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Investigating Space-Charge Effects in TITAN's Multi-Reflection Time of Flight Mass Spectrometer

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Nuclear masses are a fundamental observable that give insight into nuclear structure, fundamental interactions, and astrophysics. Multi-Reflection Time of Flight (MR-TOF) mass spectrometers provide high mass separation power in a short amount of time by bouncing ions between electrostatic mirrors. This increases the flight path of trapped ions allowing ions with the same energies but different masses to separate. The high mass resolving powers and short storage times have contributed to MR-TOF devices becoming common for beam purification and mass spectrometry in rare-isotope-beam (RIB) and accelerator facilities around the world. However, Coulomb interactions among ions within the trapping volume can cause deviations from the desired MR-TOF performance. These space-charge effects limit the ion flux that MR-TOF devices can separate. Two well-known effects, self-bunching and peak coalescence, have been observed at the TRIUMF Ion Trap for Atomic and Nuclear Science (TITAN) MR-TOF mass spectrometer and elsewhere. These effects occur when enough space charge in the trap prevents the ion bunches from temporally separating from one another. Since typically the RIB is a cocktail of masses, the injected ion bunch either stays the same width or becomes narrower with increasing time in the trap. Peak coalescence is a similar effect that causes bunches of different ion species to merge with each other, making mass separation impossible. We have simulated detector deadtime as a function of ion flux, enabling estimations of individual ion pulse widths and heights. These simulations and the data analysis will be presented and used to estimate the impact on the MR-TOF performance.

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