

# Theory Division of YerPhI

## Summary

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### **Title:**

Theoretical Physics Division of YerPhI is one of the main divisions of the Institute and was always considered as important center of modern theoretical physics in Armenia.

### **Organization:**

Theory Division consists of many small groups, working on different problems. This structure was formed historically and appeared as one of the optimized schemes for self organization of the scientific division in critical conditions with extremely small funding from Armenia's budget and main money flow coming from abroad -grants, visits, etc.

### **Conception:**

- The activities of the members cover a large area from mathematical and theoretical high energy physics to the theory of biopolymers, the main direction of investigation being the **Theoretical high energy physics: phenomenology and field theory.**
- The work of the Division is based mainly on collaborations with laboratories and universities abroad, including experimental laboratories
- Each year the Division has 1-2 PhD students who defend their Theses and obtain a position in the Division or get postdoctoral positions in universities worldwide.
- Members of the Division are involved in various forms of activities in scientific community of Armenia: teaching courses in universities, participating as members in scientific councils, providing expertise for proposal's evaluation in national competitions, etc..

## **Recent Years Highlights**

- **Publications, 2004-2009**  
During last 5 years the members of the Division published **more than 270 articles** in international journals.

**Here we mention some important results:**

### **Phenomenology**

- **a)** The branching ratio of the  $\bar{B} \rightarrow X_s \gamma$  decay at  $O(\alpha_s^2)$  is calculated. The result is:

$$\mathbf{B}(\bar{B} \rightarrow X_s \gamma) = (3.15 \pm 0.23) \cdot 10^{-4} \text{ for } E_\gamma > 1.6 \text{ GeV in the } \bar{B} \text{-meson rest frame.}$$

Combining with the existing experimental results for the branching ratio of the  $\bar{B} \rightarrow X_s \gamma$  decay, this result can be used for testing the standard model and its extensions. [1] has been cited 208 times.

**b)** The hard function H at next-to-next-to-leading order (NNLO) in perturbation theory was calculated for  $\bar{B} \rightarrow X_u l \bar{\nu}$  decay. Combined with the known NNLO result for the jet function J, this completes the perturbative part of the NNLO calculation for this process. This result can be used for the precise determination of CKM matrix element  $V_{ub}$  [2]. (H. Asatryan)

- Recently, a global analysis of the experimental data on azimuthal asymmetries in semi-inclusive deep inelastic scattering (SIDIS), from the HERMES and COMPASS Collaborations, and in  $e^+e^-$  annihilation processes, from the Belle Collaboration, was performed [3]. The extraction of the Collins fragmentation function and (*for the first time*) of the transversity distribution function for  $u$  and  $d$  quarks were done. (A. Kotzinian [3])
- Developed a new description of the neutrino oscillations in matter with varying density which is both accurate and has all advantages of a full analytic treatment. Perturbative formulas for the oscillation probabilities which are valid for arbitrary density profile is derived and applied for propagation of the solar, supernova and accelerator neutrinos in matter of the Earth. (A. Ioannisian [4]).
- An improvement of the standard Dispersion Relation approach and the Unitary Isobar Model was proposed, that made it possible to describe the entire set of available CLAS data on electroexcitation of nucleon resonances (I. Aznaurian [5]).
- It was shown that the charm density in the proton can, in principle, be determined from high- $Q^2$  data on the azimuthal  $\cos(2\varphi)$  asymmetry and the Callan-Gross ratio  $R(x, Q^2) = F_L / F_T$  in heavy flavor leptonproduction (N. Ivanov [6]).

### Approved Proposals and LOI:

Members of the Department (I. G. Aznauryan, N. Ya. Ivanov and A. M. Kotzinian) made key contributions to preparation of the following research projects approved by TJNAF PACs:

- "Measurement of the Beam Spin Asymmetry in the Deuteron Disintegration by Linearly Polarized Photons at  $E_\gamma = 1.2 - 2.2$  GeV", LOI-06-101.
- "Meson spectroscopy in the coherent production on  $^4\text{He}$  with CLAS", E-07-009.
- "Determination of the Azimuthal Asymmetry in Deuteron Disintegration by Linearly Polarized Photons at  $E_\gamma = 1.1 - 2.3$  GeV", approved by CLAS Collaboration, June 2008.
- "Nucleon Resonance Studies with CLAS12 in the Transition from Soft to Partonic Physics", PR-09-003.
- "Semi-inclusive Pion Production with Longitudinally Polarized Target at 12 GeV", LOI12-06-109.
- "Probing the Proton's Quark Dynamics in Semi-Inclusive Pion Production at 12 GeV", PR12-06-112.
- "Studies of Spin-orbit Correlations with Longitudinally Polarized Target", PR12-07-107.
- "Lambda Polarization in the Target Fragmentation Region", LOI12-07-101.

### Observational Cosmology

- In collaboration with the Boomerang team (University of Rome) our Cosmology Group studied non-Gaussianities in the CMB maps: analyzed the properties of excursion sets in Boomerang (150 GHz), then of Wilkinson Microwave Anisotropy (WMAP) satellite's 3 and 5-year 94 GHz temperature maps. (V. G. Gurzadyan [7])

### Field Theory

- The quantum one loop trace anomaly of the higher spin conformal conserved currents in the bulk of  $\text{AdS}_4$  is obtained. The structure of this trace anomaly in the external higher spin fields is investigated. (R. Manvelyan [8]).
- A new procedure, allowing to calculate the higher instanton contributions (2, 3 and 4) to the Seiberg-Witten prepotential is obtained. Some applications to non perturbative effects in Gauge and String Theories are considered. (R. Poghossian [9]).
- A general form factor formula for the scaling  $Z(N)$ -Ising model is constructed. Exact expressions for matrix elements are obtained for several local operators. In addition, the commutation rules for order, disorder parameters and para-Fermi fields are derived. Because of the unusual statistics of the fields, the

quantum field theory seems to be not related to any classical Lagrangian or field equation. (H. Babujian [10]).

- A new 4x4 solution to the  $osp_q(1|2)$ -invariant Yang-Baxter equation with simple dependence on the spectral parameter is found and 2x2 matrix expressions for the corresponding Lax operator is proposed. The general inhomogeneous universal spectral-parameter dependent  $R$ -matrix is derived. It is proven, that there are two independent solutions to the homogeneous  $osp_q(1|2)$ -invariant YBE, defined on the fundamental three dimensional representations (D. Karakhanyan, Sh. Khachatryan [11]).

### **Statistical Physics**

- New method for quantum state determination via purely commutative measurement is proposed (A: E. Allahverdyan [12]).
- The general algorithm to compute exact asymptotic expansions for the partition functions and their derivatives for critical lattice models, including the Ising model, dimer model, and Gaussian model is developed (N. Izmailian [13]).

- **Grants: More than 40 grants**

#### **Sources:**

INTAS, Alexander von Humboldt Foundation, Volkswagen Foundation, ISTC, SCOPES, ANSEF, CRDF, NFSAT, Science Foundation Ireland, etc.

- **PhDs: 12 PhD theses during 2004-2009.**

- **Scientific council memberships:**

8 members of the Department are involved in scientific councils of YerPhI and Yerevan State University.

- **Editorial Boards:**

V. G. Gurzadyan: co-editor of Int. Journ. Mod. Phys. D; of book series "Advances in Astronomy and Astrophysics", Cambridge Sci. Publ. (UK).

## **Expected development of Division**

What we expect and suggest for the near future of the Theory Division of YerPhI (5-10 year)?

- The ages of most active members are in the 40-55 range, and one can expect that most of them will continue to work in a next 5-10 years. Younger members will do the same, probably, and one can expect that some new younger members will appear from among the post-graduate student body. Whether some may return or relocate from abroad is questionable, but possible, especially for some postdoctoral fellows.
- Scientific scope of our researches is defined by personal interests of *staff members* and is expected to be a natural continuation of present ones, according to international development of corresponding fields.
- Important influence on Division has a policy of our government. Up to now main feature of that policy is small increase of funding weakly connected with results of the Division's work.
- For development we need a continuous funding (provided by the government) for 1-2 Ph.D. students per year.
- The most natural way of finding new opportunities for the Theory Division is connected with teaching. Taking into account that in general the members of the Theory Division are able to provide a high level teaching of corresponding subjects for MS-courses a reasonable suggestion would be:  
***To organize permanent MS programs/courses (5'th and 6'th years of university education) for theoretical and mathematical physics on the basis of the Theory Division of YerPhI.***
- Another way could be the creation of an international theoretical physics laboratory in Yerevan, with

national and international positions, filled on a competitive basis, with reasonable salaries. Funding of such a laboratory can be provided by e.g. long-term international grants and financial support of the Armenian government. The establishment of such joint programs requires decisions and agreements on a level of e.g. the Commission of European Communities, one country's government or even one large western university, depending on a source of funding on one hand, and the Armenian government on the other.

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