Measurements with an Advanced Trapping System at the future GSI facility FAIR

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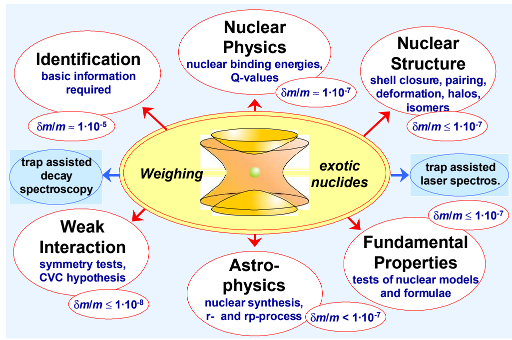
Introduction

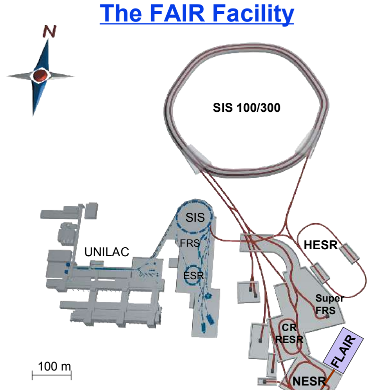
Ion traps play an important role not only in high-precision experiments on stable particles but also on exotic nuclei. Besides accurate mass measurements they have recently been introduced to nuclear decay studies and laser spectroscopy as well as to tailoring the properties of radioactive ion beams. This broad usage of trapping devices at accelerator facilities is based on the manifold advantages of a three-dimensional ion confinement in well controlled fields: First, the extended observation time is only limited by the half-life of the radionuclide of interest, yielding very high precisions for instance for mass measurements. Second, stored ions can be cooled and manipulated in various ways, even polarization and charge breeding of the ions are possible, giving a unique tool in order to prepare otherwise impossible experiments. Third, it is possible to create a backing free source of radioactive nuclei and to collect light particles (e^- and e^+) very efficiently, reducing a number of uncertainty in classical spectroscopic experiments. The MATS Collaboration proposes an advanced trapping system at the future GSI facility FAIR for high-precision mass measurements and decay studies on short-lived radionuclides.

Motivation and Fields of Application



The mass and its inherent connection with the nuclear binding energy is a basic property of a nuclide. Thus, precise mass values are important for a variety of applications, ranging from nuclear-structure studies, test of nuclear mass formulas, to tests of the weak interaction and of the Standard Model. The required relative accuracy ranges from 10^{-5} to below 10^{-8} for radionuclides, which most often have half-lives well below 1 s. Substantial progress in Penning trap mass spectrometry has made this method a prime choice for precision measurements on rare isotopes. Further-more, ion traps can be used and offer advantages for precision decay studies and trap assisted laser spectroscopy studies.

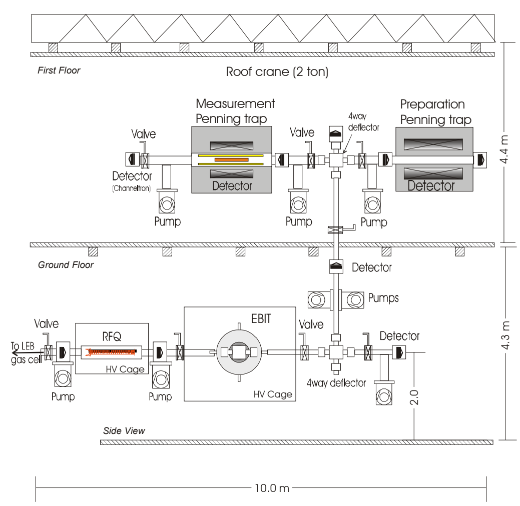
The FAIR Facility



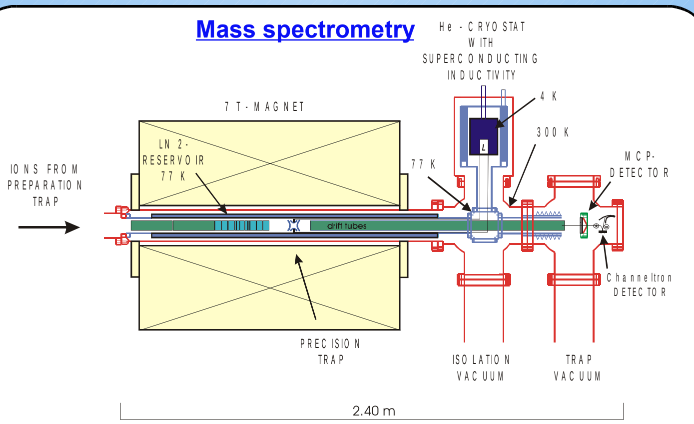
FAIR (Facility for Antiproton and Ion Research) is the future project of the GSI. A big double-ring accelerator is the core component of the facility, which is connected to a complex system of storage rings and experimental stations. The new facility is going to provide ion beams with currently unique intensity as well as higher energies so that intensive secondary beams - e.g. exotic nuclei or antiprotons - can be produced for the planned experiments. MATS will be installed at the Low Energy Branch of the Super FRS where radioactive beams with up to 10 000 higher yields than anywhere else will be available.

Figure of the proposed Experimental MATS Setup

With MATS at FAIR we aim for applying two different techniques to very short-lived radionuclides: High-precision mass measurements and in-trap conversion electron and alpha spectroscopy. The experimental setup of MATS is a unique combination of an electron beam ion trap for charge breeding, ion traps for beam preparation, and a high precision Penning trap system for mass measurements and decay studies. Each subsystem is a versatile tool itself and allows different high-precision experiments resulting in a broad physics output. For beam preparation an ion beam cooler and buncher will be used. A magnetic multi-passage spectrometer is implemented for q/A separation of the highly-charged ions. For further details see the Technical Proposal submitted to the FAIR.

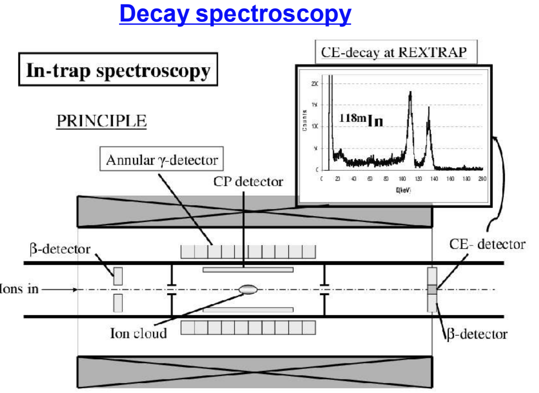


Mass spectrometry



For the mass measurements, MATS offers both a high accuracy potential and a high sensitivity. A relative mass uncertainty of 10^{-9} can be reached by employing highly-charged ions and a non-destructive Fourier-Transform-Ion-Cyclotron-Resonance (FT-ICR) detection technique on single stored ions. This accuracy limit is important for fundamental interaction tests, but also allows to study the fine structure of the nuclear mass surface with unprecedented accuracy, whenever required. The use of the FT-ICR technique provides true single ion sensitivity. This is essential to access isotopes that are produced with minimum rates and that very often are the most interesting ones.

Decay spectroscopy



MATS will be build such that in-trap decay spectroscopy becomes available. Novel spectroscopic tools for in-trap high-resolution conversion-electron and charged-particle spectroscopy from carrier-free sources will be developed, aiming *e.g.* at the measurements of quadrupole moments and E0 strengths. With the possibility of both high precision mass measurements of shortest-lived isotopes and decay studies, its high sensitivity and accuracy potential MATS is ideally suited to for the study of very exotic nuclides that are only produced at the FAIR facility.

General Information

The MATS Collaboration consists presently of 52 members from 16 institutes. A letter of intent for the MATS project was submitted in April 2004 to the FAIR committee. After approval by the physics advisory committee of FAIR a MATS writing group was set up and submitted in time a Technical proposal on the 15th of January 2005 to FAIR.

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