Preface

The understanding of aggregates of matter in terms of its elementary constituents and their interactions is a problem of fundamental interest with far reaching ramifications in science and technology. Much like the electromagnetic force between atomic nuclei and electrons gives rise to a rich variety of macroscopic materials, the strong (nuclear) force is expected to generate intricate matter structures and phases at the subatomic level, at densities of about a trillion times larger than ordinary matter and beyond.

The theoretical foundation of the Strong Force, Quantum Chromodynamics (QCD), is well established, as part of the Standard Model of Elementary Particles, with quarks and gluons as the fundamental degrees of freedom. However, key phenomena in strong interactions have evaded a profound understanding to date, most notably the confinement of quarks and gluons into hadrons and the generation of mass. These phenomena are believed to be intimately related to phase changes in strongly interacting matter, which is one of the main motivations for the research addressed in the present book. In nature, hot deconfined matter (the so-called Quark-Gluon Plasma) filled the early universe, just a few microseconds after the Big Bang, while present-day compact stars may contain cold and baryon-rich quark matter in their interior. The prospect of creating and studying this fundamental form of matter in modern-day laboratory experiments is truly fascinating. It enables a close interplay of experimental data and theoretical interpretation which is pivotal for scientific progress in this field. Nearly forty years of nuclear collision experiments, at laboratories across the world, have led to spectacular new insights, including the discovery of new forms and novel properties of matter.

Some of these developments have identified the regime of high baryon densities as a particularly interesting one. This is the main motivation for the proposed Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt. Closely related science will be pursued in a complementary fashion in an “energy scan” at the existing Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory. The ambitious goals of these projects have increased the need for a detailed, yet comprehensive, assessment of the current theoretical understanding of matter at high baryon densities, in order to help develop and focus the capabilities of future detectors and accelerators. Such an assessment constitutes the first main objective of the present "CBM Physics Book", and as such is intended to render the latter a useful resource for experienced researchers in the field. As the project evolved, the scope of the CBM Physics Book expanded from the originally envisaged more specific discussion of the physics of high baryon density. The positive feedback and broad participation of contributors suggested a more general presentation of the physics of strongly interacting matter. The Editorial Board seized this opportunity to implement various pedagogical components, including more elementary introductory sections and intermediate summaries of the main Parts of the book. A rather general overall introduction on "Facets of Matter" is intended to be accessible to an interested non-expert. The pedagogic measures are aimed at realizing a second main objective: to make the physics of hot and dense matter in heavy-ion collisions accessible to entry-level graduate students starting their research in this field.

The CBM Physics Book is structured into five topical units ("Parts"). Part I surveys the bulk properties of strongly interacting matter, including its equation of state and phase structure. Part II discusses elementary (hadronic) excitations of QCD matter, which, in particular, provide the conceptual basis for "probing" its properties. Part III addresses the concepts and models regarding the space-time dynamics of nuclear collision experiments – tools essential to connect bulk-matter properties and its excitations to experimental data. A compilation of relevant observables from current and past high-energy heavy-ion facilities is presented in Part IV, augmented by theoretical predictions specific to CBM. Part V finally gives a brief description of the experimental concepts and components underlying the CBM detector.

The official start of the CBM-Book project may be associated with a "kick-off" meeting of approximately 30 world-leading scientists in June of 2005 at GSI (Darmstadt). At this meeting four topical working groups were initiated, one for each of the four original parts of the book, in a process open to anyone interested and willing to join. The fifth part was added later to reflect progress in design studies of the detector. Each working group consisted of up to a dozen scientists headed by two to three elected conveners. The conveners were entrusted with organizing the collection of the scientific material and combining it into a topical unit for each part of the book. The scientific efforts were further supported by several 1 week workshops held at the International Center for Theoretical Nuclear Physics and Related Areas (ECT*) in Trento in 2006 and at GSI in the following years.

The CBM Physics Book is based on an impressive number of high-quality contributions authored by leading scientists in the field, as listed at the beginning of each part. These contributions represent forefront research on diverse aspects of strongly interacting matter. While covering the topic from a broad perspective as indicated above, CBM-specific connections have been stipulated throughout.

The approximately 4-year process of putting together the final volume of ∼1,000 pages required substantial organizational efforts. About 2 years into the project the necessity for another level of editorial work became evident, which led to the formation of the Editorial Board (EB). Its members naturally emerged as the leading conveners of each part, S. Leupold (Part I), R. Rapp (II), J. Knoll (III+technical editing), J. Randrup (Part III), P. Senger (IV+V), C. Höhne (Part V), as well as B. Friman (executive summary). Their task was to establish overall coherence of the material by suitable adjustments in the structure of the various parts, e.g. by incorporating umbrella paragraphs to improve the connections of sections and chapters. Summaries of each part highlight the main points with topical foci that may serve as a quick reference.

The EB hopes that the large efforts devoted by the many contributing scientists toward completion of this book will stimulate further progress in the field of strongly interacting matter in particular, and in the applications and developments of concepts for describing strongly coupled systems, in general. It ultimately remains with the reader to judge in how far the objectives of this book have been realized. The EB expects that significant parts of this book will have to be rethought, rewritten and augmented when confronted with the reality of experimental data. It will be exciting to witness these developments in the years to come.

The combination of the primary research review character of this book with components of a more pedagogical design may fit quite suitably the format of "Lecture Notes in Physics". The EB is very grateful to the editors of Springer Verlag for the opportunity to publish the present volume in this series.

The primary thanks go to all our scientific colleagues, listed below, who have contributed in various ways to the completion of this book, be it as contributing authors or as conveners collecting and distilling the material, towards a well tuned presentation of the different parts. Many thanks are also in order to the numerous colleagues who contributed ideas, discussion or other pertinent material, thereby opening valuable perspectives on various aspects of this book. Further thanks are also in order to the students performing simulations for the design study of the future detector. Without all their help the book would not have developed into its present form. Despite the broad authorship, the vast scope of the physics of strongly interacting matter inevitably implies that possibly some important results have not got covered in a complete fashion, or might have simply got overlooked. While thanking all the authors for their valuable contributions, the EB apologizes to researchers whose work was not appropriately covered or cited.

The EB gratefully acknowledges Frank Wilczek's prelude to this book sharing his thoughts on strongly interacting matter. Finally, the EB thanks GSI, the CBM collaboration and the ECT* for supporting the progress in compiling this book with pertinent scientific workshops and meetings.

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