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Graduate Texts in Physics

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Particles and Nuclei

An Introduction to the Physical Concepts

Seventh Edition

 Springer

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Preface

Since the first German edition of this textbook in 1993, many extensions and corrections of the text have been added in every further edition. For the present seventh English edition, the text of several chapters and also many figures have been thoroughly revised and updated, and plenty of additional information has been added.

Werner Rodejohann joined the team of authors. He mainly cared about the chapters that deal with neutrinos and the Higgs particle. A new Chap. 11 has been added with the focus on neutrino properties, neutrino oscillations and Majorana neutrinos; additional aspects of the latter topic are summarised in Chap. 18. Chapter 12 has been extended by a discussion on spontaneous symmetry breaking, the Higgs potential and the experimental observation of the Higgs particle at the LHC.

Updates on experimental results include new information about the elastic form factors of proton and neutron, in particular from JLab experiments (Chap. 6) and the final results for the proton structure function F_2^p and charged-current cross-sections obtained by the experiments H1 and ZEUS at the HERA electron/positron-proton collider HERA (Chaps. 8, 10, 12). Chapter 15 has been substantially extended by a discussion of CP violation in the decay of neutral K- and B-mesons and its detailed investigation by fixed-target experiments with high-energy kaon beams at CERN and FNAL and the two B-factory experiments BaBar and BELLE. A section on the investigation of the nucleon's spin structure in deep-inelastic lepton-nucleon scattering with polarised beams and targets has been added to Chap. 16.

We would like to thank Lara de Nardo, Markus Diefenthaler and Friedrich Stinzing for producing some of the new figures and Armine Rostomyan and Morgan Murray for carefully reading and correcting the translations of several newly written paragraphs.

Heidelberg, Germany
March 2015

The authors

Preface to the First Edition

The aim of *PARTICLES AND NUCLEI* is to give a unified description of nuclear and particle physics because the experiments which have uncovered the substructure of atomic nuclei and nucleons are conceptually similar. With the progress of experimental and theoretical methods, atoms, nuclei, nucleons and finally quarks have been analysed during the course of this century. The intuitive assumption that our world is composed of a few constituents – an idea which seems attractive, but could not be taken for granted – appears to be confirmed. Moreover, the interactions between these constituents of matter can be formulated elegantly and are well understood conceptually, within the so-called standard model.

Once we have arrived at this underlying theory, we are immediately faced with the question of how the complex structures around us are produced by it. On the way from elementary particles to nucleons and nuclei, we learn that the “fundamental” laws of the interaction between elementary particles are less and less recognisable in composite systems because many-body interactions cause greater and greater complexity for larger systems.

This book is therefore divided into two parts. In the first part we deal with the reduction of matter in all its complication to a few elementary constituents and interactions, while the second part is devoted to the composition of hadrons and nuclei from their constituents.

We put special emphasis on the description of the experimental concepts, but we mostly refrain from explaining technical details. The appendix contains a short description of the principles of accelerators and detectors. The exercises predominantly aim at giving the students a feeling for the sizes of the phenomena of nuclear and particle physics.

Wherever possible, we refer to the similarities between atoms, nuclei and hadrons, because applying analogies has not only turned out to be a very effective research tool but is also very helpful for understanding the character of the underlying physics.

We have aimed at a concise description but have taken care that all the fundamental concepts are clearly described. Regarding our selection of topics, we were guided by pedagogical considerations. This is why we describe experiments

which – from today’s point of view – can be interpreted in a straightforward way. Many historically significant experiments, whose results can nowadays be much more simply obtained, were deliberately omitted.

PARTICLES AND NUCLEI (TEILCHEN UND KERNE) is based on lectures on nuclear and particle physics given at the University of Heidelberg to students in their 6th semester and conveys the fundamental knowledge in this area, which is required of a student majoring in physics. On traditional grounds these lectures, and therefore this book, strongly emphasise the physical concepts.

We are particularly grateful to J. Hüfner (Heidelberg) and M. Rosina (Ljubljana) for their valuable contributions to the nuclear physics part of the book. We would like to thank D. Dubbers (Heidelberg), A. Fäßler (Tübingen), G. Garvey (Los Alamos), H. Koch (Bochum), K. Königsmann (Freiburg), U. Lynen (GSI Darmstadt), G. Mairle (Mannheim), O. Nachtmann (Heidelberg), H.J. Pirner (Heidelberg), B. Stech (Heidelberg) and Th. Walcher (Mainz) for their critical reading and helpful comments on some sections. Many students who attended our lecture in the 1991 and 1992 summer semesters helped us through their criticism to correct mistakes and improve unclear passages. We owe special thanks to M. Beck, Ch. Büscher, S. Fabian, Th. Haller, A. Laser, A. Mücklich, W. Wander and E. Wittmann.

M. Lavelle (Barcelona) has translated the major part of the book and put it in the present linguistic form. We much appreciated his close collaboration with us. The English translation of this book was started by H. Hahn and M. Moinester (Tel Aviv) whom we greatly thank.

Numerous figures from the German text have been adapted for the English edition by J. Bockholt, V. Träumer and G. Vogt of the Max-Planck-Institut für Kernphysik in Heidelberg.

We would like to extend our thanks to Springer-Verlag, in particular W. Beiglböck for his support and advice during the preparation of the German and, later on, the English editions of this book.

Heidelberg, Germany
May 1995

Bogdan Povh
Klaus Rith
Christoph Scholz
Frank Zetsche

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