Achim Stahl

Physics with Tau Leptons

With 236 Figures

Springer

Springer Tracts in Modern Physics

Springer Tracts in Modern Physics provides comprehensive and critical reviews of topics of current interest in physics. The following fields are emphasized: elementary particle physics, solid-state physics, complex systems, and fundamental astrophysics.
Suitable reviews of other fields can also be accepted. The editors encourage prospective authors to correspond with them in advance of submitting an article. For reviews of topics belonging to the above mentioned fields, they should address the responsible editor, otherwise the managing editor.
See also http://www.springer.de/phys/books/stmp.html

Springer Tracts in Modern Physics
Volume 160

Springer
Berlin
Heidelberg
New York
Barcelona
Hong Kong
London
Milan
Paris
Singapore
Tokyo

Dr. Achim Stahl
Universität Bonn
Physikalisches Institut
Nussallee 12
53115 Bonn
Germany
E-mail: stahl@physik.uni-bonn.de

Library of Congress Cataloging-in-Publication Data

Stahl, Achim, 1962-
Physics with tau-leptons / Achim Stahl.
p. cm. -- (Springer tracts in modern physics, ISSN 0081-3869 ; v. 160)
Includes bibliographical references and index.
ISBN
1. Leptons (Nuclear physics) 2. Leptons (Nuclear physics)--Decay. I. Title. II. Springer tracts in modern physics ; 160.

QC1 .S797 vol. 160
[QC793.5.L42]
539 s--dc21
[539.7'211]

99-047498

Physics and Astronomy Classification Scheme (PACS): 14.60.Fg, 13.35.Dx, 13.10.+q, 12.38.Qk, 12.60.-i, 11.30.Er, 14.60.Lm

ISSN 0081-3869
ISBN 3-540-66267-7 Springer-Verlag Berlin Heidelberg New York

Typesetting: Camera-ready copy by the author using a Springer LaTeX macro package
Cover design: *design & production* GmbH, Heidelberg

Printed on acid-free paper SPIN: 10730869 56/3144/tr 5 4 3 2 1 0

Preface

The τ lepton, being the heaviest lepton known to date, offers some unique features which make it an excellent tool for challenging our current understanding of particle physics. This book reviews the many aspects of experimental investigations performed with τ leptons.

Although the electron and the muon – the charged leptons of the first two generations – have been studied more extensively and with higher precision than the τ, there has always been some prejudice that deviations from the Standard Model of particle physics are more likely to become visible in the third generation. Such a prejudice can, of course, be justified only in the framework of a new model and is indeed true for many of them. This makes the τ lepton a good candidate in the search for physics beyond the Standard Model. Another unique feature of the τ lepton is the possibility to access its spin through the dynamics of its parity-violating, weak decay. Although techniques of spin measurements for electrons or muons are well established, the τ lepton is the only elementary fermion for which this is experimentally feasible with a modern high-energy-physics collider detector. With this information at hand, testing the predictions of a given model becomes more stringent.

The τ is also the only lepton heavy enough to decay into hadrons. These decays offer an ideal laboratory for the study of strong interactions, including the transition from the perturbative to the nonperturbative regime of QCD in the simplest possible reaction. This might explain the tremendous efforts ongoing in τ physics (for other reviews see [1–8]).

This review starts with a short look back to the discovery of the τ lepton and its identification as the first member of a new generation (Chap. 1), followed by some experimental aspects of τ physics (Chap. 2) and a thorough description of the measurements of its static properties (i.e. mass, lifetime, branching ratios, etc.) in Chap. 3. The next chapter deals with the production of τ leptons in high-energy e^+e^- collisions and the contribution of τ physics to the precision tests of the electroweak theory at the Z^0 pole and above. Chapter 5 describes the impact of strong interactions on hadronic decays of the τ. Chapter 6 is devoted to results achieved at hadron colliders. Intimately linked to the τ lepton is its neutrino, the topic of Chap. 7. Finally, there are three chapters describing searches for indications of physics beyond the scope of the Standard Model. The book ends with a consideration of the outlook for the future of τ physics.

τ physics is a very lively field with a lot of discussions between the various groups. The highlights are the biennial τ workshops, where many of the new results are presented. There have been five of them:

- 1990 in Orsay, France, organized by M. Davier and B. Jean-Marie [9]
- 1992 in Columbus, Ohio, organized by K.K. Ghan [10]
- 1994 in Montreux, Switzerland, organized by L. Rolandi [11]
- 1996 in Estes Park, Colorado, organized by J.G. Smith and W. Toki [12]
- 1998 in Santander, Spain, organized by A. Pich and A. Ruiz [13]

and we are looking forward to the next workshop in the year 2000 in Victoria, Canada. The proceedings are a good source of information to start from, too [9–13].

The preparation of such a book is impossible without the help of many. I want to especially thank our τ working group at the University of Bonn. They have produced some of the results described here and carefully checked the manuscript: N. Wermes, M. Kobel, V. Cremers, A. Höcker, M. Thiergen, J. Colberg, M. Schumacher, B. Kunst, H. Voss, R. Sieberg, A. Posthaus, N. Tesch, U. Müller, F. Scharf, S. Menke, R. Bartoldus, K. Linowsky, A. Hauke, R. Kemp, W. Mader, and A. David.

Bonn, August 1999 *Achim Stahl*

Contents