Preface

Perhaps the most fascinating aspect of the strong interaction of particle physics is the wealth of qualitatively different regimes it exhibits. Modern nuclear physics deals with phenomena typically occurring at energy, momentum, temperature, or density scales between a few MeV and a few GeV. A relatively new goal in the field is to connect nuclear phenomena directly to the fundamental theory of the strong interaction, quantum chromodynamics. QCD has only a few free parameters, and it is remarkable that so much can, in principle, be predicted from so little.

In certain regimes, such as low-energy nuclear few-body systems, effective field theories provide a systematic approach. QCD can then be used to determine their low-energy parameters and to test their range of validity. But certain observables, like the spectrum of excited hadrons and the charge distributions of the nucleon, or the transition from the hadronic phase of QCD to a plasma phase at high temperatures, have no obvious simpler description in terms of effective degrees of freedom. A systematic treatment then involves the full complexity of QCD.

Lattice QCD provides a framework to handle the theory of the strong interaction from first principles in a wide range of energies relevant to nuclear physics. It is a discretized formulation of QCD on a spacetime lattice which preserves its SU(3) gauge symmetry. The latter is key to its ability of handling the theory in its non-perturbative regime. Numerical techniques and high-performance computing are an essential part of lattice QCD. The success of lattice QCD calculations depends thus on its practitioners being proficient both in quantum field theory and in programming and numerical methods.

In the summer school held at the Institute for Nuclear Theory in Seattle, 6–24 August 2012 (http://www.int.washington.edu/PROGRAMS/12-2c/), a series of courses were delivered, aimed at giving graduate students not only an overall understanding of lattice gauge theory, but also at covering in detail how one applies lattice gauge theory to the calculation of key quantities in nuclear physics. The list of lectures held at the school is given hereafter. State-of-the-art algorithms for generating gauge ensembles and fermion propagators were covered. Students performed numerical exercises on using lattice QCD code, analyzing and fitting data, and on utilizing new hardware, such as graphics processing units (GPUs) and the CUDA environment. In this book you will find the contents of the lectures on the most central physics topics written up. We hope that they provide an accessible and solid introduction to nuclear physics applications in lattice QCD for graduate students and any interested physicist.

Seattle, WA, USA Huey-Wen Lin
Mainz, Germany Harvey B. Meyer
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