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With 30 Figures

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The 1st edition was published under the title: Fields, Symmetries, and Quarks
© 1989 McGraw-Hill Hamburg

ISSN 0172-5998
ISBN 978-3-642-08458-4

Library of Congress Cataloging-in-Publication Data applied for.

Die Deutsche Bibliothek - CIP-Einheitsaufnahme
Mosel, Ulrich: Fields, symmetries, and quarks / Ulrich Mosel. - 2., rev. and enl. ed.

ISBN 978-3-642-08458-4 ISBN 978-3-662-03841-3 (eBook)
DOI 10.1007/978-3-662-03841-3

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© Springer-Verlag Berlin Heidelberg 1999
Originally published by Springer-Verlag Berlin Heidelberg New York in 1999
Softcover reprint of the hardcover 2nd edition 1999
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Typesetting: Camera ready by the author using a Springer TEX macro package
Cover design: *design & production* GmbH, Heidelberg
Computer to plate: Mercedesdruck, Berlin
SPIN: 10652003 55/3144/di - 5 4 3 2 1 0 – Printed on acid-free paper

Preface

This revised and extended edition of the book *Fields, Symmetries, and Quarks*, originally published by McGraw-Hill Book Company, Hamburg, 1989, contains a new chapter on electroweak interactions which has also grown out of lectures that I have given in the meantime. In addition, a number of changes, mainly in the metric used, in the discussion of the theory of strong interactions, QCD, and in the chapter on hadron physics, have been made and errors have been corrected.

The motivation for this book, however, is still the same as it was 10 years ago: This is a book on quantum field theory and our present understanding of leptons and hadrons for advanced students and the non-specialists and, in particular, the experimentalists working on problems of nuclear and hadron physics.

I am grateful to Dr. S. Leupold for a very careful reading of the revised manuscript, many corrections, and helpful suggestions and to C. Traxler for producing the figures and for constructive discussions.

Giessen, September 1998 *Ulrich Mosel*

Preface to the First Edition

This is a book on the elements of quantum field theory, symmetries, gauge field theories and phenomenological descriptions of hadrons with special emphasis on topics relevant to nuclear physics. It has been written by a nuclear theorist, in particular for nuclear physicists, including experimentalists, and in general for scientists who need a working knowledge of field theory, symmetry principles of elementary particles and their interactions and the quark substructure of hadrons without having to be experts in each of these fields.

At the highest energies now employed in nuclear physics we start to probe phenomena of high-energy and particle physics in the nuclear environment. It is one of the purposes of this book to provide the necessary theoretical background for this study of fundamental symmetries in nuclear processes, subnuclear degrees of freedom, multi-quark systems and their interactions in a coherent, detailed, but nevertheless didactic way that stresses physical principles and introduces theoretical formalisms only as far as they are really necessary for a systematic understanding of the material discussed.

This book can serve a second purpose: it has grown out of notes for lectures that I gave at the University of Giessen first in 1984 and then again in 1987. The lectures were attended by students in their sixth semester (third year) who had a background in nonrelativistic and relativistic quantum theory, including the method of second quantization and the Klein-Gordon and Dirac equations, but no knowledge of field theory. Since field theory is usually not a mandatory course for our physics students, many of them leave the university without knowing much about it. Most of them have never heard about gauge field theories and their importance for our present day understanding of basic interactions. It was the purpose of this course to provide the essential ideas of these fields for students who were interested in a deeper understanding of the forces of nature but did not necessarily want to become specialists in field theory or particle physics. A course based on this book, perhaps shortening or leaving out the last two more specialized chapters on bag models, can fulfill their needs.

The book starts out with an elementary introduction into classical field theory, the quantization of free fields and a very short treatment of interacting fields in its first three chapters. Gauge field theories require a working knowledge of global symmetries in field theories. This topic is therefore discussed in detail in the second part of this book.

The third part is then concerned with the general structure of gauge field theories and contains a thorough discussion of the still less widely known features of non-Abelian gauge field theories. The two examples of most importance to nuclear physicists are clearly the theory of electroweak interactions, which unifies electromagnetic and weak interactions, and Quantum Chromodynamics (QCD), which describes the strong interactions of hadrons. Because there are already many excellent textbook treatments of the electroweak interactions available, I have chosen here to discuss only QCD because of its importance for our understanding of hadronic matter. QCD predicts bag-like ensembles of quarks that make up the nucleons; it also predicts the existence of a new phase of nuclear matter, the so-called Quark–Gluon Plasma. It is here that nuclear physics and particle physics meet.

The last two chapters then contain detailed discussions of phenomenological bag models. The MIT bag is discussed in much detail so that all theoretical calculations can be followed step by step. Since in all other bag-models the calculational methods and steps are essentially identical this chapter should enable the reader to actually perform such calculations unaided. A last chapter finally discusses the topological bag models which have become quite popular over the last few years. All of these discussions have not until now been available in the textbook literature.

The bibliography contained in this book will enable readers to study many topics in more detail and will help them to go on to topics not covered here. I have in general tried, whenever available, to cite only recent review articles about the topics treated. There the detailed references to the original literature can be found.

I am grateful to many of my students for helpful comments and suggestions on early versions of the lecture notes. I am particularly thankful to one of my graduate students, Bernhard Blättel, who worked through the whole book correcting numerous mistakes but also suggesting improvements in language, style and presentation. He also reminded me constantly of the available background knowledge of students. I am also very much indebted to Elke Szauter for typing the whole manuscript and making numerous alterations; finally I would like to thank Dieter Masak and Ulrich Post for their help in preparing the figures for this book.

Giessen, April 1988 *Ulrich Mosel*

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