TITAN TRIUMF's Ion Trap for Atomic & Nuclear science

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Introduction & Motivations

The TITAN (TRIUMF Ion Trap for Atomic and Nuclear science) experiment at TRIUMF (TRI-University Meson Facility) use a unique combination of a Penning trap and a Electron Beam Ion Trap (EBIT) to achieve mass measurement with a relative accuracy of $\delta m/m \sim 10^{-8}$ on short-lived isotopes with half-lives of only 50 ms. The mass is determined from the cyclotron frequency ν_c of the ion in the homogenous magnetic field B of the Penning trap magnet:

$$\nu_c = \frac{q}{m} \cdot \frac{B}{2\pi}$$

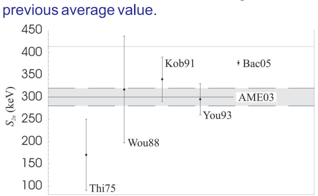
The use of Highly Charged Ions (HCI) will increase the mass measurement resolution by a factor of q corresponding to the charge state of the HCI:

$$R = \frac{m}{\delta m} = \frac{\partial \nu_c}{\partial m} \frac{1}{\delta \nu_c} \approx \frac{T_{RF} \cdot q \cdot B \cdot \sqrt{N}}{m}$$

Where T_{rf} is the duration of the radio-frequency excitation and N is the number of mass measurements.

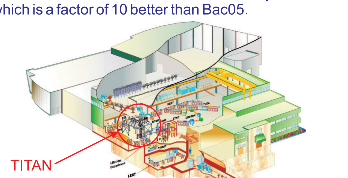
Besides measuring the mass of unstable HCI, the versatile TITAN experiment can also operate with high accuracy on singly charge and/or stable ions.

The TITAN experiment will do its first mass measurement on singly charged $^{11}Li^{+}$, which is a halo nuclei: it has a ^{9}Li core surround by a weakly bound di-neutron halo. The root mean square radius of ^{11}Li depends on the 2-neutrons separation energy S_{2n} and a recent measurement has a 2 ℵ disagreement with the previous average value.



Two-neutron separation energy S_{2n} value from previous experiments. See Bac05 for ref.

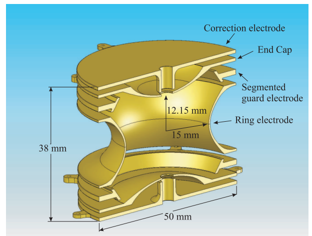
Since the mass of ^{9}Li is well know, the error in the calculation of S_{2n} comes mainly from the mass measurement of ^{11}Li, a very accurate mass measurement of ^{11}Li is necessary to solve the disagreement. With the high yield of ^{11}Li produce by ISAC (Isotope Separator and ACcelerator), assuming an excitation time of 20 ms and 10 000 counts, TITAN can achieve an absolute mass uncertainty of 550 eV, which is a factor of 10 better than Bac05.



The Isotope Separator and ACcelerator (ISAC) facility at TRIUMF.

Other motivations for high accuracy mass spectrometry are:
- Shell closure effects, existence and locations of magic numbers far from the valley of stability.
- Test the unitary of the CKM matrix and the CVC hypothesis.
- Study of rp-process waiting-point nuclei.

Other than mass measurement, the TITAN set up can also be used for:
- Collinear laser spectrometry on cooled ion bunches using the RFQ.
- Study of the branching ratio of odd-odd intermediate nuclei in double-beta decay using the EBIT in Penning trap mode.
- X-ray spectrometry of short-lived radioactive nuclei.

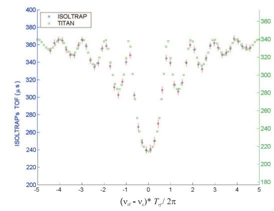


Cross-sectional view of a Solid Work rendered drawing of TITAN's precision Penning trap electrode structure.

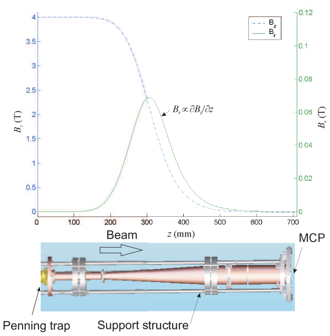
TITAN's Mass measurement Penning Trap

TITAN's Penning trap will measure the cyclotron frequency ν_c of the ion using the time-of-flight (TOF) technique: after an excitation of duration T_{rf}, the ions are released and enter the fringe field of the superconducting magnet. There, the coupling of their magnetic moment with the magnetic field gradient $\partial B_z/\partial z$ induce a radial to axial conversion of their momentum. The effect of this conversion can be affected by changing the voltage applied on a drift tube situated in strong magnetic gradient region. When the excitation frequency $\nu_{rf} = \nu_c$ the conversion is maximize, therefore the shortest TOF correspond to the cyclotron frequency ν_c.

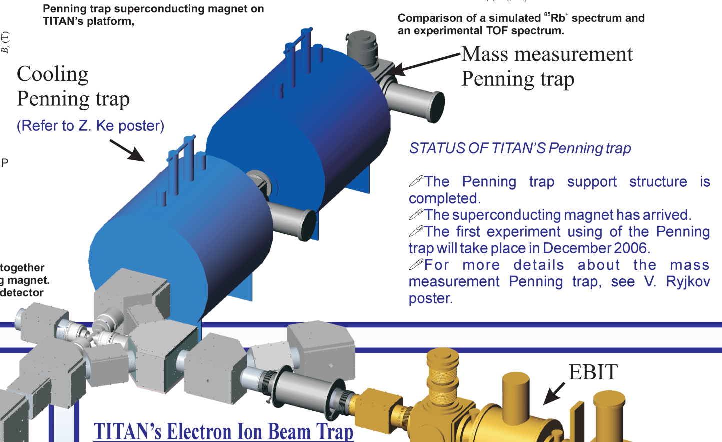
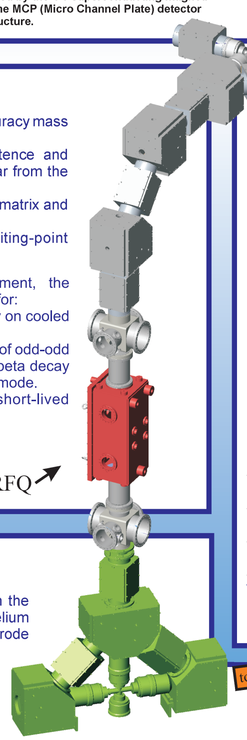
Penning trap superconducting magnet on TITAN's platform,



Comparison of a simulated $^{85}Rb^{+}$ spectrum and an experimental TOF spectrum.



Electrode structure for the extraction from the Penning trap together with the magnetic field produced by the 4 T superconducting magnet. Shown are the Penning trap, the MCP (Micro Channel Plate) detector and the extraction support structure.

STATUS OF TITAN'S Penning trap

- The Penning trap support structure is completed.
- The superconducting magnet has arrived.
- The first experiment using of the Penning trap will take place in December 2006.
- For more details about the mass measurement Penning trap, see V. Ryjkov poster.

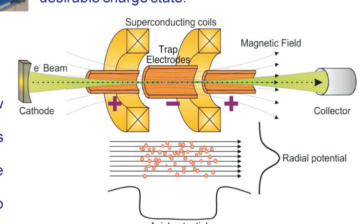
TITAN's Electron Ion Beam Trap

Photo of the EBIT on TITAN's platform.

The function of TITAN's Electron Beam Ion Trap (EBIT) is to increase the charge state of the singly charged ions coming from the RFQ. In the TITAN EBIT, the ions are trapped by an axial potential well, while a 5 A electron beam strip the ions to the desirable charge state.

STATUS OF TITAN'S EBIT

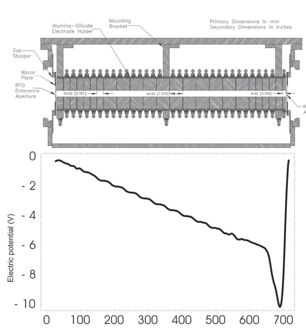
- The EBIT and its HV cage are now installed on the platform.
- The design of the injection beam line is completed.
- The commissioning of the EBIT will take place in September/October 2006.
- For more details about the EBIT, refer to talk of M. Froese.



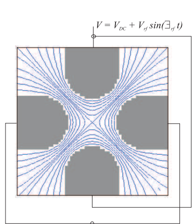
The segmented electrode structure of the EBIT provides an axial trapping while the magnetic field produced by the Helmholz coils radially confines the electron beam.

TITAN's Radio Frequency Quadrupole

The function of TITAN's Radio-Frequency Quadrupole (RFQ) is to cool and bunch the continuous radioactive beam produced by the ISAC facility. The beam is cooled with helium buffer gas and bunched by an axial potential well created by the segmented electrode structure.



Up: Schematic view of TITAN's RFQ electrode structure. Down: Axial potential of the RFQ.



Quadrupolar focusing potential produced by the RFQ RF field.

STATUS OF TITAN'S RFQ

- The RFQ and its HV cage are installed vertically in the experimental hall.
- The injection and extraction beam line are completed.
- The commissioning of the RFQ will take place in Sept. 2006.
- For more details about the RFQ, refer to poster of M. Smith.

Photo of the electrode structure of TITAN's RFQ.

Status and Outlook

- The RFQ is installed in the ISAC hall
- The EBIT is installed on the platform
- The precision Penning trap magnet has arrived
- The cooler Penning trap is under design

Assembly and commissioning of the Penning trap is on the way. A first experiment on short-lived singly charged ^{11}Li will take place in December 2006. The first experiment using unstable highly charged ions is planned for 2007.

References

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