The TITAN EBIT

First Charge Breeding of Radioactive Isotopes

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A mass, \( m \), is measured with Penning trap mass spectrometers from the cyclotron frequency of trapped ions (\( \nu_c \); ion charge, \( q \); magnetic field strength):
\[
\nu_c = \frac{qB}{2m}
\]

The precision is proportional to the ion charge state:
\[
\frac{\Delta m}{m} \propto q
\]

For a fixed observation time \( t_{\text{obs}} \), and number of detected ions \( N \), highly charged ions (HCI’s) “boost” the precision of mass measurements.

**TITAN: High-precision mass measurements**

The TITAN (TRIUMF’s Ion Trap for Atomic and Nuclear science) facility consists of 3 (later 4) ion traps: a radio-frequency quadrupole (RFQ) cooler, an Electron Beam Ion Trap (EBIT) and a Penning trap. The TITAN EBIT is a charge state breeder to boost the precision of mass measurements.

**Outlook & References**

- Breeding of injected ions to higher charge states.
- Installation of a time-resolved DAQ system for charge breeding time measurements by X-ray and TOF spectroscopy.
- Energy spread and transverse emittance studies of beams extracted from the EBIT.
- Mass measurements of \(^{78}\text{Kr} \) and \(^{78}\text{Br} \) (June), and superallowed \(^{39}\text{mK} \) (Sept.) & \(^{74}\text{Rb} \) (Oct.) with highly charged ions.

**Recent progress & preliminary results**

**FIRST time-of-flight spectrum of residual gas ions extracted from the EBIT.**

<table>
<thead>
<tr>
<th>Mass (amu)</th>
<th>Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.1</td>
<td>4000</td>
</tr>
<tr>
<td>20.2</td>
<td>3500</td>
</tr>
<tr>
<td>20.3</td>
<td>3000</td>
</tr>
<tr>
<td>20.4</td>
<td>2500</td>
</tr>
<tr>
<td>20.5</td>
<td>2000</td>
</tr>
</tbody>
</table>

**FIRST TOF-ICR resonance of a highly charged ion in the TITAN Penning trap.**

**FIRST charge breeding of an injected short-lived radioactive isotope (\(^{29}\text{Na} \)).**

<table>
<thead>
<tr>
<th>Mass (amu)</th>
<th>Counts</th>
</tr>
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<tbody>
<tr>
<td>23</td>
<td>100</td>
</tr>
<tr>
<td>24</td>
<td>50</td>
</tr>
<tr>
<td>25</td>
<td>20</td>
</tr>
</tbody>
</table>

**THIRD time-of-flight spectra of charge bred injected stable ions (\(^{29}\text{Na} \)).**

<table>
<thead>
<tr>
<th>Mass (amu)</th>
<th>Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>100</td>
</tr>
<tr>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>31</td>
<td>20</td>
</tr>
</tbody>
</table>

**Funding received; installation planned for Dec. 2009.**

**Design values**

- Present max. e-beam energy: ~70 keV
- Planned cathode upgrades: 1 & 5 A
- Max. magnetic flux density: 8 T
- Theoretical breeding times: @ 400 mA, 25 keV
- Bare \( ^{20}\text{Ar}^{+} \): He-like \( ^{23}\text{Na}^{+} \): ~2 ms; Bare \( ^{20}\text{Ar}^{+} \): ~30 ms

**Demonstrated values**

- Present max. e-beam current: 500 mA
- Maximal cathode upgrade: 1 & 5 A
- Theoretical breeding radius: ~40 \( \mu \text{m} \)
- Electron beam current density: \( 10^{7} \text{ions} / \text{cm}^{2} \times \text{sec} \)

**Milestone**

- New cathode: \( ^{23}\text{Na}^{+} \) or \( ^{24}\text{Mg}^{+} \) or \( ^{27}\text{Al}^{+} \)
- Detecting \( ^{23}\text{Na}^{+} \) at \( 10^{11} \text{ions/m}^{2} \times \text{sec} \)

**Outlook & References**

- Breeding of injected ions to higher charge states.
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