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THE EUROPEAN PHYSICAL JOURNAL SPECIAL TOPICS

Editorial

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Abstract. Hadron physics addresses a variety of fundamental phenomena arising from the many-body structure of strongly interacting systems. This special issue of the European Physical Journal contains 21 selected papers and review articles. They address key questions in low energy hadron physics and summarise the experimental and theoretical results which have been obtained within the Collaborative Research Center CRC443 – "Many-body structure of strongly interacting systems".

The physics of hadrons, mesons and baryons, lies at the heart of almost all research in modern nuclear and particle physics. Definite answers to many fundamental questions in high energy and astrophysics require precise knowledge of the structure and dynamics of hadrons, the building blocks of ordinary matter. Beyond that, hadron physics faces a variety of new and fundamental phenomena which arise from the intrinsic many-body structure of strongly interacting systems. In the case of quantum electrodynamics (QED) similar phenomena emerge in complex many-body systems, which are not directly manifest in the fundamental field theory. They are subjects of investigation in chemistry, molecular or condensed matter physics. Modern hadron physics exhibits these phenomena in quantum chromodynamics (QCD) and strongly interacting systems like mesons, baryons and nuclei.

A many-body structure is one of the characteristic features of any quantum field theory. Due to quantum fluctuations, the interpretation of even the simplest systems in terms of a fixed number of constituents fails at some level. In the case of QED, these effects can be calculated perturbatively with extremely high precision. In QCD the the situation is much more challenging because any expansion in terms of the strong coupling constant fails at the typical energy scale of hadrons. Therefore, hadrons represent a comprehensive laboratory to study fundamental aspects of quantum field theories in the strong coupling regime, like confinement, a non-trivial vacuum structure, the generation of scales, the dynamical breaking of symmetries and the emergence of new structures, which are equivalent to effective degrees of freedom. Powerful tools to study these issues in a wide range of energy scales are provided by electroweak probes in lepton scattering and real photon absorption experiments. Leptons and photons interact with the electroweak charges and the magnetisation of quarks inside a hadron in a relatively weak and well understood way, providing undistorted information about such basic hadronic properties as transverse size, magnetic moments, distribution of charge and magnetism, flavour structure, polarisabilities and excitation spectrum. The exploration of the full potential of electroweak probes at typical nuclear and sub-nuclear energy scales is the focus of the experimental and

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theoretical research at the Institut für Kernphysik of the Johannes Gutenberg-Universität Mainz. For more than three decades novel techniques in electron acceleration have been developed and operated in the Institute. The Mainz Microtron MAMI, a series of race-track microtrons, provides a high-quality continuous wave electron beam for a broad range of experiments. A comprehensive overview of results obtained with the 855 MeV stage, MAMI B, was given in a Symposium on twenty years of physics at MAMI, which was held in Mainz in 2005 [1].

Over the years 1998–2010 the research at MAMI was supported by the Deutsche Forschungsgemeinschaft by means of the Collaborative Research Center CRC443 – "Many-body structure of strongly interacting systems" whose resources were of utmost importance to sustain an effective doctoral and postdoctoral program. During this period a new, unique accelerator stage, the harmonic double-sided Microtron, MAMI-C, was developed, constructed and, since 2007, successfully used for experiments.

This special issue of the European Physical Journal contains 21 selected papers and review contributions summarising the main scientific results that have been obtained within the CRC443 or in close collaboration with it. The contributions focus on the following topics:

- Form factors in elastic electron scattering.
- Polarisabilities.
- Nucleon resonances.
- Effective field theories and lattice QCD.
- Nuclear few-body systems.

The articles provide a comprehensive overview and reference on the recent progress in experimental and theoretical approaches to low energy hadron physics with electroweak probes. From these results, new questions and ideas have emerged which form the basis for future studies of hadrons and QCD in this most interesting low-energy domain.

Our special thanks goes to the Deutsche Forschungsgemeinschaft for the constructive advice and support by means of the Collaborative Research Center CRC443. Furthermore, we thank the Physics Faculty, the Johannes Gutenberg-Universität and the State of Rhineland-Palatinate for continued and coherent support.

We are extremely grateful to the state and to the federal ministries (BMBW, BMFT) who financed the construction of the new MAMI C accelerator and the installation of the *Wilson* multiprocessor computer cluster for dedicated calculations in lattice QCD.

Among the many international funding agencies contributing to the research program and the experiments at MAMI we would like extend our deep appreciation to the US-American DOE, the French CEA and CNRS, the Italian INFN, and the British EPSRC and STFC. The accessibility of MAMI to scientists from other institutions in Europe is supported via the European I3HP Transnational Access program.

Beyond the financial support, we received invaluable scientific support and advice from numerous colleagues. We especially thank the members of our international Program Advisory Committee and the evaluation and expert committees of the CRC443. Last but not least, we thank all our colleagues from various universities and institutions all over the world for the constructive and fruitful collaboration in various common experimental and theoretical projects.

References

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