Laboratory "Elementary Particle Theory" - Annual Report 2011

Prof. Dr.Sc. Emil Nissimov (Head)

I. Principal Current Research Topics

The scope of current science research projects in the Laboratory embraces various major trends in modern theoretical and mathematical physics**.** It is centered around two principal broad range world-wide actively developing research areas **(a) studies of the quantum structure and geometric nature of the fundamental forces between elementary particles at (ultra-)high energies,** and **(b) studies of lepton-hadron interactions**. The principal research topics of the members of the Laboratory include:

(a) Gauge/gravity duality and integrability in string theory relevant for the Anti-de-Sitter/conformal-field-theory correspondence (*P. Bozhilov*);

(b) Globally conformal invariant field models (*I. Todorov, N. Nikolov*);

(c) Models of supersymmetric vertex algebras within the axiomatic approach to globally conformally quantum field theory (*N. Nikolov*);

(d) Lightlike branes in the physics of black holes, elementary particle physics and cosmology, in particular, new cosmological brane-world scenarios with lightlike brane "universes" (*E. Nissimov, S. Pacheva*);

(e) Black holes in higher-dimensional general relativity (*E. Nissimov, S. Pacheva, B. Ivanov*);

(f) Two-dimensional non-critical string models - obtaining exact results in Liouville gravity with matter in the presence of boundaries (*V. Petkova*)

(g) Applications of quantum group and conformal invariance to integrable models, generalized Hopf-type internal symmetries and superselection rules (*A. Ganchev, L. Georgiev, L. Hadjiivanov, T. Popov, I. Todorov*);

(h) Conformal and Schroedinger (super-)algebras in various dimensions - construction of boundary-to-bulk intertwining operators in (super-)AdS/CFT correspondence (*V. Dobrev, S. Mihov, S.Stoimenov*);

(i) Topological quantum computation with non-abelian anyons - applications of braid group representations to quantum computers (*L. Georgiev*);

(j) Applications of Lie superalgebras to noncanonical quantum systems (*T. Palev, N. Stoilova, V.Molotkov*);

(k) the spin structure of the nucleon (*E. Christova, D.Stamenov*);

(l) test for Physics beyond the Standard Model through effects of CP violation at the hadron collider at CERN, LHC, and at the planned e+e- collider (*E. Christova, E. Ginina*).

Further projects include applications of generalized functions of Colombeau for modeling of singularities (*B. Damyanov*), as well as supercomputer simulations (*N. Ilieva-Litova*).

II. International Collaboration

The research in above areas is carried out within a wide international collaboration, financed under bilateral research grants, with scientists from several leading world-renown institutions in various countries around the globe, whose current partial list icludes:

(1) *Algeria* – Centre Universitaire de Mascara;

(2) *Austria* – Erwin Schrödinger Institute for Mathematical Physics (ESI), Vienna; Institut für Hochenergiephysik der Universität Wien;

(3) *Belgium* – University of Ghent;

(4) *France* – C.E.A. Saclay (Gif-sur-Yvette), Institut des Hautes Etudes Scientifiques (Bur-

sur-Yvette); Université de Paris-Sud (Orsay), Ecole Polytechnique (Palaiseau), L.A.P.P. (Annecy); Université Paul Sabatier (Toulouse); Université Henri Poincaré (Nancy); Institut de Recherche Mathematique Avancée CNRS et Université de Strasbourg; Centre de Physique Théorique (Marseille);

(5) *Germany* – Institut für Theoretische Physik der Universität Göttingen; Technische Universität Clausthal; Max-Planck Institut für Mathematik, Leipzig; Institut für Theoretische Physik der Justus-Liebig-Universität, Giessen; Institut für Theoretische Physik der Universität Hamburg;

(6) *Ireland* – Dublin Institute of Technology

(7) *Israel* – Ben-Gurion University (Beer-Sheva);

(8) *Italy* – I.C.T.P. and S.I.S.S.A. (Trieste), University of Trieste; Rome University "Tor Vergata" & INFN;

(9) *Japan* – Osaka Prefecture University;

(10) *Marocco* – University Mohamed I (Oujda);

(11) *Republic of Korea* - Ewha University (Seoul);

(12) *Russia* – J.I.N.R. (Dubna);

(13) Switzerland - Theory Group of C.E.R.N. (Geneva); University of Geneva;

(14) *Ukraine* - Odessa National Polytechnic University; National Antarctic Centre, Kiev;

(15) *United Kingdom* – Imperial College, London;

(16) *United States of America* – Pennsylvania State University (Abington); CLASS12 Collaboration at Jefferson Laboratory, Newport News, VA; University of Massachusetts, Amherst.

Throughout 2011 the Laboratory has been visited by the following foreign scientists within various collaborative projects and academic agreements:

(1) Prof. Elliot Leader (Imperial College, London, United Kingdom);

(2) Prof. Eduardo Guendelman (Ben-Gurion University, Beer-Sheva, Israel);

(3) Prof. Karl Henning-Rehren (Institut für Theoretische Physik der Universität Göttingen, Germany);

(4) Prof. Jean-Louis Loday (Institut de Recherche Mathematique Avancée CNRS et Université de Strasbourg, France);

(5) Prof. Alexander Sidorov (J.I.N.R., Dubna, Russia).

In 2011 members of the Laboratory organized the ***IXth International Workshop "Lie Theory and Its Applications in Physics"*** (Varna, June 2011), attended by 80, mainly foreign, lecturers and participants from most European countries, U.S.A, Canada, Japan, Turkey and Israel, who delivered 63 lectures and talks, to be published in the **"Springer Proceedings in Mathematics"** (2012). The website of the Workshop is at http://theo.inrne.bas.bg/~dobrev/LT-9.htm

III. Project Funding

Members of the Laboratory have been participating in several large networks financed by the European Commission as well as in other international multipartner projects:

(a) TMD network ***"Mapping out the Transverse Structure of the Nucleon"*** of the FP7 Hadron Physics2 Project;

(b) EU 7-th Framework ***"Partnership for Advanced Computing in Europe"*** (PRACE AISBL) - projects RI-261557 and RI-283493;

(c) 3-node network (Clausthal-Leipzig-Sofia Cooperation), financed by the Alexander von Humboldt Foundation *"**Quantum systems related to noncommutative geometries, their symmetries and evolution equations**"*;

(d) ***France-Bulgaria Academic Exchange Program "Rila"*** - project No.112;

(e) ***Academic Exchange Agreement between Ben-Gurion University (Israel) and Bulgarian Academy of Sciences***;

(f) ***Korean Federation of Science and Technology*** - WCU (World Class Universities) Grant No. R32-2008-000-101300.

Furthermore, two groups of scientists from the Laboratory have earned two prestigious grants with significant funding from the Bulgarian National Science Foundation within the framework program "Ideas":

(g) ***"Quantum Structure and Geometric Nature of Fundamental Forces"*** – Bulgarian National Science Foundation (BNSF) Grant DO 02-257/2008 (in collaboration with Departments of Physics and Mathematics of Sofia University);

(h) "***Structure of the nucleon and lepton-nucleon processes***" – BNSF Grant DO 02-288/2008 (in collaboration with Laboratory " Mathematical Modeling in Physics" of the same Institute).

Also, members of the Laboratory participate in other multidisciplinary projects financed by BNSF:

(i) ***"Center of Excellence Supercomputer Applications"*** - BNSF Grant CVP02/2009;

(j) ***"Development of New MRI-Compatible PET Technologies"*** - BNSF Grant DO 02-183/2008;

(k) ***"High-Performance Supercomputer Computations"*** - BNSF Grant DRRP7RP02/13 (2010)

IV. Main Current Research Achievements in the Laboratory

In 2011 the members of the Laboratory (co)authored **61 scientific works** altogether, among them - 17 original papers in international science journals, 4 original papers and 2 science education papers in national science journals, 17 original full text contributions in international conference proceedings, the rest of the papers pending publication. Throughout 2011 scientific papers of Laboratory's members have received over **300 independent citations** in international science journals worldwide.

The research in the Laboratory is organized along four main Institute's projects as follows.

IV.1 Quantum field theory, quantum groups and quantum statistics

Coordinator: Assoc. Prof. Dr. Ludmil Hadjiivanov

Members: Acad. Ivan Todorov, Acad. Tchavdar Palev, Assoc. Prof. Dr. Alexander Ganchev, Assoc. Prof. Dr. Luchezar Georgiev, Assoc. Prof. Dr. Nedialka Stoilova, Assoc. Prof. Dr. Nikolay Nikolov, Assist. Prof. Dr. Todor Popov, Assist. Prof. Vladimir Molotkov

The research activity of the group has been devoted to the study of various (space-time and internal) symmetries and statistics naturally arising in quantum field theory (QFT), as well as to general quantum mechanical and quantum field theoretic problems like quantization and renormalization. Some recent discoveries like the quantum Hall effect and graphene have focused the attention of the physical community to processes described by low-dimensional models, opening the door to generalized (Hopf-like, or "quantum") symmetries and braid group (instead of "ordinary", permutational) statistics. Similar algebraic structures appear in the Connes-

Kreimer's approach to renormalization, the latter being a necessary ingredient of any QFT with non-trivial interactions. The modern treatment of these problems relates various branches of mathematics like algebra, functional analysis, differential geometry and combinatorics and so forms a remarkably rich area in mathematical physics. On the other hand, it aims to possible practical applications, e.g. in the field of (topological) quantum computing, that have attracted great interest recently.

A brief account of the scientific results in 2011 is given by the following list.

The configuration (x-)space renormalization of euclidean Feynman amplitudes in a massless quantum field theory has been reduced to the study of local extensions of associate homogeneous distributions. An operadic approach to the renormalization group was developed. Its relation to the combinatorial Connes-Kreimer approach was established.

The canonical quantization of the chiral Wess-Zumino-Novikov-Witten (WZNW) monodromy matrices, both the diagonal and the general one, requires additional numerical factors that can be attributed to renormalization. The field-theoretic and algebraic aspects of this phenomenon for the SU(n) WZNW model have been discussed, and it was shown that these quantum renormalization factors are compatible with the natural definitions for the determinants of the involved matrices with non-commuting entries.

The structure of the edge states' Hilbert space for a general disk-shaped fractional quantum Hall liquid has been investigated in the setup of a quantum Hall Fabry-Perot interferometer. The Hilbert space is explicitly decomposed into sums of tensor products of charged and neutral sectors and the introduction of Aharonov-Bohm flux modifies only the charged part. The price for this simplification is the appearance of special selection rules for pairing charged and neutral sectors depending only on the numerator of the quantum Hall filling factor. This decomposition together with the flux threading procedure allows us to analyze in detail the Coulomb blockade phenomena in the electronic Fabry-Perot interferometers.

An orthogonal basis of weight vectors for a class of infinite-dimensional representations of the orthosymplectic Lie superalgebra osp(1|2n) and for all irreducible covariant tensor representations of the general linear Lie superalgebra gl(m|n) has been introduced, which is a step towards an explicit construction of the parastatistics Fock space. A linear spin chain, for which the coupling strength contains two parameters was investigated. It was shown that the single fermion eigenstates of the Hamiltonian can be computed in explicit form. This leads to a closed form expression for the correlation function of the spin chain. Two new models for the finite one-dimensional harmonic oscillator were proposed, based on deformations of the Lie algebra u(2) extended by a parity operator, and a class of irreducible unitary representations of these algebras was constructed.

It was shown that, via the Tornike-Kadeishvili homotopy transfer theorem, the set of self-dual Young tableaux (fillings of Young diagrams symmetric with respect to the diagonal) is endowed with a structure of a homotopy commutative associative algebra C_∞ generated in degree 1. In the Woronowicz' approach to non-commutative differential geometry on a quantum group, the quantum tangent space carries the structure of a quantum Lie algebra. The quantum Lie algebras compatible with a given braiding (R-matrix) have been studied exhaustively, and solutions have been obtained for the examples with braiding given by the standard Drinfeld-Jimbo R-matrix (arising as the solution corresponding to the so called "ice condition" on the R-matrix entries) and the Cremmer-Gervais and boundary Cremmer-Gervais R-matrix (both arising as solutions of the so called "rime condition").

Two of the project members had a lecturing activity at the University of Sofia. A graduate

course on Quantization has been delivered by acad. I. Todorov at the Faculty of Physics (typed lecture notes have been also prepared), and a graduate course on Theory of operator algebras, by N. Nikolov at the Faculty of Mathematics (a preliminary version of the notes is available on the web). Another project member (T. Popov) has delivered lecture courses on theoretical and mathematical physics at the African University of Science and Technology, Abuja, Nigeria.

IV.2 Conformal and Superconformal Symmetry in String and Field Theory Models, Non-Standard Quantum Groups and Invariant Equations

Coordinator: Prof. Dr.Sc. Dr.Habil. Vladimir Dobrev
Members: Prof. Dr.Sc. Valentina Petkova, Prof. Dr. Orlin Stoychev, Assoc.Prof. Dr. Marian Stanishkov, Assoc.Prof. Dr. Stephan Mikhov, Assist.Prof. Dr. Stoimen Stoimenov

Summary of activities and results for 2011

● As a first attempt to apply 2d CFT techniques to the quantisation of strings on AdS_5 x S^5 it is shown that scalar 3-point correlators, computed in the literature in the supergravity approximation, are reproduced as a clasical limit of vertex operator operator correlators in 2d quantum affine conformal theories.
● We studied the so-called AGT correspondence between 4D N=2 super YM theories and 2D conformal field theories, in particular, the recurrence relation of the conformal blocks in N=2 super-conformal theories.
● We studied topological defects in 2d conformal field theories with application to the alternative quantum Liouville theory computation of the averages of Wilson and 't Hooft operators in 4d topological supersymmetric theories.
● We adapt earlier results on the classification of the positive energy unitary irreducible representations of the N-extended D=4 conformal superalgebras su(2,2/N). We apply these results to the classification of (1/N)-BPS and possibly protected states.
● We continue the project of systematic construction of invariant differential operators on the example of the non-compact algebras su(n,n). Our choice of these algebras is motivated by the fact that for n=2 this is the conformal algebra of 4-dimensional Minkowski space-time. Furthermore for general n these algebras belong to a narrow class of algebras, which we called 'conformal Lie algebras', which have very similar properties to the conformal algebras of n^2-dimensional Minkowski space-time. We give the main multiplets of indecomposable elementary representations for n=2,3,4, including the necessary data for all relevant invariant differential operators.
● The ageing algebra is a local dynamical symmetry of many ageing systems, far from equilibrium, and with a dynamical exponent z=2. Here, new representations for an integer dynamical exponent z=n are constructed, which act non-locally on the physical scaling operators. The new mathematical mechanism which makes the infinitesimal generators of the ageing algebra dynamical symmetries, is explicitly discussed for a n-dependent family of linear equations of motion for the order-parameter. Finite transformations are derived through the exponentiation of the infinitesimal generators and it is proposed to interpret them in terms of the transformation of distributions of spatio-temporal coordinates. The two-point functions which transform co-variantly under the new representations are computed, which quite distinct forms for *n* even and *n* odd. Depending on the sign of the dimensionful mass parameter, the two-point scaling functions either decay monotonously or in an oscillatory way towards zero.
● We studied the representations of the multiparameter quantum group deformation of the superalgebra gl(m/n).

IV.3 Modern Aspects in Gravity and String Theories

Coordinator: Prof. Dr.Sc. Emil Nissimov

Members: Prof. Dr.Sc. Svetlana Pacheva, Assoc.Prof. Dr. Plamen Bozhilov, Assoc.Prof. Dr. Boyko Ivanov, Assoc.Prof. Dr. Blagovest Damyanov, Assoc.Prof. Dr. Nevena Ilieva-Litova.

The theory of membranes and their higher-dimensional counterparts (*p*-branes), black hole and wormhole physics, as well as the integrability aspects within the context of gravity/gauge-theory duality is one of our primary research areas in view of their fundamental importance in modern non-perturbative string theory of elementary particles at ultra-high energies, in "string-inspired" cosmology and their applications to description of non-perturbative phenomena in condensed matter physics and (relativistic) hydrodynamics.

(IV.3a) *Lightlike Membranes in Black Hole Physics, Particle Physics and Cosmology*
(E. Nissimov, S Pacheva)

In a series of previous papers we have proposed a new class of brane theories which are qualitatively distinct from the standard Nambu-Goto type brane models and provide a systematic lagrangian description of lightlike branes. It is well known lightlike branes are of substantial interest in general relativity as they describe impulsive lightlike signals arising in various violent astrophysical events, e.g., final explosion in cataclysmic processes such as supernovae and collision of neutron stars. Lightlike branes also play important role in the description of various other physically important cosmological and astrophysical phenomena such as the “membrane paradigm” of black hole physics and the thin-wall approach to domain walls coupled to gravity. More recently they became significant also in the context of modern non-perturbative string theory. In our 2011 papers a variety of physically interesting results has been obtained:

(1) We have found a new physically interesting mechanism of spontaneous compactification of space-time – compactification of part of the space dimensions induced by a lightlike brane which serves as a “bridge” between a “normal” uncompactified universe and a compactified "tube-like" universe.

(2) We have proposed a concise general scheme for constructing solutions of Einstein-Maxwell-Kalb-Ramond gravity-matter system in bulk space-time interacting self-consistently with one or more (widely separated) codimension-one electrically charged lightlike branes. We presented several explicit classes of solutions with different physical interpretation as wormhole-like space-times with one, two or more ``throats", singularity-free black holes, brane worlds and space-times undergoing a sequence of spontaneous compactification-decompactification transitions. As a particularly interesting case we have obtained solutions describing lightlike braneworlds. Among other things the latter provide a natural explanation of the undetectability of (large) extra dimensions from the point of view of an observer confined to the lightlike brane "universe".

(3) We have studied gravity coupled to a special kind of a nonlinear electrodynamics, which is known to produce in flat space-time a QCD-like confining potential between charged fermions. We found the following new physically interesting features: (i) appearance of a constant vacuum radial electric field in charged black holes within Reissner-Nordström-de-Sitter-type and/or Reissner-Nordström-anti-de-Sitter-type space-times, in particular, in electrically neutral black holes with Schwarzschild-de-Sitter and/or Schwarzschild-anti-de-Sitter geometry; (ii) novel mechanism of dynamical generation of cosmological constant through the nonlinear gauge field; (iii) appearance of a confining-type effective potential in charged test particle dynamics in the

above black hole backgrounds.

(d) We have found further two physically interesting effects triggered by the above gravity/nonlinear-gauge-field system in the context of wormhole physics. First, Misner-Wheeler "charge without charge" effect is known to be one of the most interesting physical phenomena produced by wormholes. In our papers we found an opposite "charge-hiding" effect in wormhole physics, namely, that a genuinely charged matter source of gravity and electromagnetism may appear electrically neutral to an external observer. We showed that this phenomenon takes place when coupling the gravity/nonlinear-gauge-field system self-consistently to a charged lightlike brane as a matter source. The "charge-hiding" effect occurs in a self-consistent wormhole solution of the above coupled gravity/nonlinear-gauge-field/lightlike-brane system which connects a non-compact "normal" universe, (comprising the exterior region of Schwarzschild-de-Sitter black hole beyond the internal horizon), to a compactified Levi-Civita-Bertotti-Robinson-type "tube-like" universe" via a wormhole "throat" occupied by the charged lightlike brane. In this solution the whole electric flux produced by the charged lightlike brane is expelled into the "tube-like" universe and, consequently, the brane is detected as neutral by an observer in the "normal" Schwarzschild-de-Sitter universe. We have further generalized the above "charge-hiding" solution to a truly charge-confining wormhole solution by coupling the gravity/nonlinear-gauge-field system self-consistently to two separate oppositely charged lightlike branes. Namely, the latter system possesses a "two-throat" wormhole solution where the "left-most" and the "right-most" universes are two identical copies of the exterior region of the neutral Schwarzschild-de-Sitter black hole beyond the Schwarzschild horizon, whereas the "middle" "universe" is of generalized Levi-Civita-Bertotti-Robinson "tube-like" form with geometry $dS2 \times S2$ (dS2 being the two-dimensional de Sitter space). It comprises the finite-size intermediate region of dS2 between its two horizons. Both "throats" are occupied by the two oppositely charged lightlike branes and the whole electric flux produced by the latter is confined entirely within the middle finite-size "tube-like" universe - charge confinement completely analogous to QCD quark confinement.

(3b) *Integrability and finite-size effects in AdS/CFT* (P. Bozhilov).

In the framework of the semiclassical approach, we compute the normalized structure constants in three-point correlation functions, when two of the vertex operators correspond to "heavy" string states, while the third vertex corresponds to a "light" state. This is done for the cases when the "heavy" string states are finite-size giant magnons, carrying one or two angular momenta,. and for three different choices of the "light" state: dilaton operator, primary scalar operator, singlet scalar operator on higher string levels.

Also, we investigate finite-size giant magnons propagating on gamma-deformed AdS_4×CP^3 type IIA string theory background, dual to one parameter deformation of the N = 6 super Chern-Simoms-matter theory. Analyzing the finite-size effect on the dispersion relation, we find that it is modified compared to the undeformed case, acquiring gamma dependence.

(3c) *General Relativity and Astrophysics* (B. Ivanov)

The gravitation of spheres of anisotropic fluid with no acceleration is classified. All characteristics of the fluid are expressed through a master potential, satisfying an ordinary second order differential equation. New solutions are found and the classical results for perfect fluids and dust are derived as particular cases. Many uncharged and charged anisotropic solutions, all

conformally flat and some uniform density solutions are found. A number of solutions with linear equation among the tangential and the radial pressure are derived, including the case of vanishing tangential pressure.

(3d) *Mathematical Aspects* (B. Damyanov, N. Ilieva-Litova)

The modeling of singularities given by distributions or discontinuous functions by means of the generalized functions of Colombeau has proved useful in many problems posed by the physical phenomena, such as geodesics for impulsive gravitational waves, jump conditions in hyperbolic systems and others. The algebra ***G*** of generalized Colombeau functions enables modeling and algebraic operations with singularities and by means of the so-called association process – obtaining of results for singular products of Schwartz distributions. We have applied these methods to find generalized models in Colombeau algebra of the class of *k*-times differentiable functions with derivatives having singularity in a point. Several results are obtained for singular products of functions of that class and derivatives of the Dirac δ-function that exist as 'ordinary' distributions.

Three-dimensional Chern-Simmons theories on certain classes of product spaces nave been considered in the context of Kontsevich diagram technique. Based on the analysis of the corresponding induced representations of the algebra, the Knizhnik-Zamolodchikov connection in the Wess-Zumino-Witten theory appears to be related to the wave-function equation in such topological theories, with a finite number of classical sources added.

IV.4 Theory and Phenomenology of Elementary Particles and Their Bound States

Coordinator: Prof. Dr.Sc. Ekaterina Christova
Members: Assoc.Prof. Dr. Dimitar Stamenov, Assist.Prof. Dr. Elena Ginina, in collaboration with Prof. Dr.Sc. Dimitar Bakalov, Assoc.Prof. Dr. Mikhail Stoilov, Assist.Prof. Dr. Boyan Obreshkov from Laboratory "Mathematical Modeling in Physics"

(4a) *Partonic spin content of the nucleon and QCD* (E. Christova, D. Stamenov)

The study of the internal (partonic) spin structure of the nucleon, *i.e.*, how the nucleon spin is built up out from the intrinsic spin and orbital angular momentum of its constituents, quarks and gluons, is one of the main problems in high energy hadron physics. Substantial efforts, both experimental and theoretical, have been made to answer this question. Our present information about the spin structure of the nucleon comes mainly from polarized inclusive and semi-inclusive deep inelastic experiments at SLAC, CERN, DESY and JLab, polarized proton-proton collisions at RHIC and polarized photo-production experiments, and their treatment in the framework of Quantum Chromodynamics (QCD).

It is well known that in the absence of neutrino reactions only the sum of the polarized quark and anti-quark densities $[\Delta q_a(x,Q^2)+\Delta\overline{q}_a(x,Q^2)]$ can be fixed from the QCD analyses of the polarized *inclusive* deep inelastic lepton-hadron scattering (DIS) data. As a result, the part of the nucleon spin $1/2\,\Delta\Sigma(Q^2)$, which is the *sum* of the spins carried out by the quarks, $\Delta q_a(Q^2)$, and anti-quarks, $\Delta\overline{q}_a(Q^2)$, is well determined, while the contribution to the spin of the nucleon carried out by the gluons, $\Delta G(Q^2)$, is still poorly constrained. In order to separate the polarized quark and anti-quark densities, and to determine the individual quark and anti-quark spin

contributions $\Delta q_a(Q^2)$ and $\Delta\bar{q}_a(Q^2)$ to the spin of the nucleon, one has to include in the analysis the polarized semi-inclusive DIS processes (SIDIS) where a hadron *h* is detected in the final state. However, in the theoretical treatment of these processes new physical quantities appear – the fragmentation function (FFs) which describe the probability for a parton to form a given hadron *h*. So, the results on the polarized densities extracted from combined QCD analyses of the DIS and SIDIS data depend on our accurate knowledge of the fragmentation functions. At present different sets of FFs exist, obtained using different assumptions, which leads to significant disagreement among the available sets. It turned out that if one uses the DSS (de Florian, Sassot, Stratmann) set of FFs in such a combined QCD analysis, the polarized strange quark density $\Delta s(x,Q^2)$ is *positive* for most of the range of measured *x*, in contradiction with the *negative* $\Delta s(x,Q^2)$, obtained and confirmed from all the QCD analyses of the inclusive DIS data alone. The resolution of this conflict, called the strange quark polarization puzzle, is a big challenge to the further investigations. It was demonstrated (Leader, Sidorov, Stamenov) that the polarized strange quark density is very sensitive to the kaon FFs, and if the set of Hirai et al. fragmentation functions is used, the polarized strange quark density from the *combined* DIS and SIDIS data analysis turns out to be *negative* and well consistent with values obtained from the pure DIS analyses.

For solving this problem an alternative, model independent approach to FFs was suggested by E. Christova and E. Leader. Different measurable quantities are suggested that give information only about non-singlet combinations of FFs, but this information is obtained without any assumptions. The results hold in any QCD order. For example, it is shown that the difference between the charged and neutral kaons in the three processes for hadron production: $e^+e^- \to h + X$, $e + N \to e + h + X$ and $pp \to h + X$, determine the same combination of FFs. Measuring it would allow 1) to check the main assumption in QCD that the FFs are independent of the process, 2) to reduce the complicated set of equations for the energy-dependence of the FFs to a single equation, and 3) to check some of the used assumptions.

(6b) *Physics beyond the Standard Model* (E. Christova, E. Ginina)

Detecting charged Higgs bosons $H^{\pm}$ at the new colliders would be a clear signal for physics beyond the Standard Model. On the other hand, in order to meet the cosmological requirements, all extensions of the Standard Model introduce new sources of CP violation. The effects of CP violation in $H^{\pm}$ production and decay in the 2-Higgs doublet model - the simplest generalization of the Standard model, are considered. The conditions for their observation at the LHC are evaluated. These effects are compared to the effects induced by the Minimal Supersymmetric Standard Model. The investigations are fulfilled in collaboration with the SUSY group of the Institute for High Energy Physics, Vienna.