchers.