Precision Mass Measurements of Radioactive Isotopes with the TITAN MR-ToF-MS

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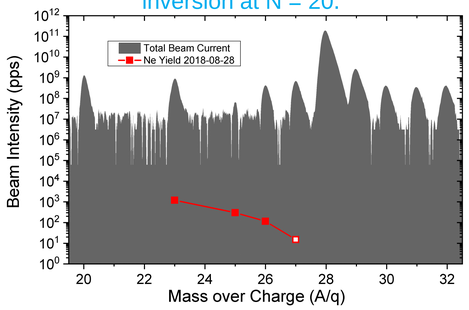
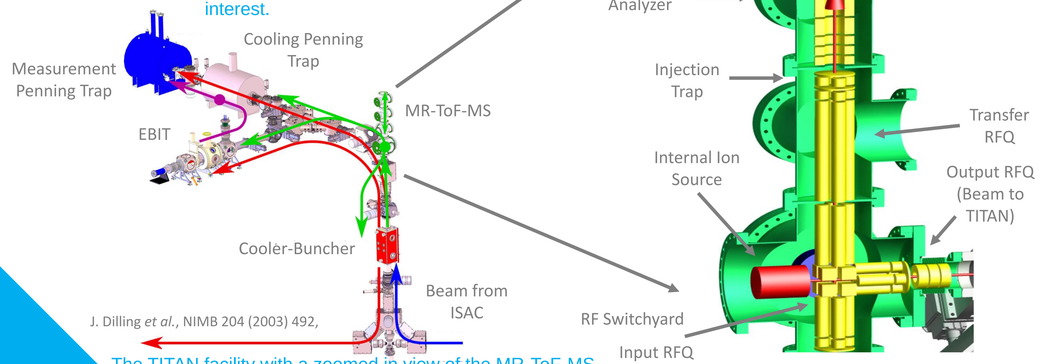
Introduction

To better understand nuclear structure, precision mass spectrometry of radioactive beams is required. Nuclides of interest become short lived and production rates drop further from stability. Additionally, these beams are frequently contaminated with both isobars and molecules which can obscure high-precision measurements. To help overcome these challenges, the Multiple-Reflection Time-of-Flight Mass Spectrometer (MR-TOF-MS) was commissioned at TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN). This device is capable of both beam purification, through mass-selective re-trapping, and fast, precise, high-sensitivity mass measurements. Furthermore, these two different modes of operation can be used sequentially enabling measurements to be done in exceedingly contaminated beams. Additionally, the technique of collision-induced dissociation has been investigated to enhance the suppression of molecular contamination by an order of magnitude. These capabilities were demonstrated during the mass measurements of neutron-rich $^{24-26}$Ne in which precisions of approximately 10^{-7} were achieved. These initial measurements demonstrates the feasibility of measuring the Ne isotopes in the region approaching the island of inversion at N = 20.



When using a plasma ion source, the beam has a high level of background contamination. This obscures the isotope of interest.



J. Dilling *et al.*, NIMB 204 (2003) 492,

The TITAN facility with a zoomed in view of the MR-ToF-MS. For this experiment, the Cooler-Buncher and MR-ToF-MS are the two traps that were used.

Mass-Selective Re-Trapping

Mass selective re-trapping allows for isobaric cleaning of contaminated beams. It has been demonstrated that isobaric contaminants can be suppressed by a factor of 10^4 which allows for the mass measurements of $^{24-26}$Ne. Before the mass measurements were done, systematic measurements were conducted to optimize both re-trapping efficiency and separation power.

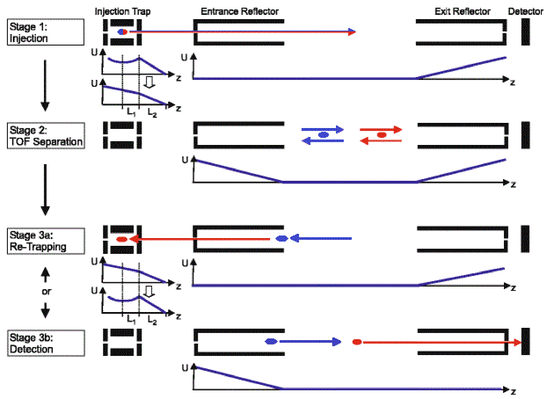
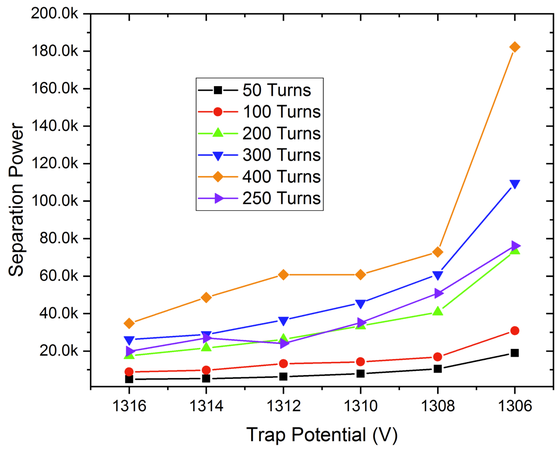


Diagram of the MR-ToF-MS operation. For more detail see: H. Wollniket al., IHMS 96 (1990) 267 and Dickel, T., Plaß, W.R., Lippert, W. et al. J. Am. Soc. Mass Spectrom. (2017) 28: 1079.

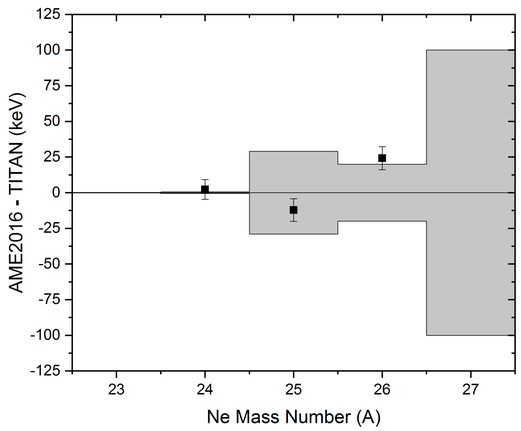
The TITAN MR-ToF-MS

Re-Trapping Characterization



By varying the injection trap depth and the number of turns, the separation power needed for a particular experiment can be tuned. However, a higher separation power can come at the expense of a decrease in efficiency.

Neon Mass Results



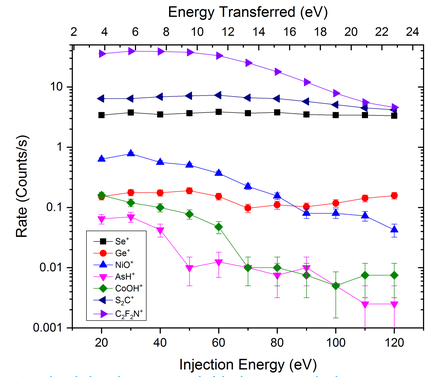
Mass measurements done for $^{24-26}$Ne are in agreement with literature values. The isotopes were produced at TRIUMF's ISAC facility using 500 MeV p^+ and delivered to the TITAN experiment re-trapping was implemented. The uncertainty of ^{25}Ne is reduced by a factor of 3 and the uncertainty of ^{26}Ne is reduced by a factor of 2.

Acknowledgements

This work was supported by the Natural Sciences and Engineering Research Council (NSERC) of Canada and the National Research Council (NRC) of Canada through TRIUMF as well as the Deutsche Forschungsgemeinschaft(DFG, grant nos. FR 601/3-1 and SFB1245 and through PRISMA Cluster of Excellence), the BundesministeriumfürBildungund Forschung(BMBF, grant now. 05P15RDFN1 and 05P12RGFN8), and the Helmholtz Association through NAVI (grant no. VH-V1-417), HMWK through 6 the LOEWE Center HCIforFAIR, and the JLU-GSI partnership.

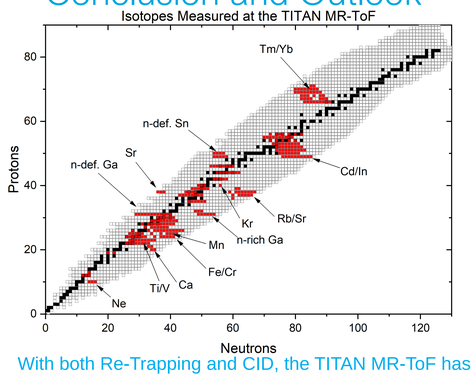
Collision-Induced Dissociation

Collision Induced Dissociation (CID) is the process by which molecules are broken up into various fragments. This is done in the He gas filled MR-ToF-MS Injection RFQ.



As the injection potential is increased, the occurrence of CID increases. Thus, the amount of isobaric molecules drops, while that of atomic species remains constant.

Conclusion and Outlook



With both Re-Trapping and CID, the TITAN MR-ToF has successfully performed many experimental campaigns extending towards the limits of nuclear existence.

- The TITAN MR-ToF-MS's capability of beam purification has been improved with re-trapping capable of suppressing isobars by 10^4 and CID capable of suppressing molecules by 10^1 to 10^2.
- As a result, high precision mass measurements of $^{24-26}$Ne were made, and are in agreement with literature. Additionally, the uncertainties for ^{25}Ne and ^{26}Ne have been reduced by a factor of 2 to 3
- The development of re-trapping and CID should allow for measurements of more neutron-rich Ne isotopes approaching the N = 20 Island of Inversion

Discovery, accelerated