TRIUMF Advanced Rare Isotope Laboratory (ARIEL)

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New science directions using a high-voltage MR-ToF device at ARIEL

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Many experiments at radioactive ion beam (RIB) facilities require isobarically and isomerically pure beams at high ion intensities. Over the years, Multi-Reflection Time-of-Flight (MR-ToF) devices have gained remarkable attention for mass separation of short-lived radionuclides. They exceed mass resolving powers of m/Δm =1e5 within a few (tens of) milliseconds. Space charge effects, however, pose a challenge for the mass separation in cases where excessively many ions are confined in the MR-ToF device. This limits the wider application of MR-ToF mass separators at RIB facilities.

By performing ion-optical simulations including space charge effects, we have shown that the ion flux in MR-ToF devices can be increased by more than two orders of magnitude when raising the kinetic energy of the stored ions and when improving the geometrical design [1-4]. According to our simulations, an ion flux between 5e7 to 1e5 ions/s will become possible for mass resolving powers between 1e4 and 5e5 assuming an energy of 30 keV of the stored ions.

In this contribution, we present an overview of highly selective and high-flux mass separation and discuss the relevance of high-voltage MR-ToF devices for next-generation RIB facilities such as ARIEL. We report the first experimental results of MIRACLS'15 keV MR-ToF device [5], which enabled highly sensitive fluorescence-based collinear laser spectroscopy (CLS) of exotic Mg and Cd ions. The latter's combination of MR-ToF and CLS has recently also enabled a multi-order enhancement in the sensitivity of electron-affinity measurements [6], allowing the determination of this quantity for heavy and superheavy elements. Furthermore, we discuss the design of FRIB's proposed 30 keV MR-ToF mass separator, which will enable both high mass resolving power and high ion throughput [3,4]. We will highlight its potential for both FRIB and ARIEL to enable new experimental opportunities.

[1] F.M.Maier et al, NIMA 1056, 168545 (2023).
[2] F.M.Maier et al, NIMA 1075, 170365 (2025).
[3] F. M. Maier, C. M. Ireland et al., NIMA 1084, 171220 (2026).
[4] C. M. Ireland, F. M. Maier et al., NIMA 1087, 171426 (2026).
[5] F. M. Maier, M. Vilen et al., NIMA 1048, 1679277 (2023).
[6] F. M. Maier, E. Leistenschneider et al., Nat. Commun. 16, 9576 (2025).

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