Laboratory "Theory of Elementary Particles"

Annual Report 2010

Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences

The current array of science research projects is centered around various major trends in modern theoretical and mathematical physics and it is executed within the framework of a broad international collaboration with leading international centers such as CERN (Geneva), ICTP and SISSA (Trieste), JINR (Dubna), as well as with numerous leading universities and academic research institutions in Austria, Belgium, Finland, France, Germany, Greece, Hungary, Israel, Italy, Romania, Russia, Serbia, Spain, Switzerland, United Kingdom, United States of America.

One of the primary research topics are **studies of the quantum structure and geometric nature of the fundamental forces between elementary particles at (ultra-)high energies**. Our projects in this area are motivated by the advent of string theory as a central and most promising model of a unified theory of all fundamental forces in Nature on the one hand, and by the unsolved challenges of this theory, on the other hand. String theory encompasses the achievements of many branches of theoretical physics, at the same time applying the tools of modern pure and applied mathematics and inspiring new progress in these most advanced fields. Our principal aim is to get further insights into the structure and behaviour of matter at very short distances, to advance research at the interface of physics and mathematics. The main emphasis is to put strings into the context of particle physics and cosmology. Hence our projects will contribute to address some of the core questions on the structure, origin and future of our Universe.

The main objectives of the above projects are:

(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. Topological defects in Liouville theory and the AGT correspondence *(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).

Another principal topic of scientific research of the laboratory are **studies of lepton-hadron interactions**. They are conducted in two main directions:

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

(b) 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).

These studies will provide knowledge of the fundamental picture of the nucleon and its constituents - the quarks and the gluons. In addition, the polarized quark and gluon densities and the fragmentation functions, the main subjects of these studies, are essential in interpreting the results of the experiments, currently running or planned in the near future, that search for New Physics beyond the Standard Model.

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

Throughout 2010 the members of the Laboratory have (co)authored 50 scientific works, among them - 2 monographs, 21 original papers in international journals with impact-factor, 14 original full text contributions in international conference proceedings, the rest of the papers pending publication.

In 2010 the members of the Laboratory have participated in the following **internationally funded projects**:

(a) EU 6-th Framework Research Training Network "HEPTOOLS" - project MRTN-CT-2006-035505;

(b) Academic exchange agreement between Ben-Gurion University (Israel) and Bulgarian Academy of Sciences (2009-2012);

(c) Scientific cooperation France - Bulgaria: project "Rila-4" No.112;

(d) Joint Institute for Nuclear Research, Dubna (Russia) - project 01-3-1070-2009/2013;

(e) Alexander von Humboldt Foundation (2010-2012);

and in the following large projects financed by the **Bulgarian National Science Foundation**: 02-257/2008, 02-288/2008, 02-115/2008 (excellence center), 02-183/2008.