Eur. Phys. J. A **25**, s01, 63–64 (2005)
DOI: 10.1140/epjad/i2005-06-072-6

**EPJ A direct**
**electronic only**

# A high-current EBIT for charge-breeding of radionuclides for the TITAN spectrometer

G. Sikler[1,a], J.R. Crespo López-Urrutia[2], J. Dilling[1], S. Epp[2], C.J. Osborne[2], and J. Ullrich[2]

[1] TRIUMF, 4004 Wesbrook Mall, Vancouver BC, V6T 2A3, Canada
[2] Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117, Heidelberg, Germany

Received: 7 December 2004 /
Published online: 3 May 2005 – 

**Abstract.** The TITAN (Triumf's Ion Trap for Atomic and Nuclear science) Penning trap mass spectrometer will be located at ISAC/TRIUMF in Vancouver, Canada. It is designed for conducting high-precision mass measurements on radionuclides via the determination of the cyclotron frequency of the ions confined within the Penning trap. An essential component of the setup will be an electron beam ion trap (EBIT) which will allow charge breeding of the radionuclides prior to the actual mass measurement. Compared to singly charged ions, the investigation of highly charged ions (HCIs) yields higher accuracies and enables access to radionuclides with half-lives considerably shorter than 100 ms. The working principle of an EBIT as well as the design of the TITAN-EBIT in particular will be described.

**PACS.** 34.80.Kw Electron-ion scattering; excitation and ionization – 32.10.Bi Atomic masses, mass spectra, abundances, and isotopes – 07.75.+h Mass spectrometers

## 1 Introduction

The atomic mass of ions can be measured with very high accuracy using Penning trap mass spectrometry (as described in, *e.g.*, [1]). While the ions are spatially confined by means of a strong homogeneous magnetic field and a weak electrostatic field they perform a characteristic gyration around the magnetic field lines: the cyclotron motion. The cyclotron frequency of an ion with charge $q$ and mass $m$ trapped in a magnetic field $B$ is given by $\nu_c = (q \cdot B)/(2\pi \cdot m)$. One way to determine this frequency, and the mass for a given $q$ and $B$, is to excite the cyclotron motion of the ions resonantly. The accuracy $\Delta\nu_c$ depends on the number of ions $N$ that contribute to the spectrum and the width of the resonance being defined by the excitation time $T_{ex}$. The relative accuracy is proportional to

$$\frac{\Delta\nu}{\nu} \propto \frac{m}{T_{ex} q B \sqrt{N}} .$$

Increasing $q$ (or $B$) enhances the relative accuracy of the mass determination. On the other hand, to reach a desired accuracy the excitation times (usually limited by the nuclear half-life of the ions under investigation) can be shorter and the required count rates can be smaller when the charge of the ions is larger. Both the number of ions and their nuclear half-life are limiting factors in investigating radionuclides very far from the valley of stability. Therefore the TITAN mass spectrometer [2] will employ an electron beam ion trap to enhance the charge state of the radionuclides considerably prior to the actual mass determination.

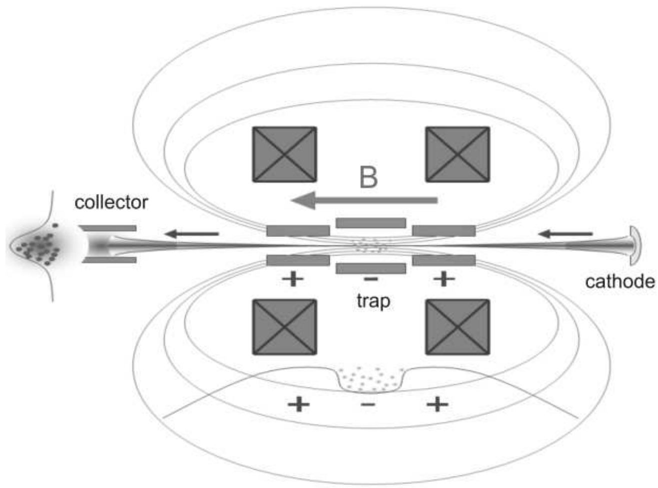


**Fig. 1.** Principle of an electron beam ion trap. An intense electron beam is compressed by a strong magnetic field. The high space charge potential provides confinement in the radial degrees of freedom, while the ions are trapped axially by external potentials applied to the trap electrodes.

[a] Conference presenter; *Present address*: Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117, Heidelberg, Germany; e-mail: `g.sikler@mpi-hd.mpg.de`

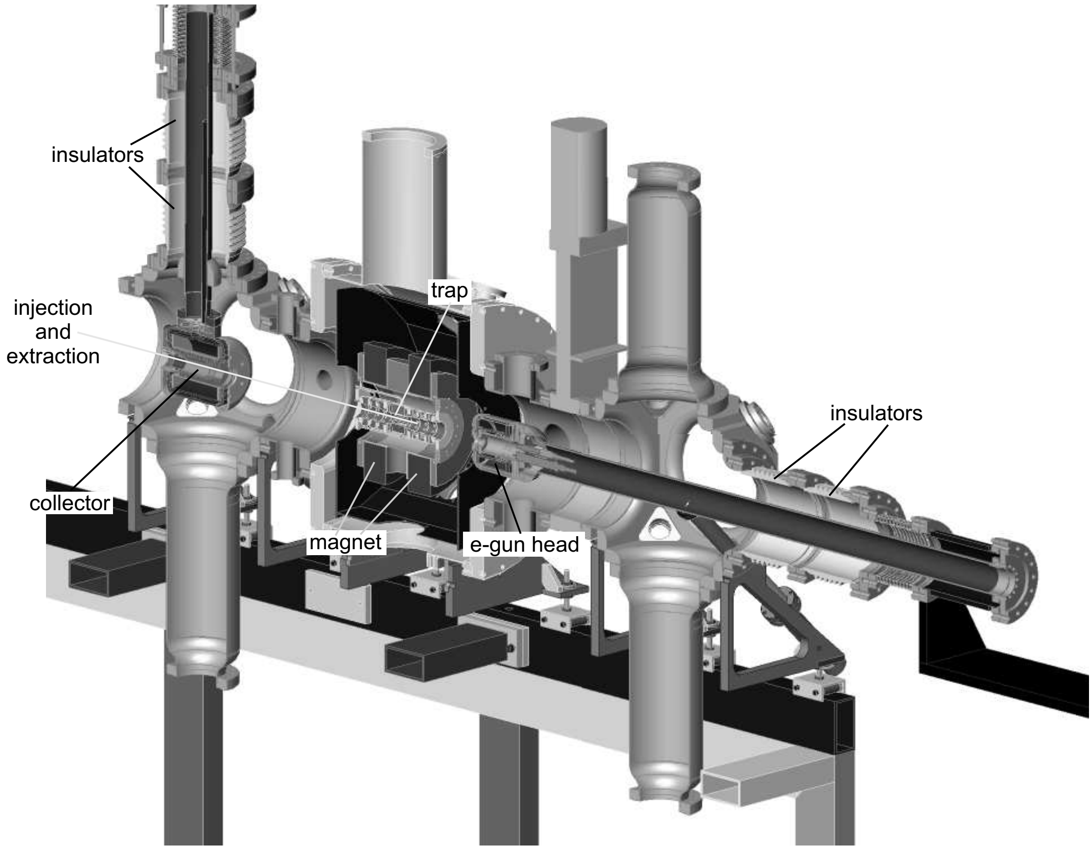


**Fig. 2.** Schematic overview of the TITAN-EBIT. A superconducting 6 T magnet with cold bore houses the actual trap setup. Both the electron gun head and the electron collector unit are adjustable with respect to the magnetic field and relative to each other to provide an optimal electron beam performance. The electron gun and the collector are floating on negative high voltage, whereas the trap is held at ground potential.

## 2 Electron beam ion trap

The electron beam of an EBIT is produced with a thermionic cathode and then electrostatically accelerated and injected into a strong magnetic field (see fig. 1). Here the electrons are radially confined by the Lorentz force, and the beam is compressed as the magnetic field strength increases. A general description of EBIT can be found in [3]. For the TITAN-EBIT the magnetic field strength will be 6 T. The acceleration voltage which gives the maximum kinetic energy of the electrons will be variable up to 80 kV and a beam current of 5 A is envisaged. With these parameters a compression of the electron beam down to 150 $\mu$m is expected. The confinement of such an amount of negative electric charge provides a space charge potential, which is more than 5 kV deep. This space charge potential allows radial confinement of the ions. Axial confinement is accomplished by applying external potentials to the trap electrodes. Whilst trapped in the dense electron beam the ions undergo further ionization through successive electron impact processes. To obtain highly charged ions in charge states such as, *e.g.*, $Xe^{44+}$, typical ionization times are in the order of 10 to 50 ms.

Figure 2 shows a rendered design drawing of the TITAN-EBIT. The radionuclides enter the EBIT as cooled bunches of singly charged ions, in the figure from the left side through the collector. The extraction after charge breeding takes place along the same path but in the opposite direction. The extraction and the transport to the Penning trap will be accomplished by means of floatable drift tubes and pulsed cavities (not drawn in the figure). The design of all parts of the TITAN-EBIT is completed and the device is currently being assembled. Stable operation at high electron beam currents is foreseen for the year 2005, as well as first off-line tests of injecting and extracting ions.

We thank our collaboration partners, the Heidelberg-EBIT group, for the outstanding support, the many advices and the friendly hospitality, that we experienced during the design and construction phase of the TITAN-EBIT.

## References

1. P.K. Ghosh, *Ion Traps* (Oxford University Press, Oxford, 1995).
2. J. Dilling *et al.*, Nucl. Instrum. Methods B **204**, 492 (2003).
3. F.J. Currell, *The Physics of Multiply and Highly Charged Ions*, Vol. **1**: *Sources, Applications and Fundamental Processes* (Kluwer Academic Publishers, Dordrecht, 2003).