Abstracts

Class B (P&E)

Inaugural Lectures by New Members of

Physics and Engineering Sciences

Chairpersons:

Muhsin Harakeh (Groningen)
Tamás Csörgő (Budapest)
Contributions to Nonlinear Dynamics, Chaos and Complex Systems

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Abstract
The main goal of this talk is to describe some of my achievements and research work in the field of nonlinear dynamics, chaos and complex systems. Among the different lines of research, I will mention results on dynamics of partial control, vibrational resonance and nonlinear resonances, fractal structures in nonlinear dynamics, modeling biological systems, predictability of chaotic dynamics, and some applications to different topics in Physics, such as galactic dynamics, chaos & entanglement, cold atoms and black hole shadows.
Bose-Einstein condensates in semiconductor microcavities

Luis Viña


Abstract
Following the observation of Bose-Einstein condensation of cavity exciton-polaritons, important advances have been obtained towards the realization of polariton-condensates based devices. I will present, as an example, the realization of an all-optical device controlling polariton condensates in confined geometries, demonstrating the realization of a novel transistor switch mediated by propagating Bose-Einstein polariton condensates in a quasi-1D semiconductor microcavity ridge. These systems also provide an unparalleled scenario to study fundamental quantum mechanical questions as, for example, those related with the coherence of condensates.

Fig.1. Scheme of a transistor based on a polariton condensate in a microcavity ridge (a) without and (b) with the gate

Fig 2. (a-e)/(i-v) Polariton emission in energy vs. position maps for the ON/OFF transistor state. The snapshots are taken at the times shown. The intensity is coded in a false color scale
On a new light-particle candidate for Dark Matter observed in high-energy nuclear transitions

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Abstract

Dark Matter is currently one of the greatest unsolved mysteries in physics. Recently, we used the Li(p,e⁺e⁻)⁸Be reaction to excite an 18.15 MeV excited state in ⁸Be and observed its internal pair (e⁺e⁻) decay to the ground state. An anomaly in the form of peak-like enhancement relative to the internal pair creation was observed at large angles in the angular correlation [1]. It turned out [2] that this could be a first hint for a 17 MeV X-boson (X₁₇), which may connect our visible world with Dark Matter. The possible relation of the X₁₇ to the Dark Matter problem, as well as the fact that it might explain the (g-2)μ puzzle, triggered great theoretical and experimental interest in the particle, hadron and atomic physics communities. Zhang and Miller discussed in detail whether a possible explanation of nuclear physics origin could be found but without any success [3].

Using a significantly modified and improved experimental setup, we reinvestigated the anomaly observed in the e⁺e⁻ angular correlation by using the new tandetron accelerator of our institute. This setup has different efficiency curve as a function of the correlation angle, and different sensitivity to cosmic rays yielding practically independent experimental results. In this experiment, the previous data were reproduced within the error bars.

To confirm the ⁸Be signal, a similar approach would be to look for other nuclear states that decay by discrete gamma rays with energies above 17 MeV through M1 electromagnetic transitions. Unfortunately, the ⁸Be system is quite special and the ⁸Be excited states decay by gamma rays that are among the most energetic compared to decay of all the nuclear states. Recently, we investigated high-energy transitions in ⁴He. In order to excite the first two excited states located at Eₓ=20.21 MeV (J=0⁺) and 21.1 MeV (J=0⁻), we used the ³H(p,e⁺e⁻)⁴He reaction at Eₚ=1.0 MeV. In this way, we excited both of the above overlapping states. We observed e⁺e⁻ pairs with an angular correlation dominated by the E₀ transition, which was expected from the 0⁻→0⁺ transition, but on top of that a small peak at Θ≈115° is also visible. This would correspond to the decay of the X₁₇ boson created in the 0⁻→0⁺ transition.

The γγ-decay of X₁₇ boson was also studied in order to distinguish between the vector and pseudo-scalar scenarios suggested recently by theoretical groups in interpreting our experimental results [4,5]. According to the Landau-Yang theorem, the decay of a vector boson is forbidden by double γ-emission, however, a pseudo-scalar one is allowed. The analysis of the data is in progress. There are also myriad other opportunities to test and confirm this explanation, including re-analysis of old datasets, ongoing experiments, and many planned and future experiments. The latter include the PADME experiment in Frascati, the DarkLight and HPS experiments at JLAB, the LHCb and NA64 experiments at CERN, the MESA experiment in Mainz, the Mu3e experiment at PSI Villigen and the VEPP-3 experiment in Novosibirsk.

REFERENCES

The Nucleosynthesis of First Star

Michael Wiescher
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Abstract
The first stars emerge about 400 Million years after the Big Bang with the end of the dark age of the Universe. The chemical composition represents a primordial abundance distribution of hydrogen, helium, and lithium isotopes as defined by Big Bang nucleosynthesis. The first stars are predicted to have had masses up to several hundred solar masses. Later generation stars are stabilized by internal nuclear burning in their interior, however, the primordial fuel distribution in first stars is insufficient causing their contraction, collapse, and transition to a first generation of supernovae. These conditions of gradual contraction provides an environment for nuclear reactions bridging the mass 5 and mass 8 gap forming the first generation of light nuclei up to mass 40 as detected in the abundance distribution of the oldest observed stars. The most likely nucleosynthesis patterns for forming these heavier nuclei will be presented.
FAIR and its impact on science and technology

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Abstract
An international consortium of 10 countries, namely Finland, France, Germany, India, Poland, Romania, Russia, Slovenia, Sweden and the United Kingdom has set out to build one of the largest accelerator facilities in the world for fundamental and applied research. This facility is being built in Darmstadt, Germany next to the existing GSI facility. About 3000 scientists from more than 50 countries will carry out experiments to understand the fundamental structure of matter at extremes, to explore exotic forms of it and to find final answers of how the universe evolved from its primordial state into what we see today. In addition, applications, only possible with accelerators, will be pursued at this facility. The research at this facility rests on four pillars: 1) Atomic, Plasma Physics and Applications; 2) Nuclear Matter Physics; 3) Nuclear Structure, Astrophysics and Reactions; and 4) Physics with High-Energy Antiprotons.
Each one of these pillars addresses the specific questions raised in the corresponding field. In this presentation, an overview of the facility along with scientific and technical challenges will be given. In addition, some research aspects will be highlighted.
Exotic shapes and collective phenomena in excited atomic nuclei

Adam Maj

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Abstract
Rotation, a collective phenomenon that was found in excited atomic nuclei, may induce important changes in the nucleus. The centrifugal force breaks the pairing between nuclei, and the nucleus starts behaving as a liquid. When rotational speed increases, the nucleus changes its shape, from spherical or slightly prolate, to the oblate one, and at some critical value, the nucleus may even undergo a sudden change of shape – from oblate to very elongated prolate. This is phenomenon in known as Jacobi shape transition. The rotation causes also that the nuclei, even at lower excitation energy, might become triaxial.
I will discuss the results of research on the phenomenon of rapid change of shape of the rotating nucleus from the flattened to the elongated ellipsoid, so called nuclear Jacobi transition. Such studies were carried out in the $A=40$ and $A=90$ nuclei, by measuring the gamma decay of another nuclear phenomenon – the Giant Dipole Resonance (GDR).
In addition, I will discuss the first results from the studies of other collective phenomena (Giant Quadrupole Resonance, Pygmy Dipole Resonance) carried out at the new proton beam facility Cyclotron Center Bronowice in Krakow.
Abstract
As in many other scientific areas, computer simulations have become an indispensable tool in materials science. Our present ability to simulate accurately and precisely the behavior of complex materials is unprecedented, due to the combination of the development of theoretical tools and numerical algorithms to solve the underlying basic physical equations, and to the overwhelming (and constantly growing) computing power of present-day supercomputers. The challenges that still needs to be overcome to have a truly predictive simulation-based materials discovery tool, which can be used even in the industrial environment, are many. Their solution will require solving hard scientific problems, but also hardware and software engineering tools to be developed in the context of the forthcoming exascale computing facilities, and new approaches like artificial intelligence and big data. Europe has been in the forefront of this scientific area, and recent initiatives aim to maintain this situation in the future.
Large and Powerful Sources for Negative Hydrogen Ions

Ursel Fantz

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Abstract

One of the world's largest scientific projects, the international fusion experiment ITER, currently under construction in Europe (Cadarache, France), needs for plasma heating and for current-drive powerful neutral beams delivering 33 MW in total by two beamlines. Key elements in this neutral beam system are large RF-driven ion sources with an area of 1 x 2 m² generating negative ion beams of up to 46 A H⁻ (40 A D⁻) stable for one hour. The ratio of co-extracted electrons to extracted ions must be always below one in order to keep the heat load on the extraction system at a tolerable amount. The latter is already at the limits of the engineering capabilities. The large beam, extracted from 1280 individual apertures, is targeted to have a uniformity of better that 90% in order to be transported without losses to the fusion plasma and avoiding damages of components in the beamline. The development at IPP started with a prototype source being 1/8 of the ITER source area followed by a ½ size ITER source at the test facility ELISE. The challenges in overcoming physical and technology aspects as well as the status of the research will be presented including the latest record values of ELISE being a milestone in the European roadmap towards the beam systems for ITER.
Self-organization in Burning Plasmas

D.J. Campbell

Retired from ITER Organization, St-Paul-lez-Durance Cedex, France

Abstract
The key physics phenomena which govern the behaviour of magnetically confined fusion plasmas in toroidal geometry have been the subject of intense research in recent decades. A detailed understanding of these high temperature, ‘collisionless’ plasmas must integrate the role of turbulent transport processes, magnetohydrodynamic stability, the interaction of high energy particles produced by fusion reactions with the thermal ‘background’ plasma, and the influence of ‘boundary conditions’ produced by interactions between the plasma and the material surfaces of the confinement vessel. Progress in advanced plasma measurement (‘diagnostic’) techniques and in the development of a sophisticated numerical simulation capability has revealed many elements of the physics determining the confinement and stability of such plasmas.

A magnetically confined plasma is a complex state in which there is significant free energy available that can generate turbulence, ‘small scale’ instabilities having characteristic length scales varying approximately over the range from the electron to the ion Larmor radius, i.e. typically ~10⁻⁴ to 10⁻² of the plasma radius, and magnetohydrodynamic (MHD) modes, ‘large scale’ instabilities with perturbation scale lengths ranging from ~10⁻³ to 10⁰ of the plasma radius. These instabilities can, in various ways, significantly influence the plasma confinement: transport of heat and particles across the confining magnetic field is generally found to be dominated by turbulent processes. It has been observed, nevertheless, that under some circumstances ‘self-organized’ behaviour can emerge which leads to substantial enhancement of the heat and particle confinement. As fusion plasmas approach the ‘burning plasma’ regime, where internal heating due to fusion products dominates other forms of heating, non-linearities can arise in the interaction between the energetic fusion particles and the thermal plasma, possibly generating novel aspects of self-organization.

The progress made in understanding plasma confinement and stability under the conditions required for significant fusion power production via deuterium-tritium reactions has provided a strong physics basis for the design of the ITER experiment, currently under construction at St-Paul-lez-Durance in southern France [1,2]. The presentation will summarize key elements of the progress made in understanding the physics of magnetically confined fusion plasmas, introduce significant examples of self-organization observed and provide a brief update on the status of the ITER project.

References
Quantum electron liquids and fractional quantum Hall effect

Arkadiusz Wójs
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Abstract
When squeezed to a narrow, effectively two-dimensional layer, and subject to low temperature and high magnetic field, a gas of electrons of appropriate density may condense into a new form of quantum matter called “quantum electron liquid”, discovered for the first time in the context of “fractional quantum hall effect” (1998 Nobel Prize in Physics). The properties of this fascinating state of strongly correlated electrons are conveniently described in terms of a new particle called “composite fermion” pictured as an electron carrying with itself some quantized magnetic flux. Elementary excitations of certain composite fermion systems may have exotic properties such as fractional and nonabelian quantum statistics, leading to such effects as memory of past trajectories. These properties have been proposed as building elements of a future “topological quantum computer”. My talk will review these fascinating concepts, with emphasis of my own field of research.
ERC Funding in Physics and Engineering

Andrzej Jajszczyk
Scientific Council of the ERC

Abstract
The talk will briefly overview the funding programs of the European Research Council (ERC) focusing on frontier, high-risk research. Physics and engineering areas will be covered, showing and discussing some relevant, key statistics. The challenges facing the ERC in the next framework programme will be outlined.