Preface

The *Problems* presented here refer to the topics discussed in the corresponding 14 chapters of the *Particles and Fundamental Interactions* textbook. This *Problems, Solutions and Supplements* book is aimed at students in a course of Experimental Particle Physics, not only as a preparation for a written examination, but also as a necessary instrument for a deeper understanding of high energy physics. It contains 170 problems of different difficulty levels. Some of them are traditional, covering most aspects of particle properties and of their fundamental interactions, and some are more advanced. Some problems are derived from our teaching experience to undergraduate students; some are derived from the admission examination to the PhD courses in Italian universities; some are completely original, from our research activities.

Each problem has an identification number and a *title* to facilitate the identification of the subject discussed in the text. Most problems are solved step-by-step, to help both students and teachers to get better acquainted to topics presented in the textbook. We follow the same chapter numeration of the textbook. To avoid confusion when we refer to chapters, equations, figures and tables of *Particles and Fundamental Interactions*, the reference is enclosed in a box. In this way, Fig. 7.2 refers to a figure in this manual, and Fig. 7.2 to a figure in the textbook. As a general advice, it is useful to try to solve problems only after a first reading of a book. Before facing the more advanced problems, we suggest to read at least up to Chap. 8 of *Particles and Fundamental Interactions*, where the introduction of particle nomenclature and classification, and the presentation of fundamental aspects of the interactions are completed.

In addition to problems and solutions, additional material is presented in form of fifteen *Supplements*. Four of them present the most powerful accelerators, those which produce *cosmic rays*. Cosmic rays were of fundamental importance for the discovery of most long-living particles, the development of particle physics and that of *astroparticle physics*. Three Supplements are devoted to the electronic signals, to data acquisition systems, to the electronic logics and triggers of the experimental apparatuses, ending with the computing effort required for the LHC collider. These issues play also a key role in the contribution that particle physics research provides

as a spin-off technology. This is also true for other four supplements, presenting additional information on interactions between charged particles and matter (multiple Coulomb scattering, synchrotron radiation) or the use of radioactive decays for dating old objects. Some problems contain, after the solutions, some comments related to past, running or future experiments (as for instance that for the neutrino beams and neutrino oscillations, the search for proton decay, the study of symmetry violation through the electric dipole moment of the neutron, the measurement of α_S, the study of astrophysical objects using charged particles and/or neutrinos, etc.).

We thank many colleagues, in particular those of the former OPAL and MACRO groups (now, CMS, OPERA and ANTARES) at the University of Bologna, for their cooperation. Finally, we are grateful to many students for their suggestions and questions that allowed us to prepare this work in a way that we hope will be useful for many.

We are responsible for the errors which inevitably could be present in this manual. Some problems contain approximations, or may be solved in different or more straightforward way. We apologize in advance for any mistake that could have survived and that the readers will discover: you are kindly encouraged to inform us.

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