Elementary Particle Theory

at the Bulgarian Academy of Sciences
and Sofia University

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Two main centers of particle physics:

- **Institute for Nuclear Research and Nuclear Energy (INRNE)** at the Bulgarian Academy of Sciences (BAS)

- **Physics Department** at Sofia University "St. Kliment Ohridski"

Theory at INRNE - BAS

Four theoretical groups (called "Laboratories"):

- "Theory of Elementary Particles"
- "Mathematical Modeling in Physics"
- "Theory of Atomic Nuclei"
- "Quantum informatics"

At present, there is a lot of overlap between the research conducted by these theory groups.

Lab. "Theory of elementary particles"

**(current staff: 15 researchers; of them: 5 Professors,
6 Associate Professors, 1 Assistant Professor, 2 Physicists, 1 Student)**

Research topics:

- Quantum field theory
- General relativity, modified theories of gravity
- Early Universe cosmology, dynamical dark energy
- String theory and holographic correspondence
- Conformal (super)symmetry, Lie (super-)algebras
- Quantum groups, generalized quantum statistics

Lab. "Mathematical modeling in physics"

**(current staff: 11 researchers; of them: 3 Professors,
3 Associate Professors, 3 Assistant Professors, 2 Physicists)**

Research topics:

- Theoretical high energy physics including phenomenology
- Physics of multiparticle quantum systems
- Quantum informatics
- General relativity and cosmology
- Methods of mathematical modeling

Lab. "Theory of atomic nuclei"

(current staff: 9 researchers; of them: 3 Professors, 2 Associate Professors, 4 Assistant Professors)

Research topics:

- Nuclear structure and nuclear reactions
- Nucleon correlations in atomic nuclei
- Nucleon density and momentum distributions
- Algebraic and geometric models of the nucleus
- Nuclear shapes and symmetries, superscaling
- Lepton scattering on nuclei, exotic nuclei

Lab. "Quantum informatics"

(current staff: 5 researchers; of them: 1 Associate Professor, 1 Physicist, 3 PhD students)

Research topics:

- Quantum information and quantum communication
- Quantum cryptography
- Quantum computers
- Quantum communication protocols, systems and networks
- Quantum entanglement

Publications and citations

Theory at INRNE-BAS during 2024

- **Publications:**

  Most are in journals with high Impact Factor.

  Number of publications by quartile: (arXiv: to be published)

Q1	Q2	Q3	Q4	SJR	arXiv
27	10	1	2	4	10

  Total : 54 papers ; plus another 8 conf. proceedings

- **Citations:**

  Number of independent citations: 1467

Main BG sources of funding

- **State-approved budget of BAS:**

  Basically, this covers only the salaries.

- **National Science Fund grants:**

  This is the only source of travel funding for many researchers in the Academy, including at INRNE.

  Currently: 5 active grants (2 of them started at the end of 2024)

  [2 other grants ended during 2024]

National Science Fund grants

Current grants:

- "Gravitation and cosmology of extreme states of matter"
  [Total amount for 3 years: 210 000 BGN (~ 107 000 EUR)]
- "Fundamental properties and universality of quantum systems: a unified approach" [Total amount for 3 years: 194 000 BGN]
- "Dualities and symmetries in particle physics and cosmology"
  [Total amount for 3 years: 170 000 BGN]
- "Precision modeling of elementary particle interactions"
  [Total amount for 3 years: 120 000 BGN]
- "Evolution of the nuclear structure, forms and symmetries in standard and extreme ranges of nuclear masses and energies"
  [Total amount for 3 years: 170 000 BGN]

Funding problems

- **Availability of funds:**
  - Not everyone, and not always, has a grant.
  - Travel funds are a limited (insufficient) percentage of the grant amount. [Ex.: 2500 EUR / person per year and a half]
- **Bureaucratic complexities:**
  - Typical grants for fundamental research have an interruption in the middle of their duration.

    More precisely, they have 2 stages, each only 18 months long, and require a midterm scientific and financial activities report and its evaluation by the BNSF, after the 1st stage.

No funding for postdocs

- **State-approved budget of BAS:**

  Does not provide funding for standard postdoc positions.

- **National Science Fund grants:**

  Provide some limited amount for (a one-time or two-time) payment to postdocs or graduate students, which is highly insufficient for a reasonable monthly salary/stipend.

A regular postdoc system is not developed/is not existent in Bulgaria. (Notwithstanding sporadic efforts, funded by the National Recovery and Resilience Plan and covering a limited number of scientific areas…)

International funding

Participation (Lab. TEP) in COST Actions:

- COST Action CA22113 "Fundamental challenges in theoretical physics"
- COST Action CA21136 "Addressing observational tensions in cosmology with systematics and fundamental physics"
- COST Action CA21109 "Cartan geometry, Lie, integrable systems, quantum group theories for applications"
- COST Action CA21106 "Cosmic WISPers in the Dark Universe: Theory, astrophysics and experiments"

Other international funding sources

- **SEENET-MTP:**

  (Southeastern European Network in Mathematical and Theoretical Physics)

  Limited funding for regional events or scientific visits

- **IRN-QFT:**

  (International Research Network on Quantum Fields and Strings)

  Mostly European scientific centers, but also a handful of US and Asian ones: limited funding for short scientific visits to those centers;

  Aimed at junior researchers (advanced PhD students and postdocs)

Theory at Physics Dept. of SU

(current staff: 16 researchers; of them: 3 Professors, 9 Associate Professors, 3 Assistant Professors, 1 Physicist)

Theoretical high-energy groups:

- "String Theory and High Energies"
- "Gravitation, Cosmology and Relativistic Astrophysics"
- "Quantum Informatics"
- "Quantum Multi-particle Dynamics"

Many common interests with the theorists at INRNE. Should try to foster collaborations between the two institutions…

Research topics

- **"String theory and high energies":**

  String and M theory, quantum gravity, quantum field theory, solitons, high energy physics

- **"Gravitation, cosmology and relativistic astrophysics":**

  Neutron stars, black holes and wormholes in General Relativity and modified theories of gravity

- **"Quantum informatics":**

  Advanced quantum technologies and methods, relevant for quantum computers and sensors

- **"Quantum multi-particle dynamics":**

  Quantum chaos and quantum thermalization in isolated quantum systems

Theory at Phys. Dept. of SU in 2024

- **Publications and citations:**

  More than 25 publications; 21 in journals with Q1 and 3 – with Q2

  More than 1000 independent citations

- **PhD students:** currently 9

- **National Science Fund grants:**

  "Machine learning via physically informed neural networks"

  [Total amount for 3 years: 280 000 BGN]

  "Testing the nature of self-gravitating compact objects with hot spots" [Total amount for 3 years: 150 000 BGN]

- **SUMMIT grant:** [Duration: 3 years]

  Funding from the Bulgarian Recovery and Resilience Plan

Funding issues at SU

Same as BAS:

- **State-approved budget:**

  Covers only the salaries

- **National Science Fund grants:**

  Same issues as described on previous slides

- **International funding:**

  Participation in European COST Actions and in SEENET-MTP

Additional source of funding:

- **SUMMIT grant:**

  Mostly for staff salaries; small percentage for travel funding

In conclusion

Suggestions for improvements:

- **Ministry of Education and Science:**

  Could institutionalize the "postdoc" position; respectively, allocate funding for postdocs annually to the leading research institutions

- **Bulgarian National Science Fund (BNSF):**

  Could decrease the bureaucratic burden, for ex., by offering:

  - grants with a single 3-year-long stage OR with two 2-year-long stages

  (i.e. grants providing longer-term financial stability, without interruptions for midterm reports and evaluations that can take several months...)

  - more flexibility in the Financial Plan of the grants

  (The "one-size-fits-all" funding limits for 'travel' vs 'equipment' etc. in each BNSF competition are not suitable for everyone...; and the current level of flexibility is highly insufficient.)