Preface

The atomic nucleus has proven to be an exceedingly interesting many-body system to study as it has brought up surprises over and over again. The building blocks are protons and neutrons, both spin-half particles. The quark degrees of freedom are not excited in low-energy investigations of the nucleus. The underlying Quantum Chromodynamics structure manifests itself rather in a complex nucleon-nucleon force with spin- and isospin-dependent terms. A strongly correlated bound quantum system, the nucleus, is thus formed that exhibits a wide spectrum of phenomena. Information on the shape and size of the nucleus, which are important quantities, may be found from scattering experiments. The interpretation is simplest in those cases where the projectile itself has no internal structure like an electron. In this case, the relevant force is electromagnetic and we learn about the charge distribution in the nucleus. The first experiments of this type were performed by Hofstadter in the late 1950s. If instead of an electron a hadron is used as the projectile, the force is dominantly the nuclear strong interaction and we derive information about the matter density. The way in which the nucleus can be observed and described depends highly on the nature and the energy of the particle with which we are probing the nucleus. In view of this, for instance, (p, p) reaction is a tool to study the nuclear matter distribution.

Stable nuclei (in total 263 isotopes) only occur in a very narrow band in the Z − N plane. All other nuclei, which are existing within the drip lines (approximately 3000 isotopes have been identified and yet another 3000 − 4000 are in terra incognita), are unstable and decay in various ways. Isobars with a large surplus of neutrons tend to convert a neutron into a proton. In the case of a surplus of protons, the inverse reaction may occur. These transformations are called β-decays. Talking about physics for nuclei far from stability gives, at least, the impression that some aspects of binding many-body systems under the influence of the strong nucleon-nucleon force could be totally different from what one notes near the valley of β-stability, *e.g.*, the appearance of new magic numbers.

Pioneering technology enabled the control of energetic electron beams in particle accelerators. These were invented in the 1930s and provided precise data on the size and shape of atoms. To probe the nucleus of atoms, higher energies were required and the acceleration of protons was added to the toolkit of physicists. However, to probe the very small, the accelerators also grew in size, complexity, and cost. Accelerators are, in essence, powerful microscopes, taking over when light is no longer sufficient.

Much of what we know about nuclei comes from nuclear reactions. In the past, these were limited to stable nuclei, available as target materials, in bombardments with beams of (other) stable nuclei, in particular light nuclei. Having short-lived nuclei available as energetic beams, allows extending such studies in an inverse laboratory kinematics to unstable radioactive nuclei away from stability. Exotic nuclei are characterized by an extreme excess of protons or neutrons and are thus located far away from the valley of stability. New structural phenomena are to be expected, such as very different proton and neutron density distributions. Reactions between nuclei play a decisive role in many astrophysical processes in the Universe. Nuclear structure effects and the dynamics of nuclear reactions are directly reflected in the various evolutionary stages of stars. Unstable nuclei, far from stability, are involved and their properties determine the fate of the relevant astrophysical processes.

The availability of energetic beams of short-lived nuclei, referred to as radioactive ion beams (RIBs), has opened the way to the study of the structure and dynamics of thousands of nuclear species never observed before in the laboratory. There is little doubt that RIB physics has transformed not only nuclear physics itself but many other areas of science and technology too, and will continue to do so in the years to come. While the field of RIB physics is linked mainly to the study of nuclear structure under extreme conditions of isospin, mass, spin and possibly also temperature, it also addresses problems in nuclear astrophysics and the study of fundamental interactions. The development of new production, acceleration and ion-storing techniques and the construction of new detectors adapted to work in the special environment of energetic radioactive beams play also such an important role that conquering the whole chart of nuclei for research looks to be only a matter of time.