Tof-Bρ Mass Measurements with the S800 Spectrometer

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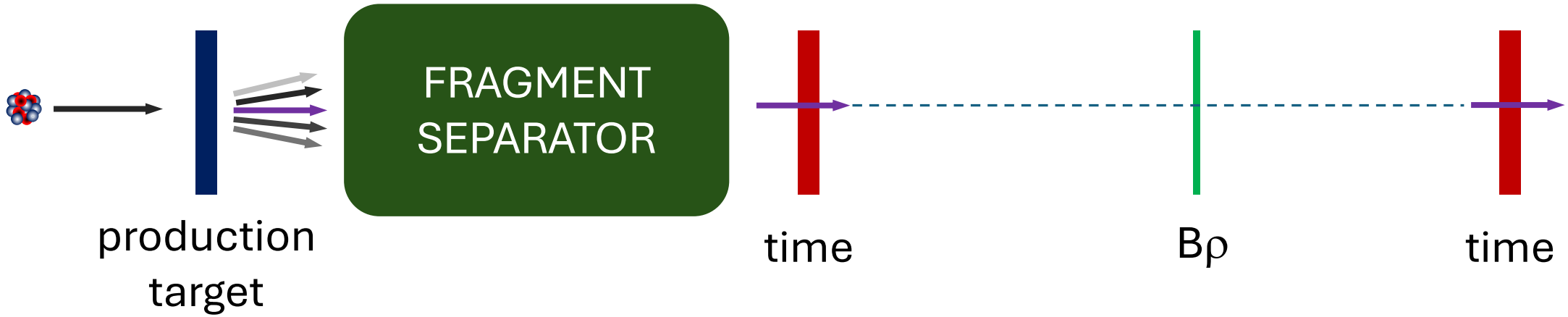
Nuclear Masses in Astrophysics for the Next 25 Years – 2026

Outline

- Principle of TOF-Bρ technique
- Experiments at the National Superconducting Cyclotron Laboratory
- Outlook for experiments at the Facility for Rare Isotope Beams

Principle of Time-of-flight Bρ Mass Measurement Experiments



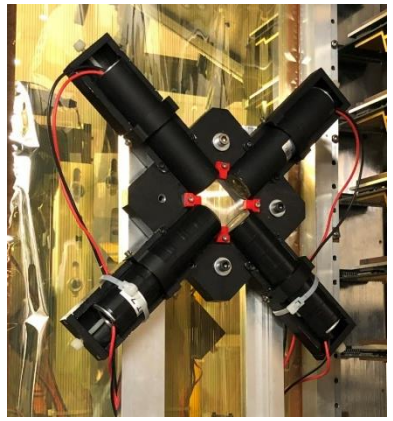
Technique pioneered with SPEG at GANIL
Sarazin et al., PRL 84, 5062 (2000)
Experimental programs with SHARAQ in RIKEN
Michimasa et al, Phys. Rev. Lett. 125 12, 122501 (2020)
and with S800 at NSCL/FRIB
M. Matos et al, NIM 696, 171 (2012)

$$B\rho = \frac{\gamma\, m\, v}{q} = \frac{\gamma\, m}{q}\left(\frac{L}{TOF}\right)$$

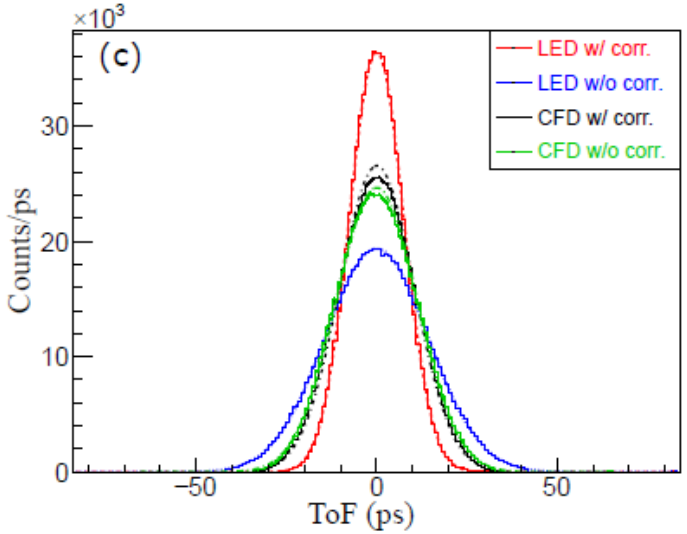
TOF-Bρ setup at the S800 spectrometer

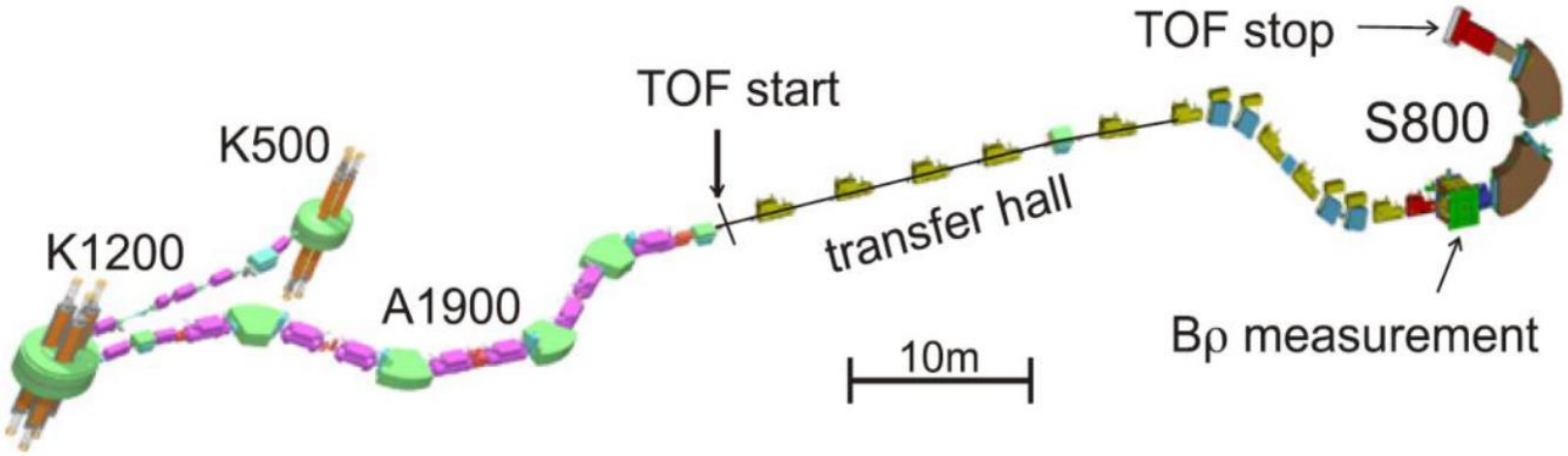
TOF: timing scintillator

- Scintillator: Eljen 228, 4x4 cm
- 4 Hamamatsu H6533 PMTs
- TAC-ADC for data acquisition



Test with ^{48}Ca beam at NSCL: resolution of σ_{TOF}=7.5 ps for LED w/walk correction



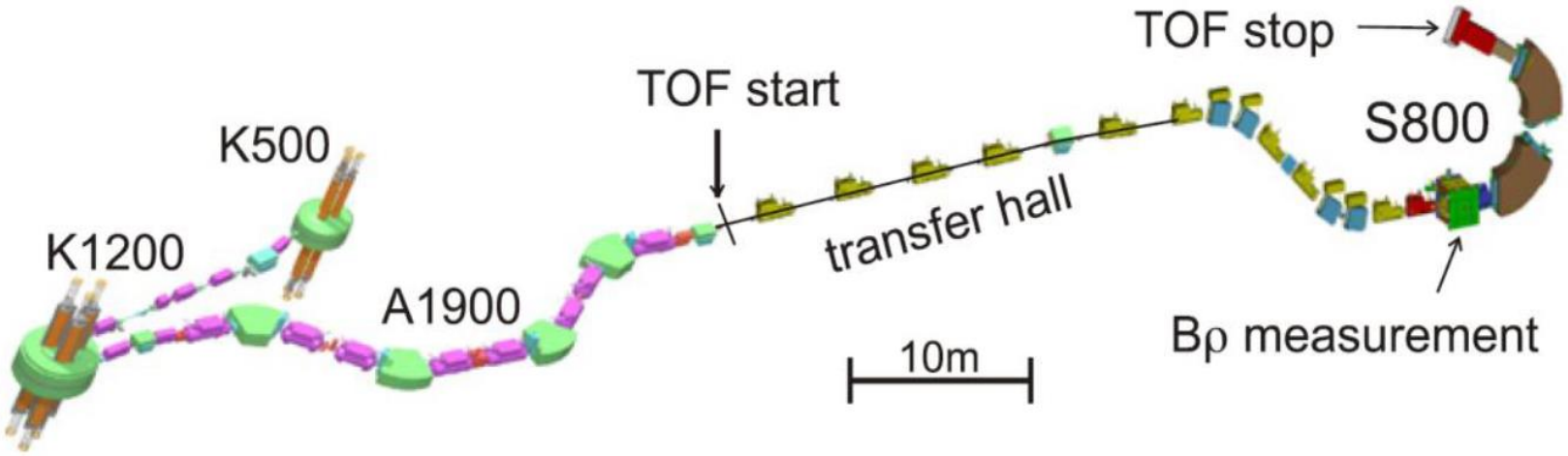


M. Matos et al, NIM 696, 171 (2012).

TOF-Bρ setup at the S800 spectrometer

Bρ: MCP detector at S800 dispersive plane:

- MCP: 8 x 10 cm, 2 plates in chevron config.
- 2 rectangular NdFeB magnets
- Foil: 70 ug/cm^2 polypropylene with sputtered gold
- Resistive plate readout



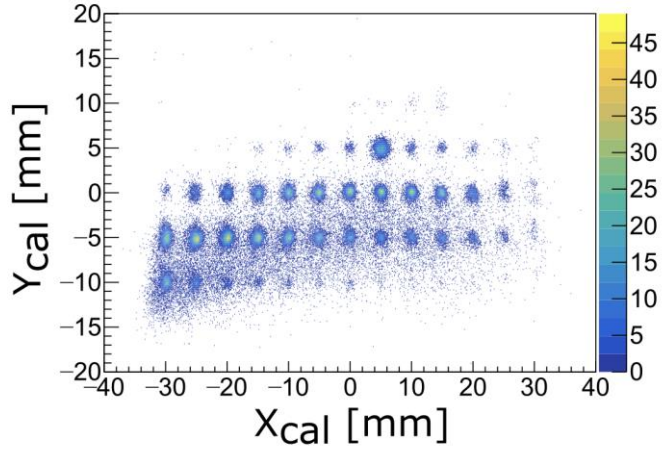
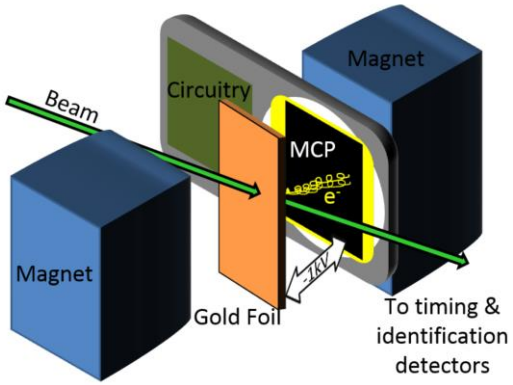
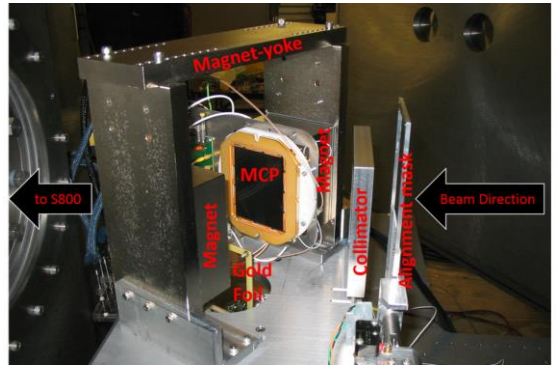


FIG. 2. Position spectrum of MCP detector using ^{124}Sn beam and a mask, which gives a position resolution (σ) of ≈0.7 mm.



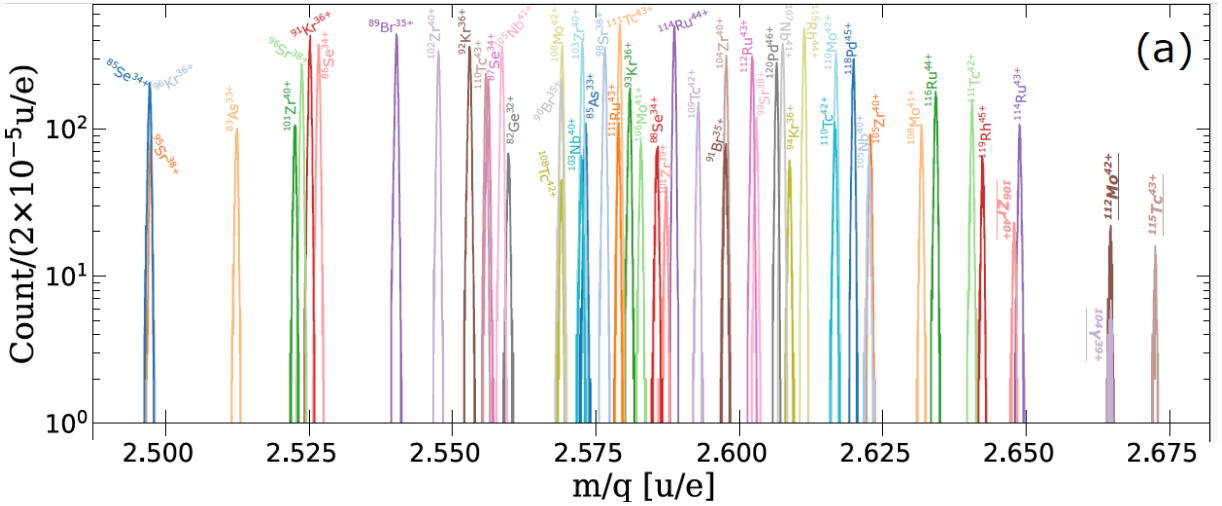


M. Matos et al, NIM 696, 171 (2012).

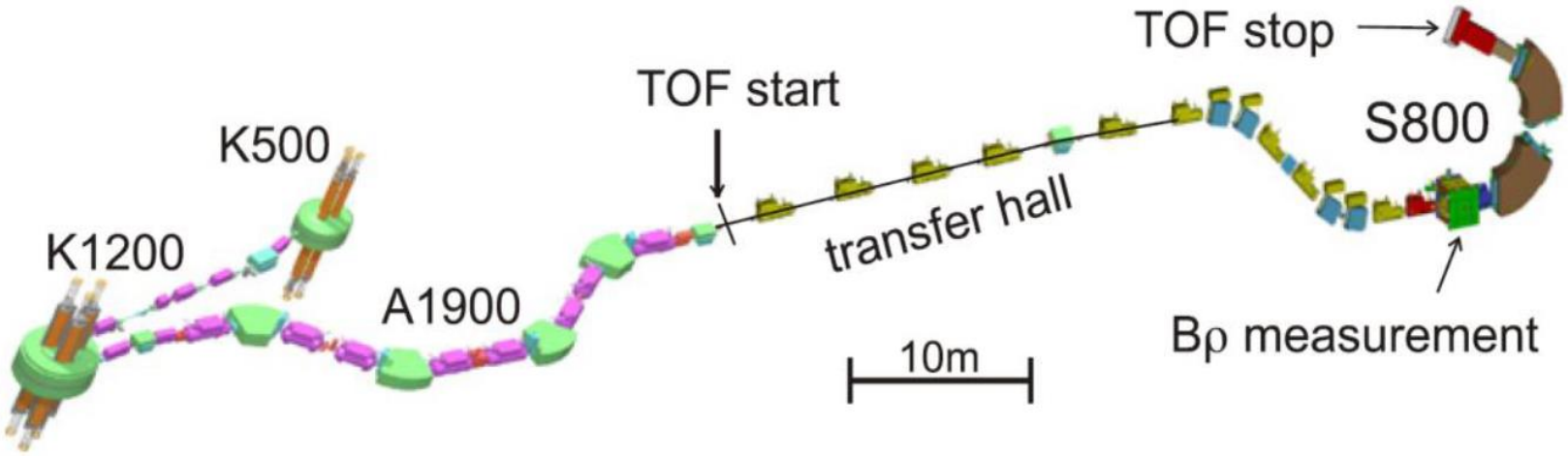
TOF-Bρ setup at the S800 spectrometer

Mass resolution: $R \approx 10\,000$

m/q spectra – N=70 region



K. Wang et al, PRC 109, 035806 (2024)



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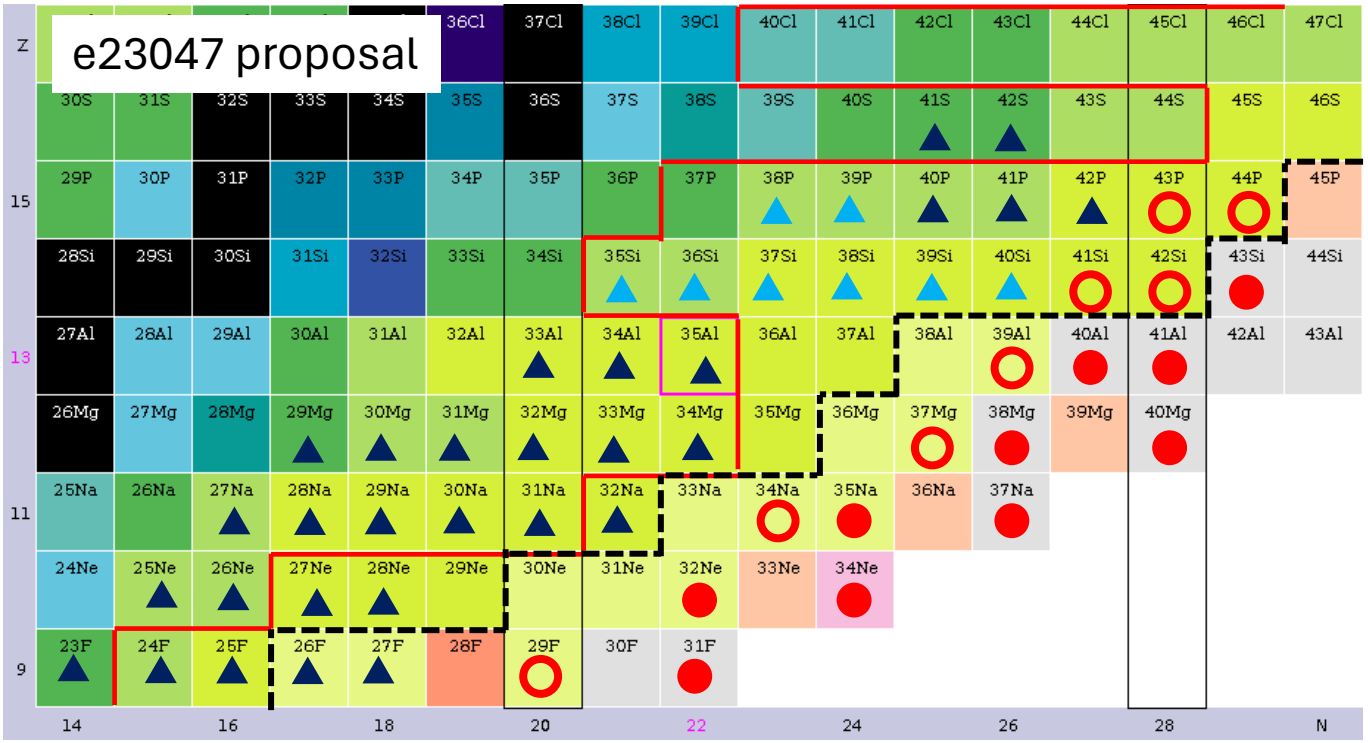
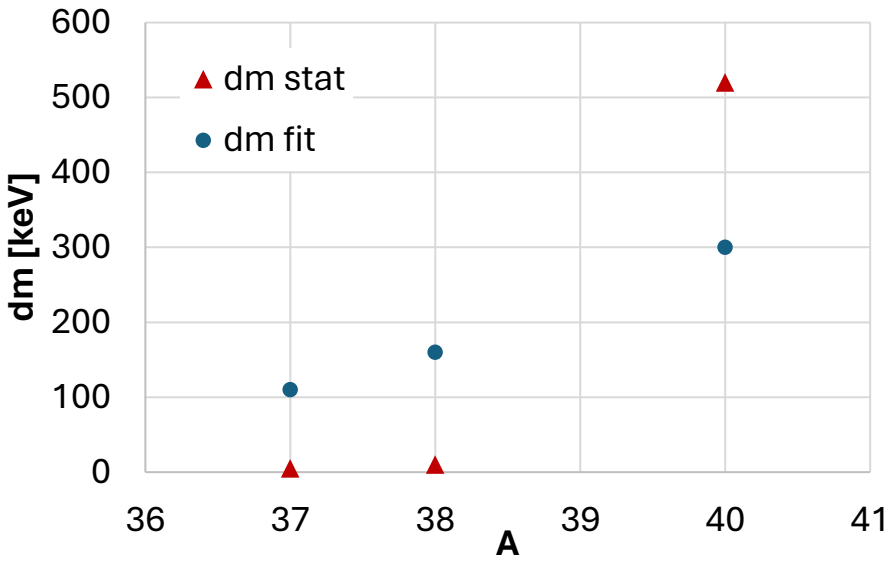
TOF-Bρ Experiments at FRIB



Estimated uncertainties for Mg isotopes



Reference mass

Known mass

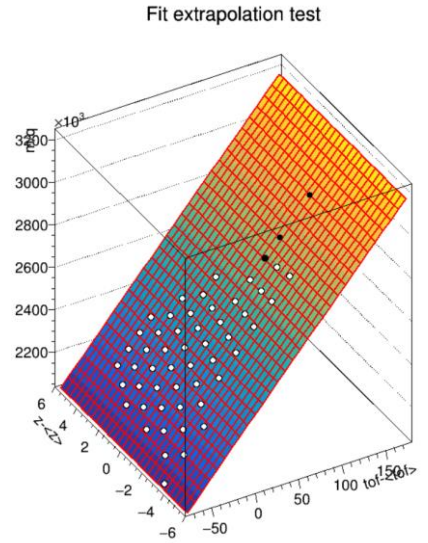
Unknown mass

δm <30 keV

$\tau_{1/2}$ < 10 ms

The experimental setup is calibrated with reference isotopes with well-known mass:

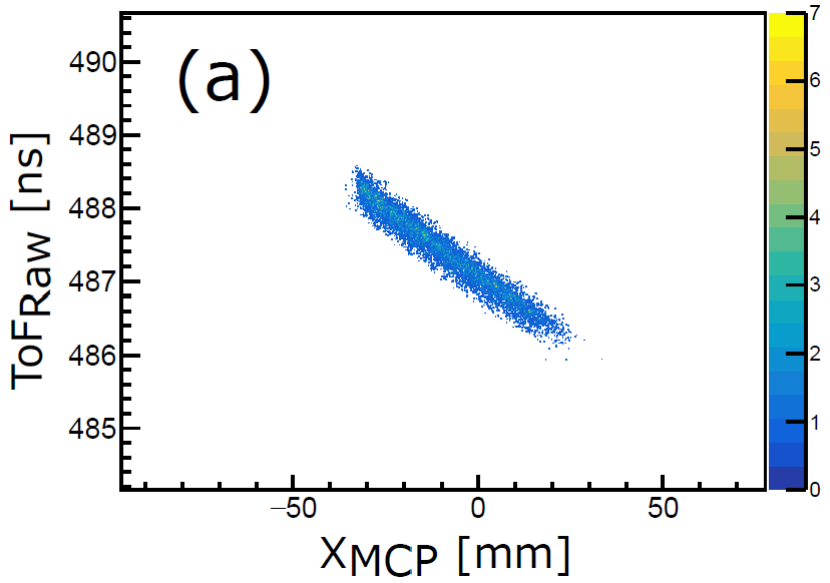
$$\frac{m}{q} = f(Z, TOF, \vec{x})$$

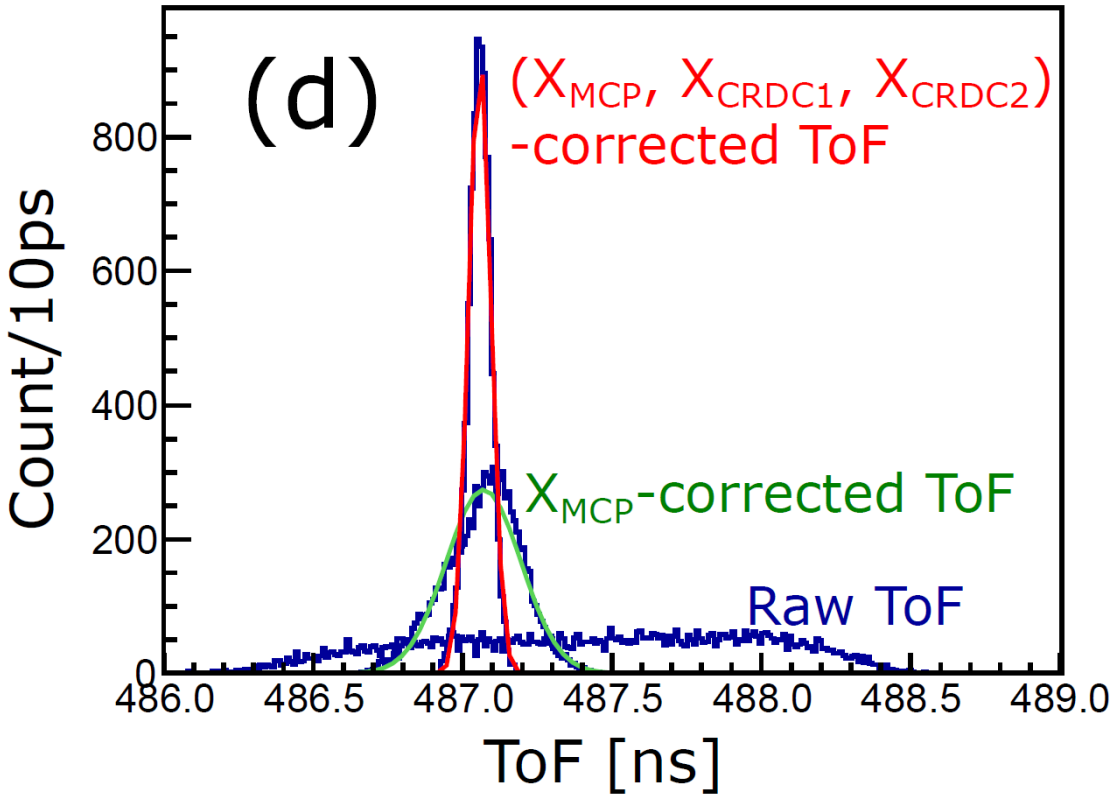


TOF corrections

The experimental setup is calibrated with reference isotopes with well-known mass:

$$\frac{m}{q} = f(Z, TOF, \vec{x})$$

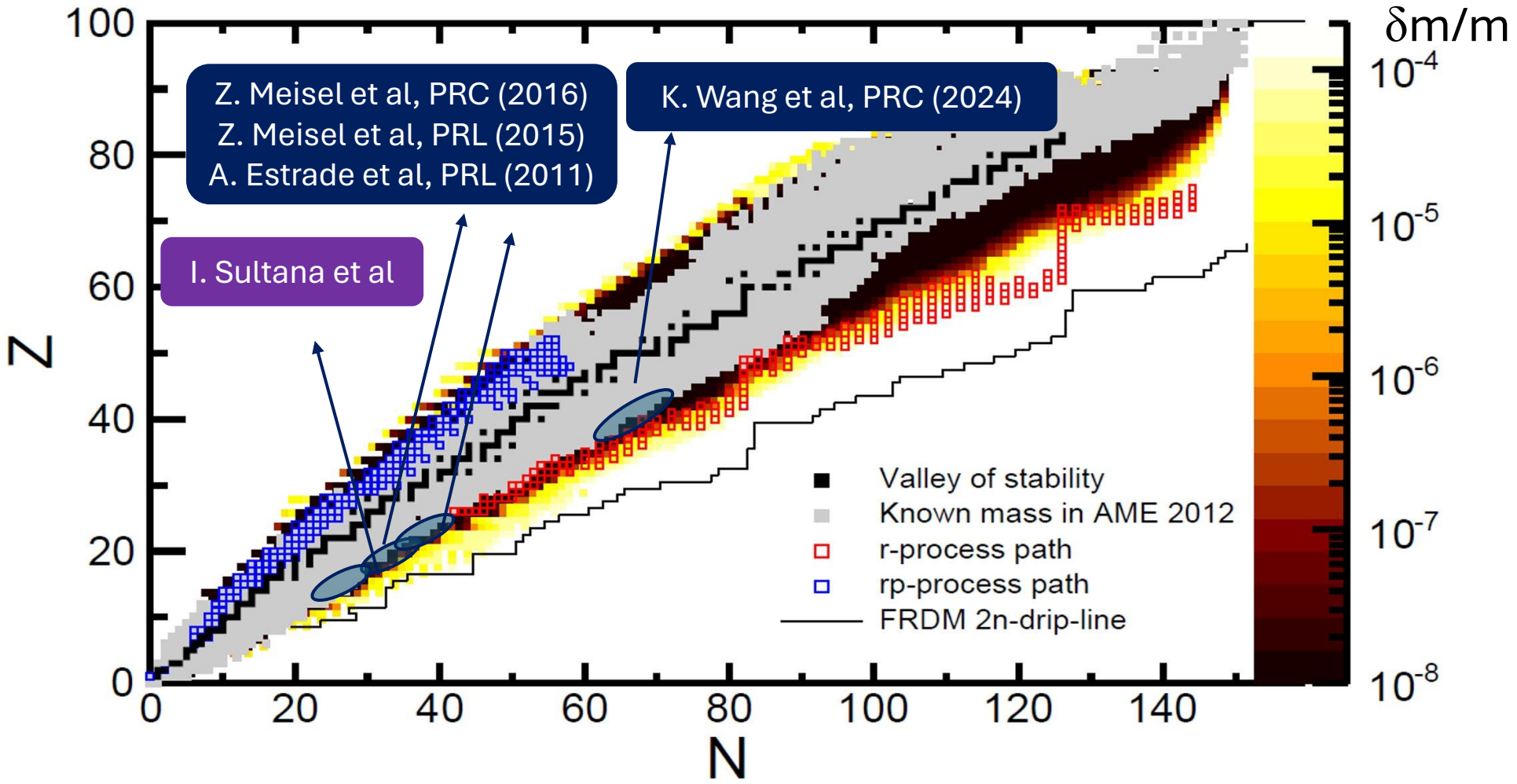




K. Wang et al, PRC 109, 035806 (2024)

TOF-Bρ Program with the S800 Spectrometer at NSCL

Potential reach at FRIB



Meisel 2020, arXiv:2004.14113

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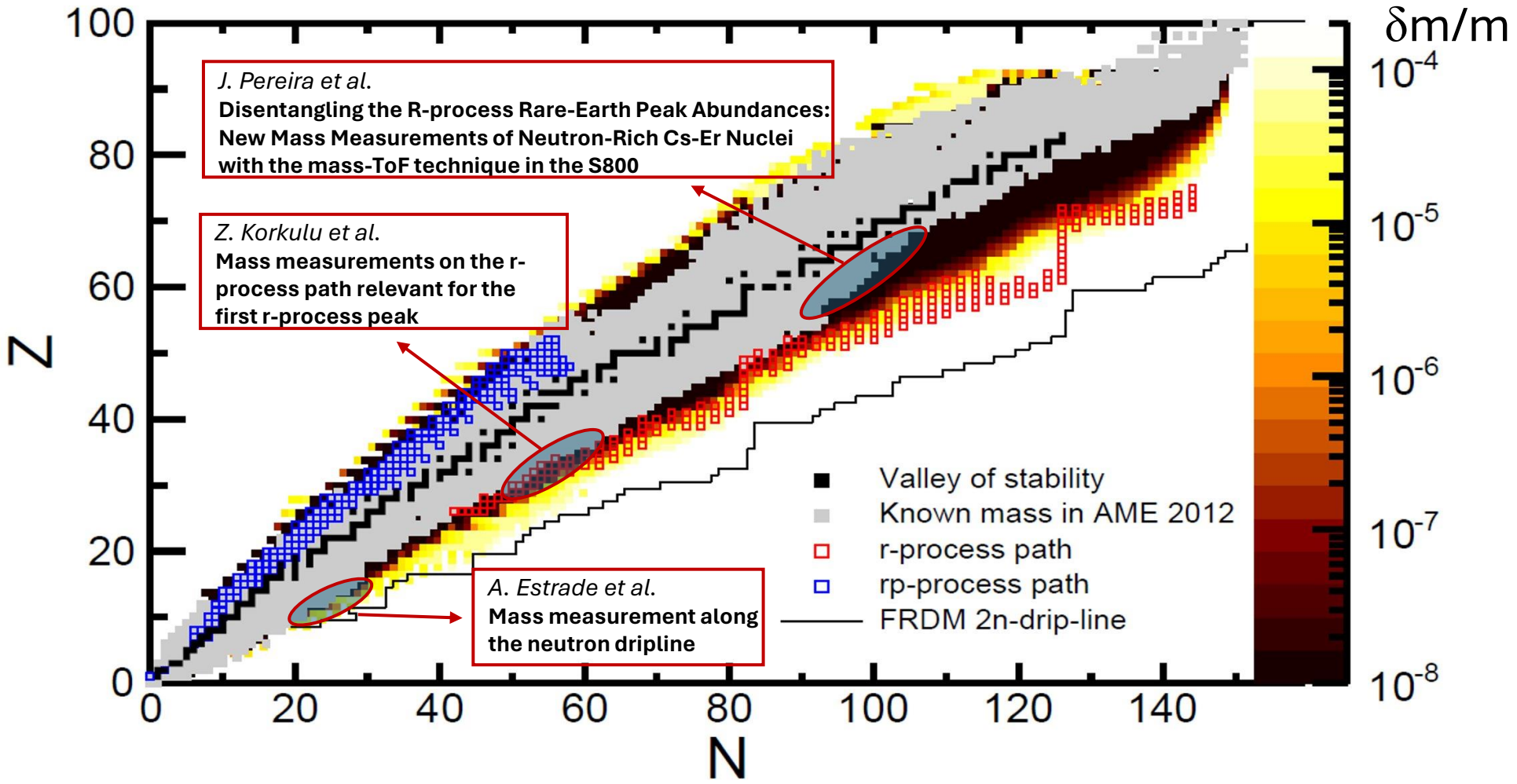
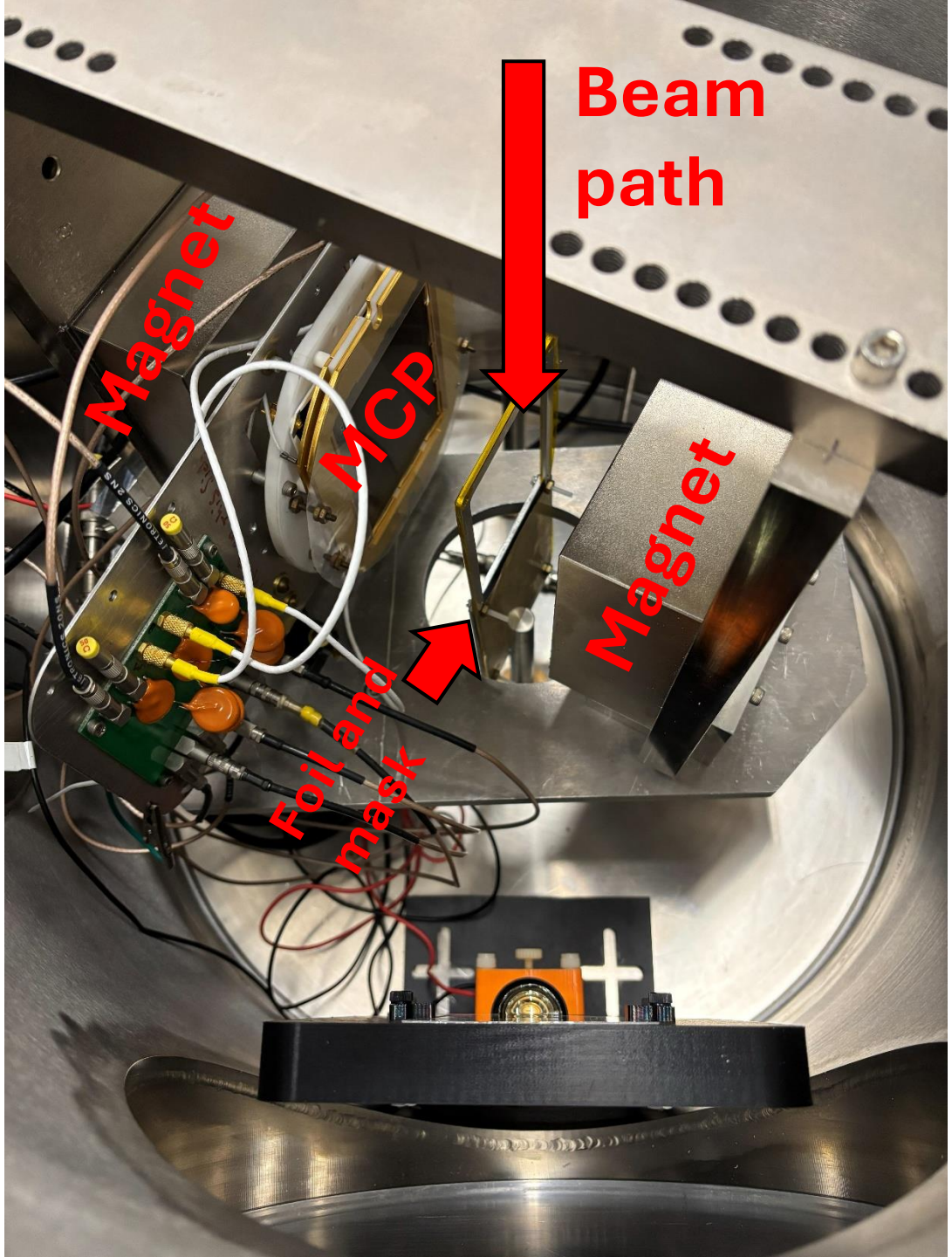


Meisel 2020, arXiv:2004.14113

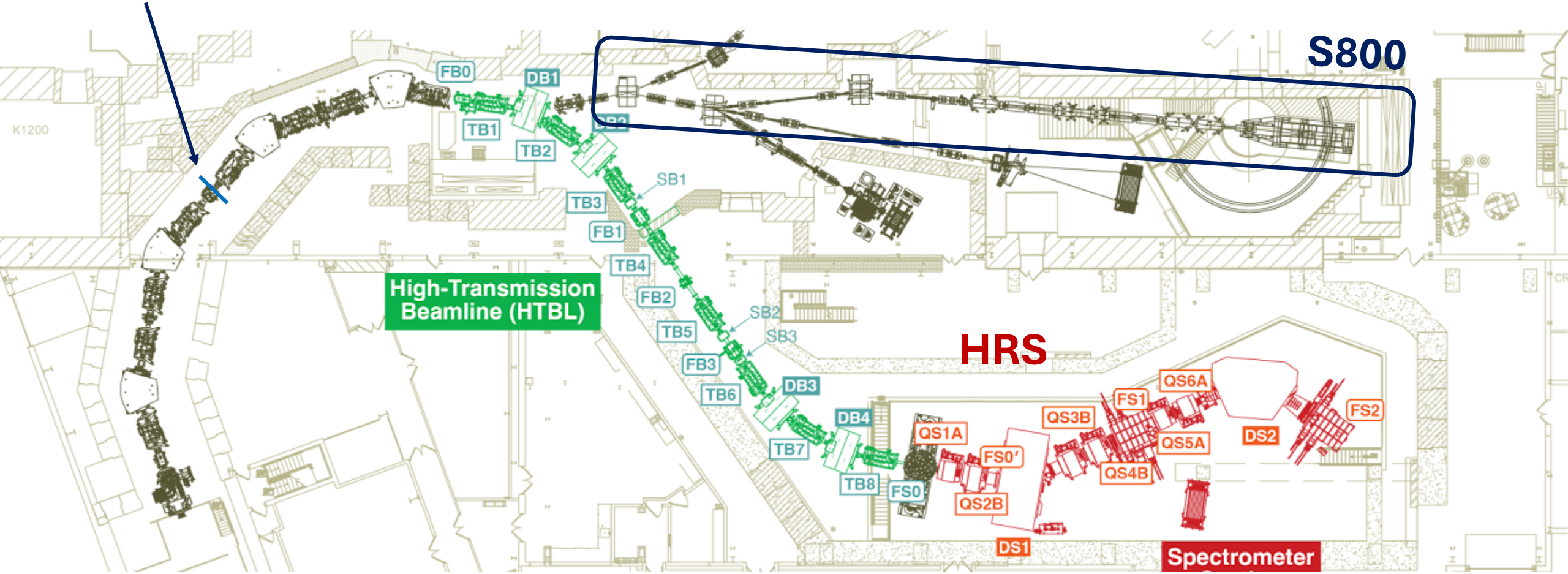
MCP setup and testing



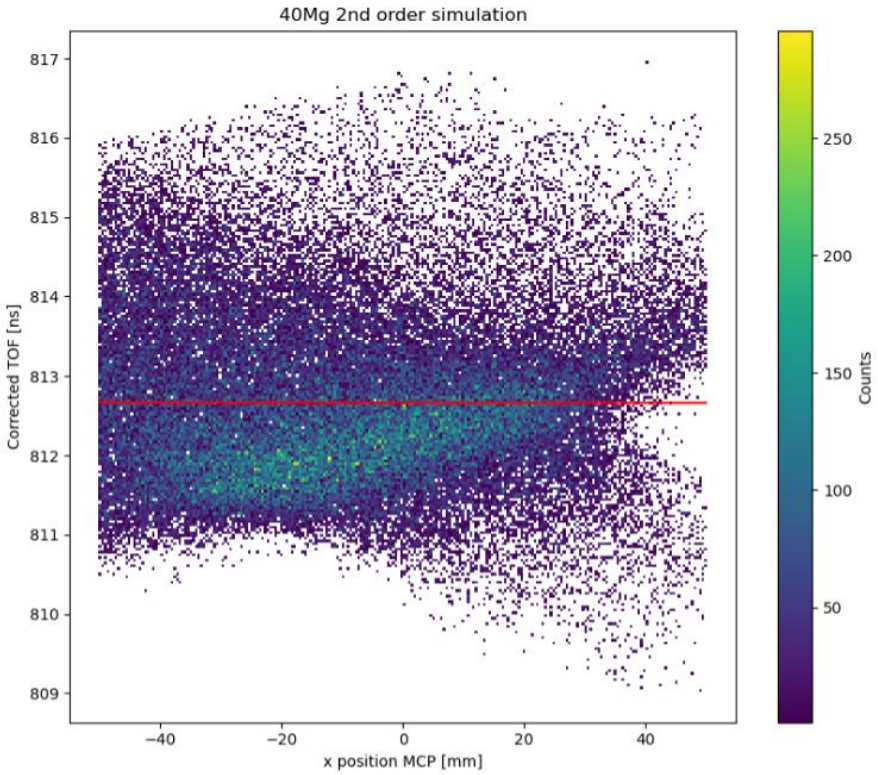
TOF-Bρ Experiments at FRIB

Flight path extended with ARIS fragment separator and (from ~2030) with High Rigidity Spectrometer (HRS)

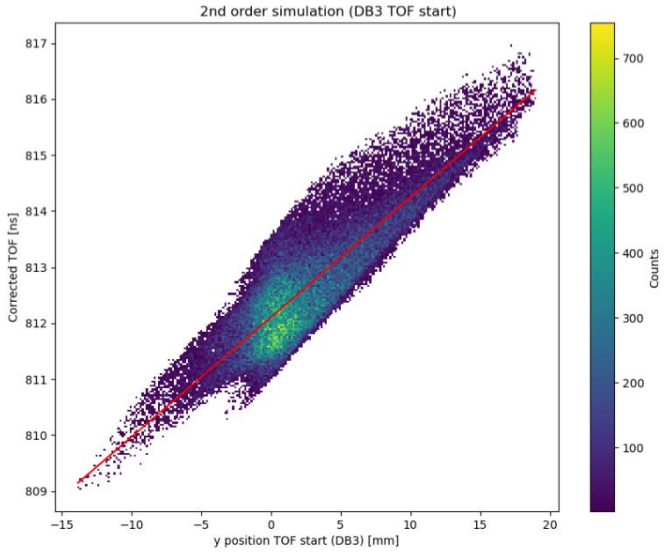
TOF start at ARIS



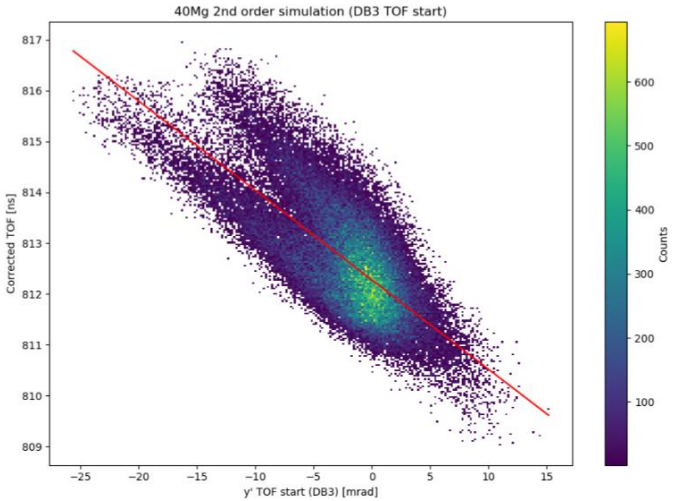
Beam Optics Simulations



Momentum-corrected TOF vs x position at MCP detector. TOF of 812.667 $\pm$ 1.067 ns



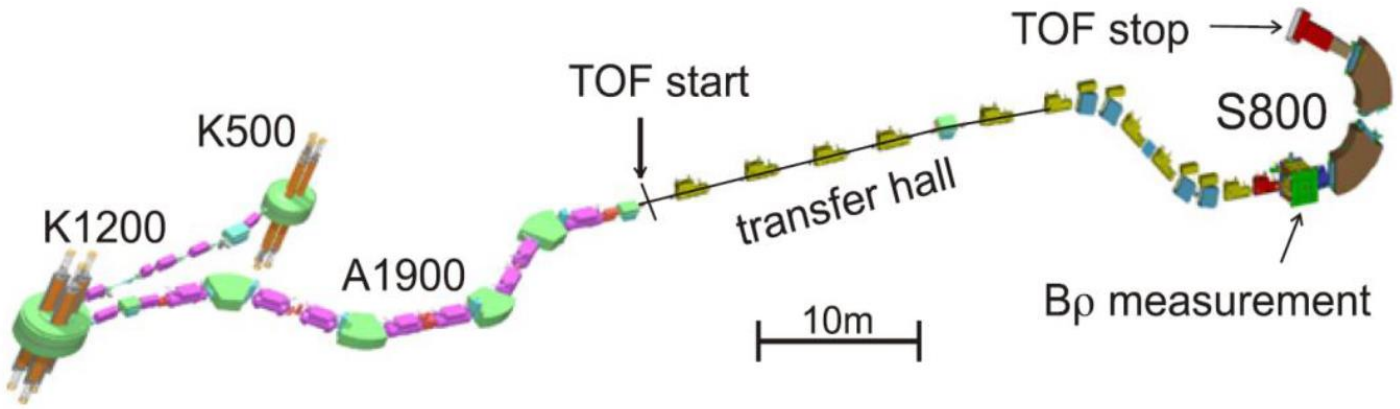
Momentum-corrected TOF vs y position at TOF start



Momentum-corrected TOF vs y' angular trajectory at TOF start

Conclusions

- TOF-Brho offers reach far from stability: efficient coupling to fast beams and short measurement time
- Experiments at the NSCL focused on neutron-rich isotopes between N=28 and N=25; program at FRIB will expands towards cases relevant to r-process nucleosynthesis
- FRIB offers opportunities to improve resolution (tracking, flight path) and high-rates for unstable ions



Thank you!

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