Low-Background In-Trap Decay Spectroscopy with TITAN at TRIUMF

Kyle G. Leach | TITAN | TRIUMF, SFU
Neutrinoless $\beta\beta$ Decay

\[ (T_{1/2}^0)^{-1} = G^0 (Q_{\beta\beta}, Z) (M_{0\nu})^2 m_{\beta\beta}^2 \]

The TRIUMF-ISAC Facility

ISAC-I and ISAC-II Facility

J. Diling, R. Kruecken, and G. Ball, Hyper. Inter. 225, 1 (2014)
TRIUMF's Ion Trap for Atomic and Nuclear Science (TITAN)

EBIT
Electron Beam Ion Trap
A. Lapierre et al, NIM A 624, 54 (2010)

CPET
Cooler Penning Trap

RFQ
Cooler and Buncher
T. Brunner et al, NIM A 676, 32 (2012)

MPET
Precision Measurement Trap
M. Brodeur et al, IJMS, 310, 20 (2012)

Beam From ISAC

Low-Background In-Trap Decay Spectroscopy with TITAN at TRIUMF

A. Lennarz, T. Brunner et al., Hyper. Inter. 225, 157 (2014)
Decay Spectroscopy with TITAN

- Cryo-Cooler
- Sikler Lens
- Collector
- Central Drift Tube
- Heat Shield
- Thin Be Window
- Electron Gun
- Helmholtz Coils
Ion-Bunch Confinement

Decay Spectroscopy on Trapped Radioactive Ions

- Up to 6 T field with a 7 cm trapping volume
- Up to 500 mA e-beam
- 7, 5 mm thick Si(Li) detectors
- 1 LeGe detector for monitoring

Decay Spectroscopy on Trapped Radioactive Ions
EBIT Ion-bunch Injection

-e-beam

ion-beam

B-field

14mm
5mm

80mm

Courtesy R. Klawitter
EBIT Ion-bunch Injection

Inner-most collector side electrode potential is lowered for injection

Courtesy R. Klawitter
Inner-most collector side electrode potential is raised for axial confinement of the ion bunch

Courtesy R. Klawitter
Inner-most collector side electrode potential is lowered again, and bunch is removed from the trap.

Courtesy R. Klawitter
A=124 On-Line Commissioning

Counts/100 eV

- Trap-full data
- Trap-full simulation
- Trap-empty data (scaled)

Sn, Cs, and Xe X-rays

53.9 keV
58.2 keV

124m Cs and 124m In γ-rays

89.4 keV
96.5 keV

511 keV
102.9 keV
120.2 keV

A. Lennarz, A. Grossheim, K.G. Leach et al., PRL submitted (2014)
**116\(^{\text{In}}\) On-Line Commissioning**

- X-rays characteristic of EC
- \(^{116}\text{In}:^{116}\text{In}^{m1},^{116}\text{In}^{m2} -- 1:100:10\)
- Significant backgrounds from \(\beta^-\) decay are difficult to deal with
- Space-charge limit of RFQ \(~10^5\)

Multiple Ion-bunch Stacking

Ions are trapped, and in charge-state $q>2^+$

Courtesy R. Klawitter
Multiple Ion-bunch Stacking

Inner-most collector side electrode potential is not lowered to the same level as injection/extraction.

Subsequent ion bunches are rapidly injected, where they are quickly charge-bred, and remain trapped.

Courtesy R. Klawitter
Multiple Ion-bunch Stacking

Ion bunches from RFQ injected every 0.015 s

24 keV Kα from $^{116}$In$^{m2}$ (t$_{1/2}$ = 2.18 s)

- Constant ion bunch injection
- Max after 700 bunches (~$10^6$-$10^7$ ions, for RFQ space charge of $<10^5$)
- e-beam: 100 mA, 1.7 keV - space charge limit is about $10^9$e
116\textsuperscript{In} Decay Spectroscopy

Counts/bin

25ms RFQ, 600 Injections = 15 s Fill

15 s Trapping/Decay

\textsuperscript{116}In K\alpha

\textsuperscript{116}In K\beta

Energy (keV)

Decay Time (s)
${}^{116}\text{In Decay Spectroscopy}$

- $^{116}\text{In K}\alpha$
- $^{116}\text{Sn K}\alpha$
- $^{116}\text{In K}\beta$
- $^{116}\text{Sn K}\beta$
- $^{116}\text{Cd K}\alpha$

Decay (preliminary):

$T_{1/2} = 2.18(1)$ s

$^{116}\text{In m2}$
Conclusions

• An ion-trap decay spectroscopy tool has been constructed and commissioned with TITAN at TRIUMF

• Consists of:
  • Up to 6 T open-access ion trap
  • 500 mA e-gun
  • Seven 5mm thick planar Si(Li) detectors

• Have achieved trapping times of minutes with no ion losses

• Demonstrated multiple-injection technique (\(^{116}\text{In}\) decay)

• Plan to perform first physics measurement on \(^{110}\text{Ag}\) this fall
Thank You!

Merci!

Harvard
Notre Dame
U. of Manitoba
McGill U.
Muenster U.,
Max Plank Inst. für Kernphysik
GANIL
CNRS/Orsay
Yale
Giessen
Stanford U.
Uni Mainz
U. of Windsor
TU Dresden
TRIUMF
UBC
SFU
TU Munich
St Mary’s

Contact TRIUMF:
4004 Wesbrook Mall | Vancouver BC | Canada V6T 2A3 | Tel 604.222.1047 | Fax 604.222.1074 | www.triumf.ca