Ion traps in nuclear physics

Mathias Gerbaux, CENBG

Developments of Radioactive Ion Beam (RIB) facilities have progressed very rapidly these last decades and allowed to shed light on exotic behaviors of the atomic nucleus and thus refine its theoretical description. One goal of these developments is to produce exotic nuclei with higher intensities and to reach the limits of stability (drip-lines and super-heavy elements). However, not only the intensity is crucial, the purity and the quality of the ion beam are also required, in particular for precision measurements with low-energy beams (30-60 keV), such as beta-decay studies, trap-based experiments or laser spectroscopy, the latter being the subject of other lectures of this Joliot Curie School. One of the main applications of ion traps in nuclear physics is the beam preparation in RIB facilities, i.e. ion beam cooling, bunching as well as high-resolution mass separation.

Besides beam improvement devices, ion traps are also used as measurement devices. In particular, they allow to measure with very high precision and accuracy the mass of the atomic nucleus, the Penning trap being the most precise technique nowadays, but the development these last years of electrostatic traps (MR-ToF) also showing high performance in mass spectrometry of short-lived nuclei. Having access to the binding energy of exotic nuclei, one of the most fundamental properties of the nucleus, allows to reveal specific nuclear structure effects, such as deformations, pairing or shell closures.

In the first part of the lecture, we will introduce the basic principles of ion trap devices, allowing to confine charged particles in a small volume. The different techniques to manipulate ions, once trapped, will be detailed. The beam preparation and mass separation techniques will then be explained. Finally, the different mass spectrometry methods will be presented and examples of recent experiments will be given, to show how mass measurements can improve our understanding on the nuclear structure, but also how they can contribute to refine nucleosynthesis processes models and to the search for physics beyond the Standard Model.