

The TITAN MR-TOF-MS for Yields, Beam Composition and Mass Measurements

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Multi-Reflection Time-Of-Flight Mass Spectrometry at TITAN

Multi-Reflection Time-Of-Flight Mass Spectrometry (MR-TOF-MS) is a method for improving the resolving power and mass accuracy of traditional TOF mass spectrometers. Ions are repeatedly reflected against electrostatic mirrors resulting in separation in time-of-flight by mass.

Presented are results from a collaboration between TITAN and the Beam Development Group at ISAC-TRIUMF to develop the P2N target for cleaner n-rich beams.

In addition to complementing TRIUMF's ISAC Yield Station, TITAN made several first time mass measurements of n-rich isotopes relevant to the astrophysical r-process.

Yields Across the Fission Peaks

- MR-TOF-MS's extraordinary **resolving power** ($\frac{\delta m}{m} = 5 \times 10^5$) and **sensitivity** (< 0.01 pps) allowed characterization of production and release properties of isotopes for across target and ion source settings.
- Five isotopic chains (Zn, Ga, Ba, Cs, Sn) measured across the A~80 and A~130 fission peaks.
- Compared to p-induced spallation on standard UCx targets, **reduced n-deficient contamination** is confirmed.

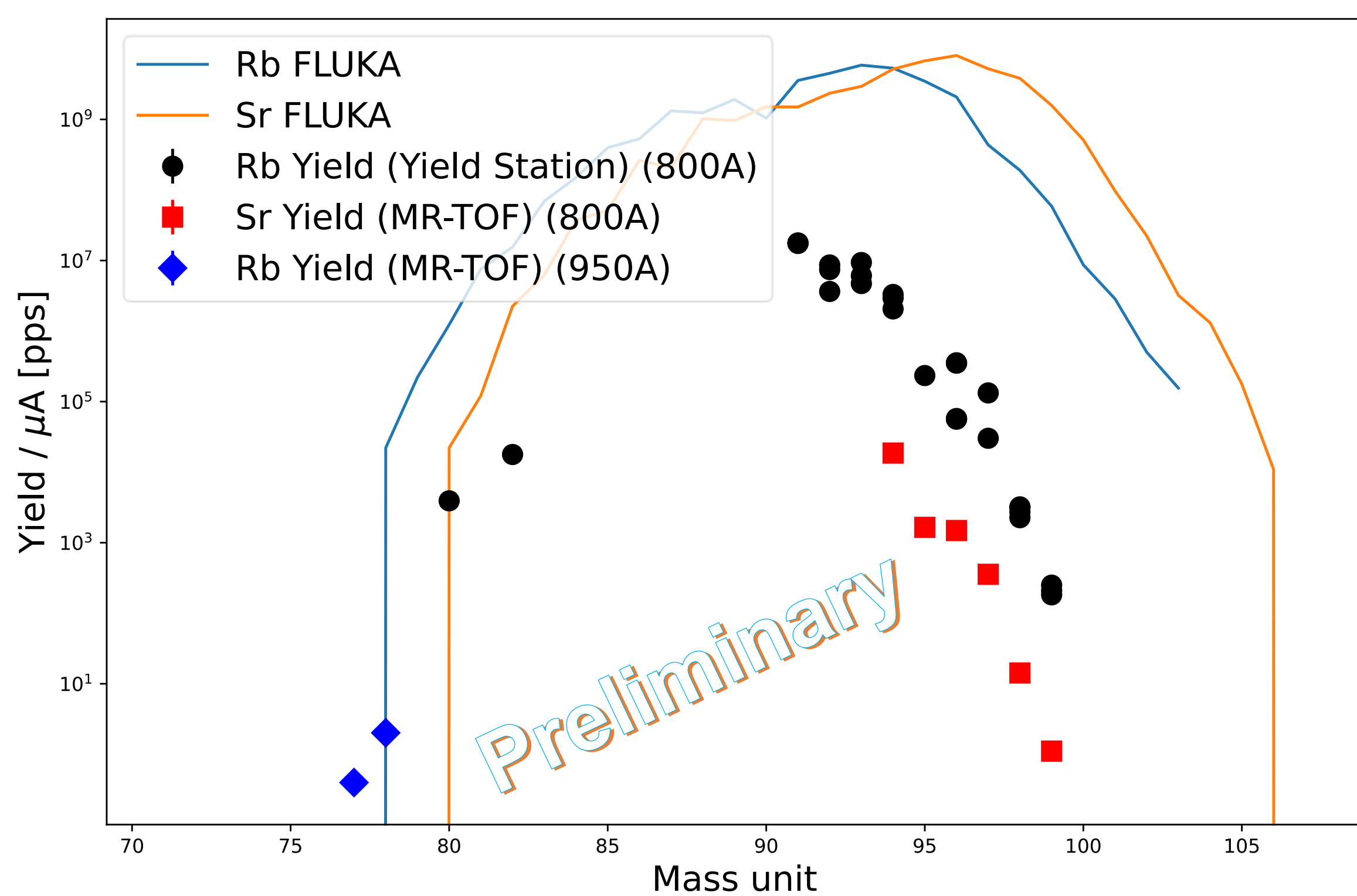


Figure 3: ISAC yield station and TITAN MR-TOF-MS yields. Comparison to FLUKA production simulation provides information on release efficiencies.

Target Optimization

Realtime feedback on all constituents of a beam allows unprecedented **optimization of ISOL target** parameters. Species of interest can be optimized while minimizing undesirable contaminants.

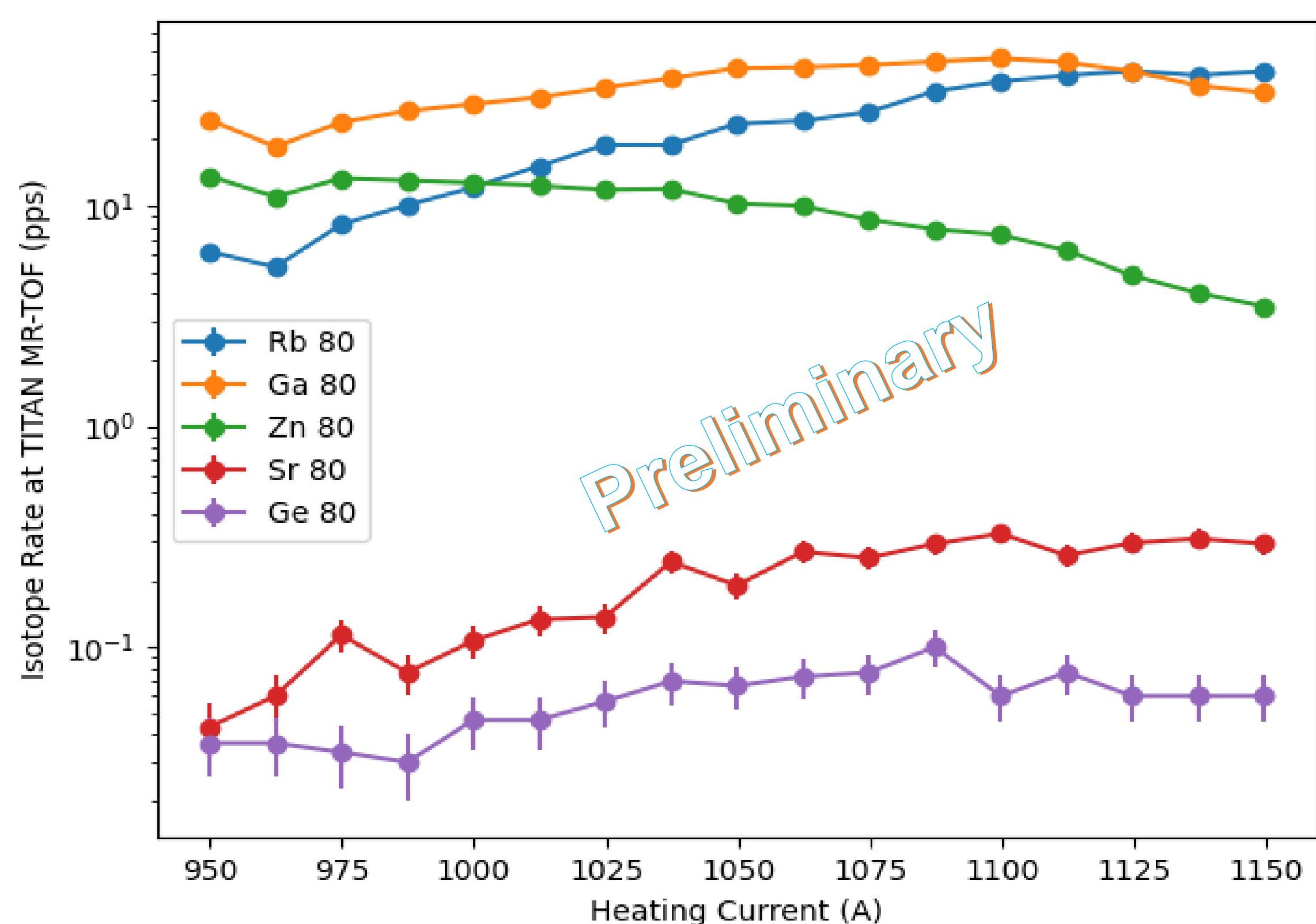


Figure 4: Comparison of rate of several isotope species as target heating current ramps. Data is binned into 5 min intervals. The rate of each species was measured simultaneously throughout the 1.5 hour ramping procedure.

P2N Target and TITAN MR-TOF-MS

The Proton to Neutron (P2N) conversion target aims to produce cleaner n-rich beams for ISAC. 500 MeV protons impinge onto a tungsten core producing ~50MeV spallation neutrons which induces fission on a surrounding uranium shell.

TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN) worked in tandem with the ISAC Yield Station to characterize the target. The Yield Station consists of a tape station, scintillators for beta detection, a Ge detector for gammas, and an alpha detector. The Yield Station is often limited to detecting only the most active constituent of the beam. TITAN employed the MR-TOF-MS to measure stable and low-rate components of the produced beam and complement the detection of the Yield Station.

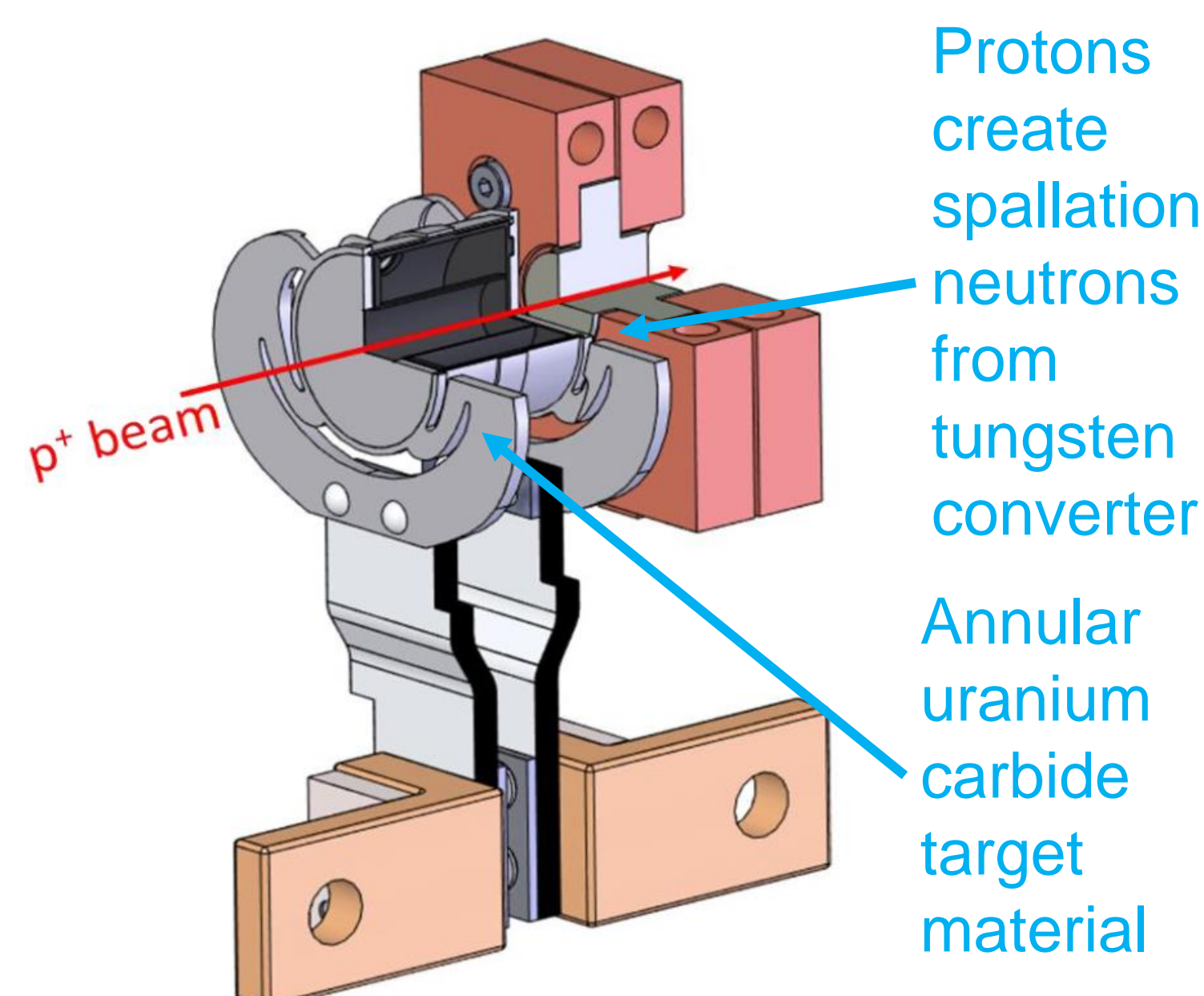


Figure 1: CAD drawing of the P2N target. Image provided by Luca Egoriti.

$$E = \frac{1}{2}mv^2 \Rightarrow$$

$$tof = \int \frac{m}{2E} dx \propto \left(\frac{m}{q}\right)^{1/2}$$

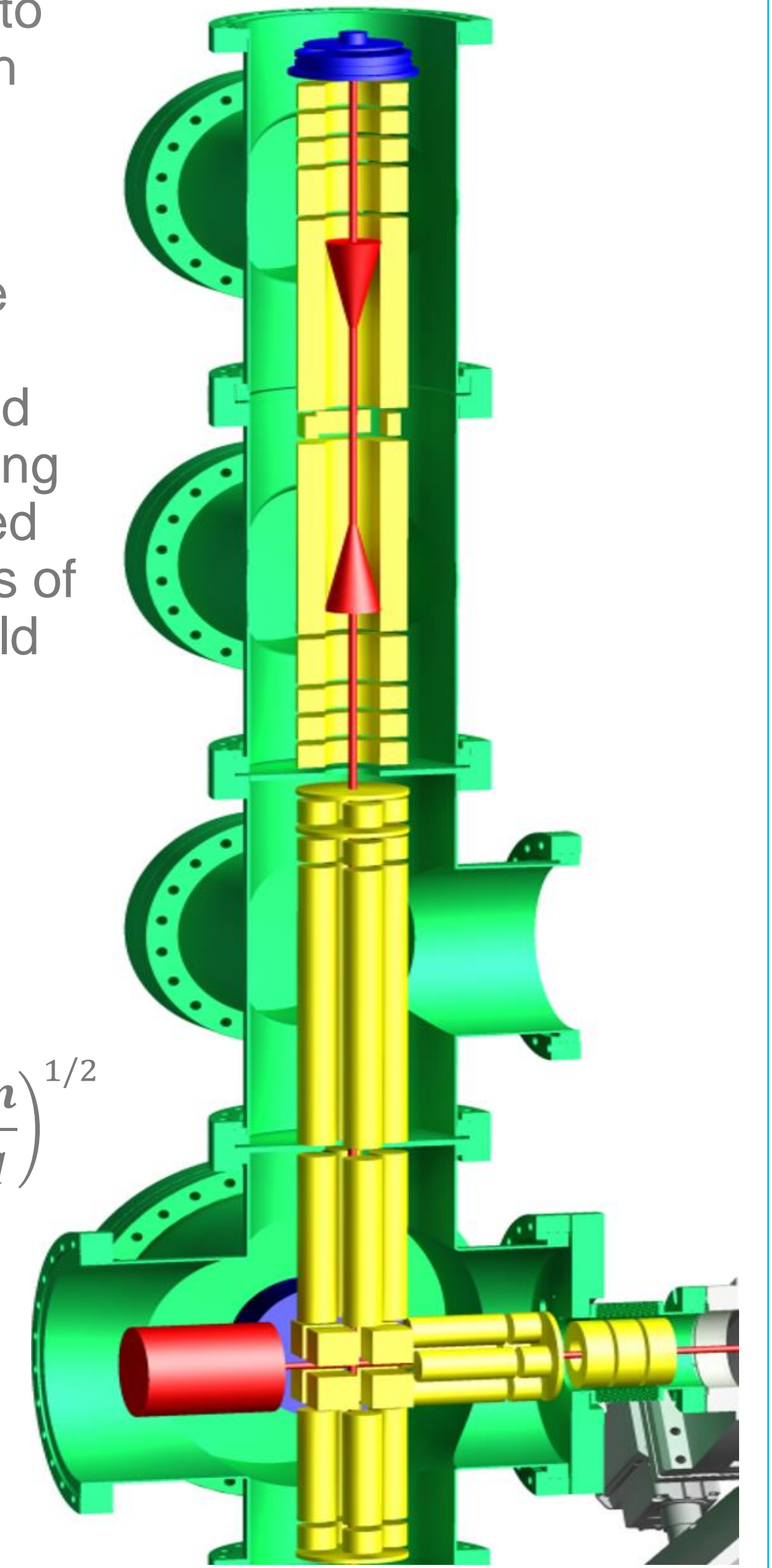


Figure 2: The TITAN MR-TOF-MS [1], as well as a mass spectrum and conceptual formula for determining mass from time-of-flight.

Mass Measurements for the r-process

In addition to yields, precision mass measurements of isotopes relevant to the astrophysical r-process were performed. **10 first time mass measurements** were made resulting in **mass uncertainties of ~10 keV**. These new mass values will improve our understanding of nucleosynthesis of elements heavier than Fe.

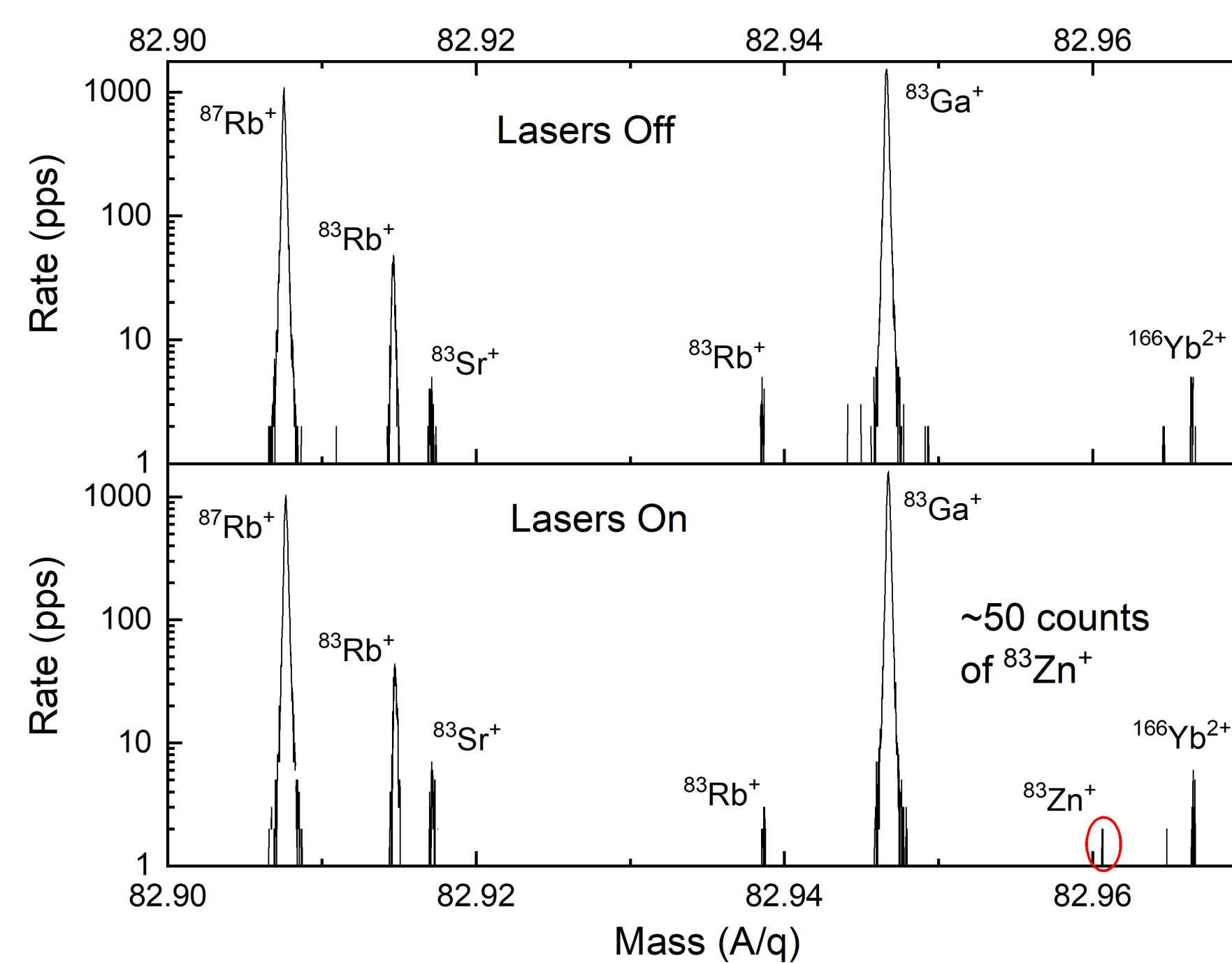


Figure 5: A mass measurement of ⁸³Zn performed during the commissioning experiment for the P2N target. Zn is identified by laser ionization on/off comparison.

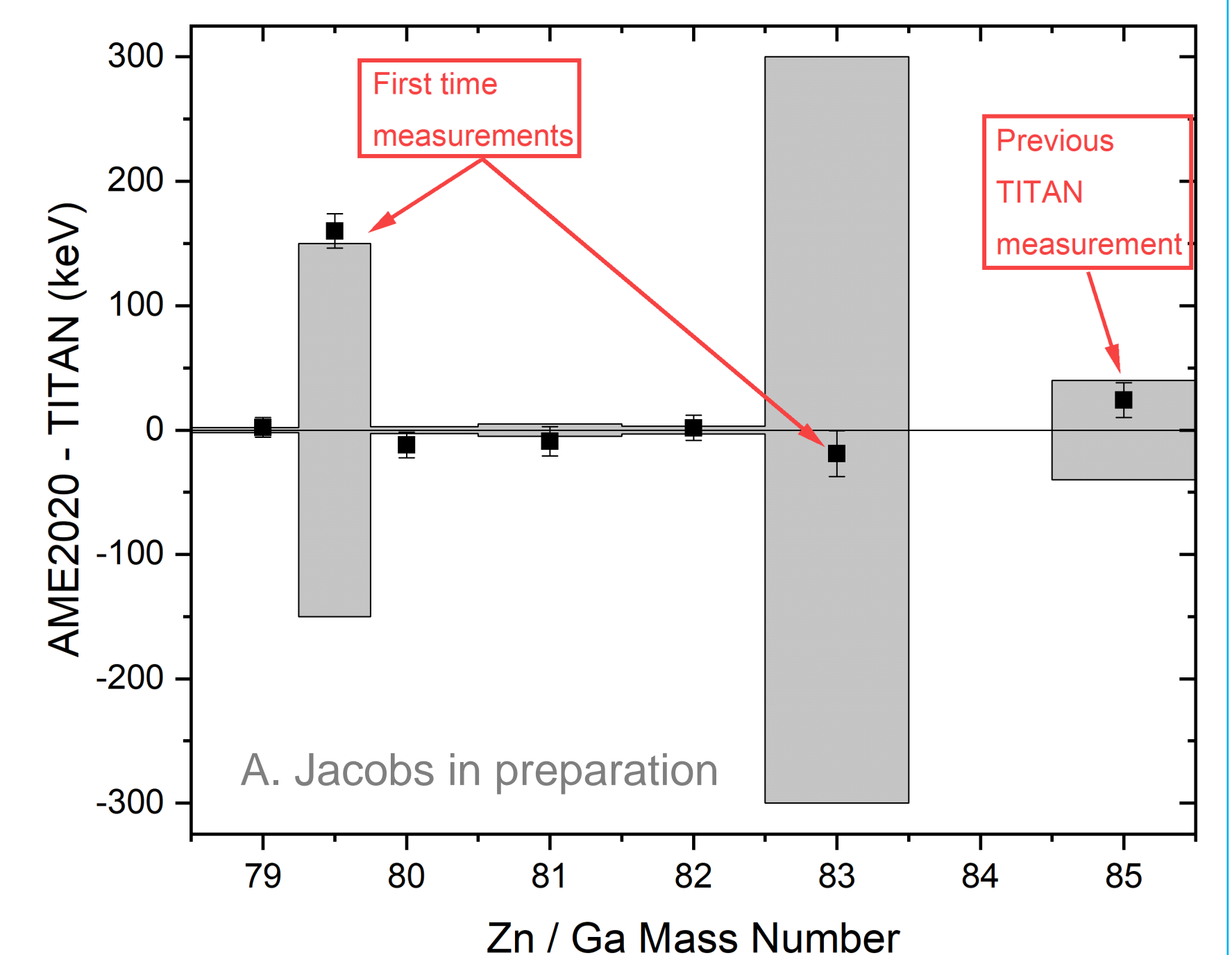


Figure 6: Several TITAN MR-TOF-MS mass measurements performed while participating in the P2N commissioning beamtime.

Outlook

- Analysis of mass measurements is ongoing. Results will provide insight into r-process nucleosynthesis.
- Yield measurements have demonstrated the potential of TITAN MR-TOF-MS in optimizing and characterizing major target and ion source developments.
- The success of P2N and TITAN's mass measurement campaign paves the way for future study of exotic species along the r-process pathway.