

# Preface

This book aims to introduce the many different aspects that correlate particle physics with astrophysics and cosmology and to introduce astrophysics by means of the experimental results recently obtained through the study of charged and neutral high-energy particles (including GeV and TeV photons).

The Standard Model of particle physics, which includes the theory of electro-weak interaction and quantum chromodynamics for the strong interaction, explains quite well all available experimental results. The theory was recently crowned by the discovery of the last missing piece: the Higgs boson. A parallel Standard Model has been derived from observational cosmology, which describes the evolution of the Universe as a whole as well as the objects within it.

“Multimessenger” astrophysics, connecting traditional astronomy with cosmic ray,  $\gamma$ -ray, and neutrino observations, has been made possible by the availability of experimental techniques and detectors used in particle physics. These developments have allowed the construction and operation of experiments in space borrowing from the techniques used at accelerators. This has made possible, with space-based experiments, the study of cosmic matter and antimatter, and the detection of high-energy  $\gamma$ -rays with good pointing capabilities. Underground laboratories, created to test particle physics beyond the Standard Model, offer an ideal low-background environment to detect neutrinos produced by the nucleosynthesis in the Sun, or by the gravitational core-collapse of a massive star. Deep underwater/ice neutrino telescopes have started to provide information on cosmic accelerators, while at the same time allowing tests of several physical properties of neutrinos.

This book is aimed primarily at those undertaking postgraduate courses, Ph.D. students, and postdoc researchers involved in high-energy physics or astrophysics research. It is also aimed at senior particle physicists usually interested in accelerator/collider physics, eager to understand and appreciate the mechanisms of the largest accelerators in the Universe. The reader is assumed to know, at an introductory level, particle and nuclear physics. Additional material (referred to as “Extras”) is freely available on the Springer website of this book.

The book is based on my lecture experiences at the University of Bologna on *Astroparticle Physics*. I have adopted here a systematic approach to cover the

experimental aspects, as well as to introduce the theoretical background. In particular, I dedicated a large effort to obtain first-order estimates of all the relevant processes described, referring to more advanced readings for deeper developments. The interpretations of experimental results of modern experiments rely in most cases on data comparison with model predictions obtained via Monte Carlo methods. These computational techniques are usually very detailed. It is important that researchers acquire the habit to critically understand the physical results of advanced simulation tools, also with simple back-of-the-envelope estimates. In this optic, I devoted great care to specify the measurement units of all relevant quantities, to develop toy-models to derive observable quantities from intuitive physics processes, and to compare the results of these simple predictions with published data.

Two words of warning about the literature: I usually quoted review papers. They are usually easier to read and helpful in introducing the reader to the inherent physics than specific research papers. Reviews, in turn, contain a detailed indication for further readings (on average, more than 200 citations for each review paper). For the permission to reproduce or adapt photographs and diagrams, I am grateful to all authors, collaborations, institutions, and laboratories quoted in each figure caption. I made every effort to secure necessary permissions to reproduce the copyright material in this work. If any omissions are brought to my notice, I will be happy to include appropriate acknowledgments on reprinting.

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Finally, I have to deeply and sincerely thank Prof. Vincenzo Flaminio, University of Pisa, who read critically and in-depth the manuscript. He has been a severe, knowledgeable, and affable reviewer, whose opinion was an important support for the author, which has contributed to significantly improve the final version.

I would also very much appreciate any corrections to mistakes or misprints (including the trivial ones), and also comments or simple observations. Please address them to: [maurizio.spurio@unibo.it](mailto:maurizio.spurio@unibo.it).

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