Measurements of the $^{238}U/^{235}U$ and $^{239}Pu/^{235}U$ Fission Cross-Section Ratios Using Monoenergetic Neutron Beams

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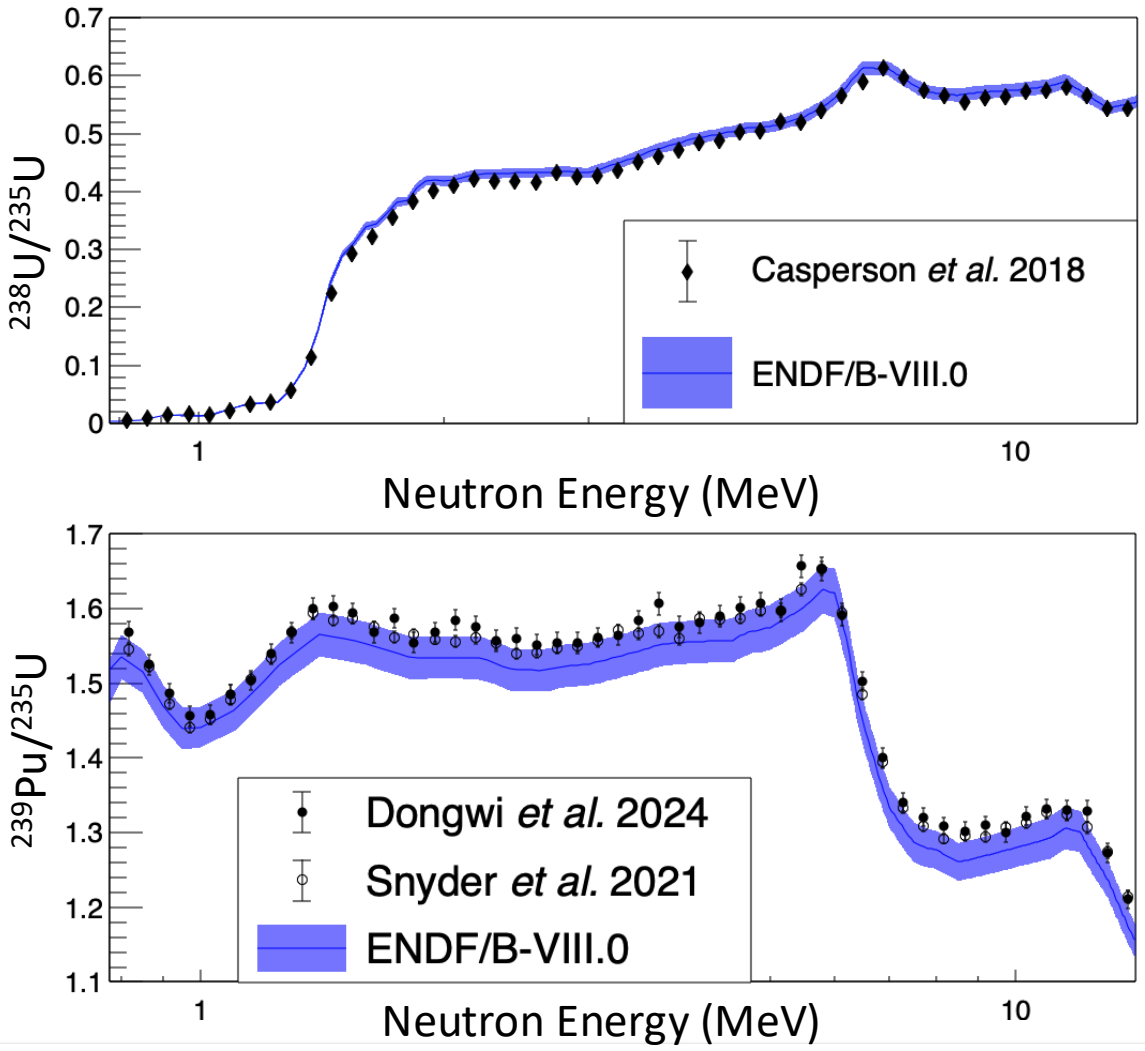
Motivation: Independent Verification of $^{238}U/^{235}U$ and $^{239}Pu/^{235}U$ Fission Cross-section Ratios

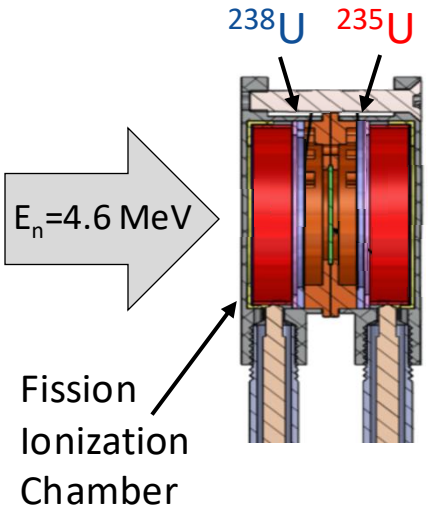
- Independently verify cross-section ratios observed by fissionTPC
- In particular, verify systematic deviations from ENDF/B-VIII evaluation
  - Shape difference around 1.5 – 2 MeV in $^{238}U/^{235}U$
  - 2% systematic shift over broad energies in $^{239}Pu/^{235}U$

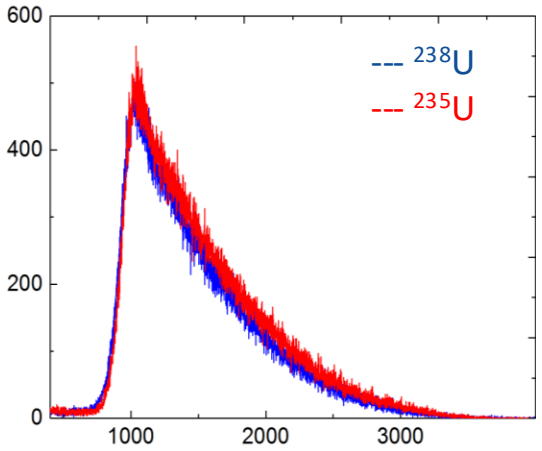


Casperson *et al.* PRC **97**, 034618 (2018).
Snyder *et al.* NDS 178, 1-40 (2021).
Dongwi *et al.* arXiv:2409.18279v1 (2024).

Fission Ratio Measurements at TUNL

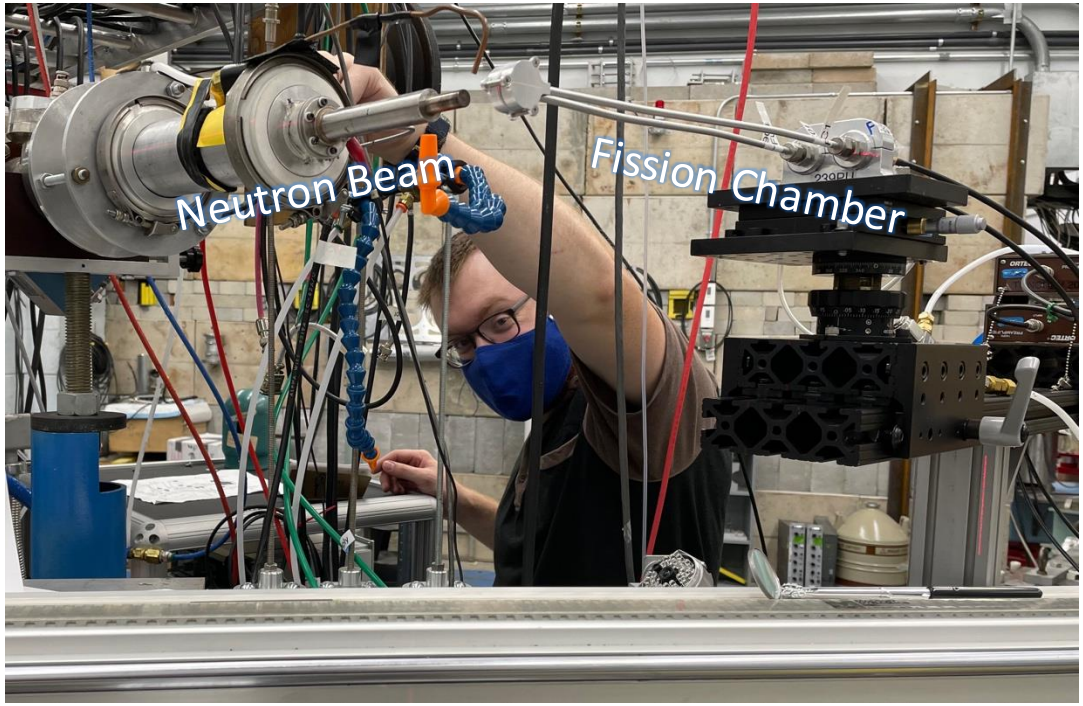
- Monoenergetic and pulsed neutron beams from 10 MV FN Tandem Van de Graaff accelerator
- Large Time-of-Flight Room
  - Minimal room return
- Dual fission ionization chambers with simple geometry and signal analysis
- Leverage LLNL-LANL-TUNL fission product yield collaboration's years of expertise successfully fielding fission chambers in neutron beams



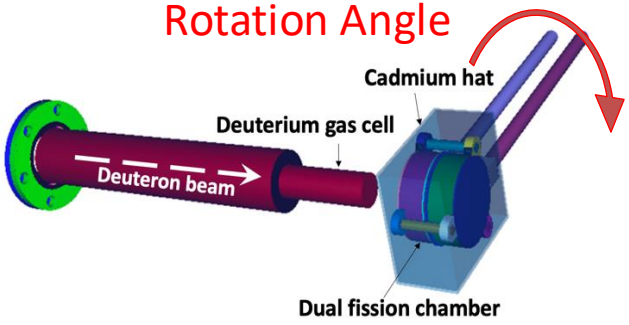


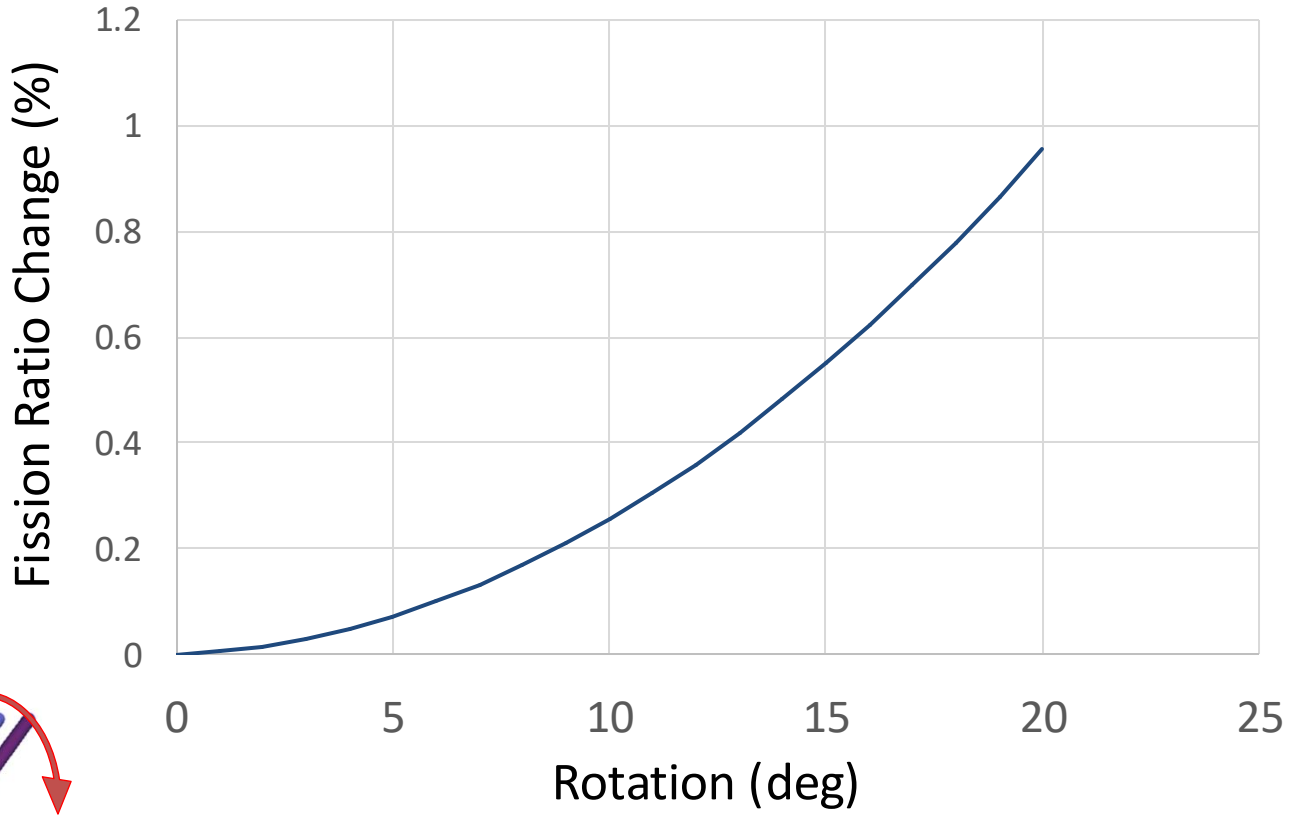
Experimental Setup in TUNL nTOF Room

- 400 ns pulsing period
  - ~2 ns FWHM
  - Neutron flux ~5E6 n/s/cm^2
- FC flip at halfway through measurement to correct for geometry effects
- Alignment monitored continuously by distance sensing laser
- Data collected from 2021-2023

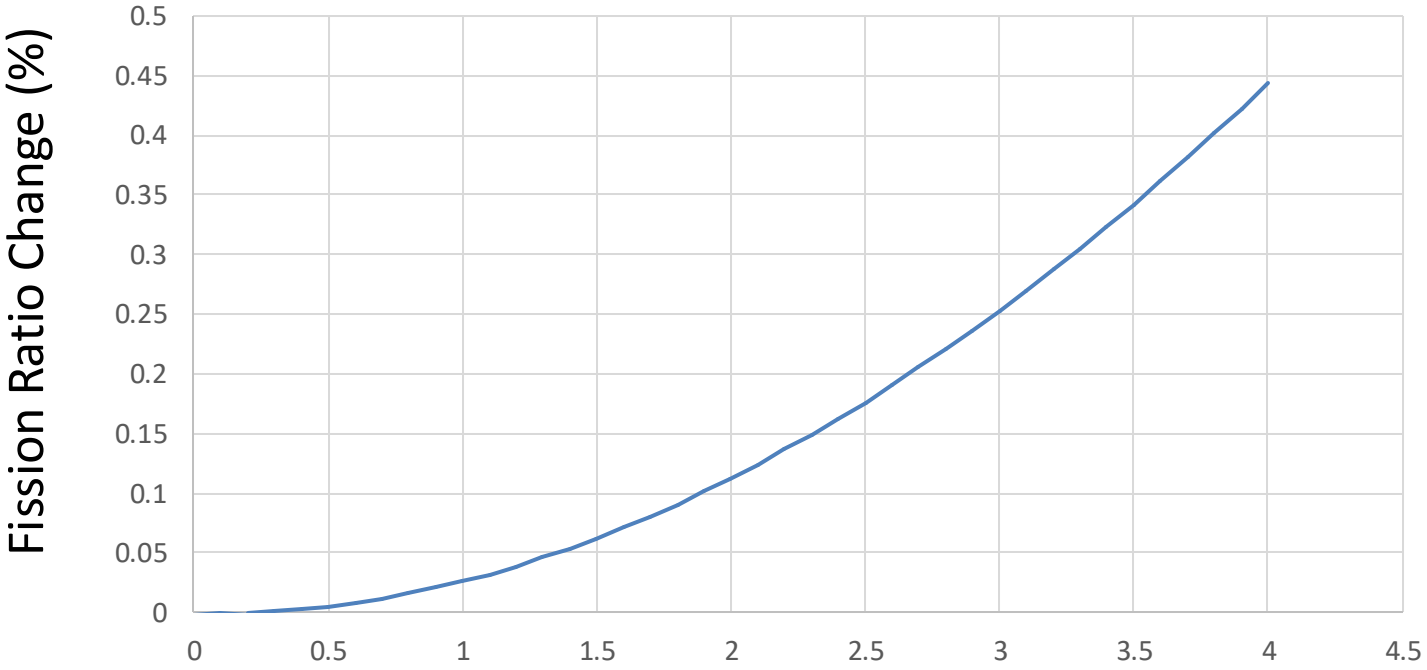


MCNP Calculations Confirm Limited Sensitivity to FC Rotation

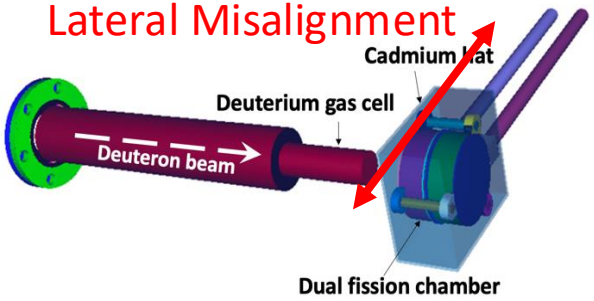




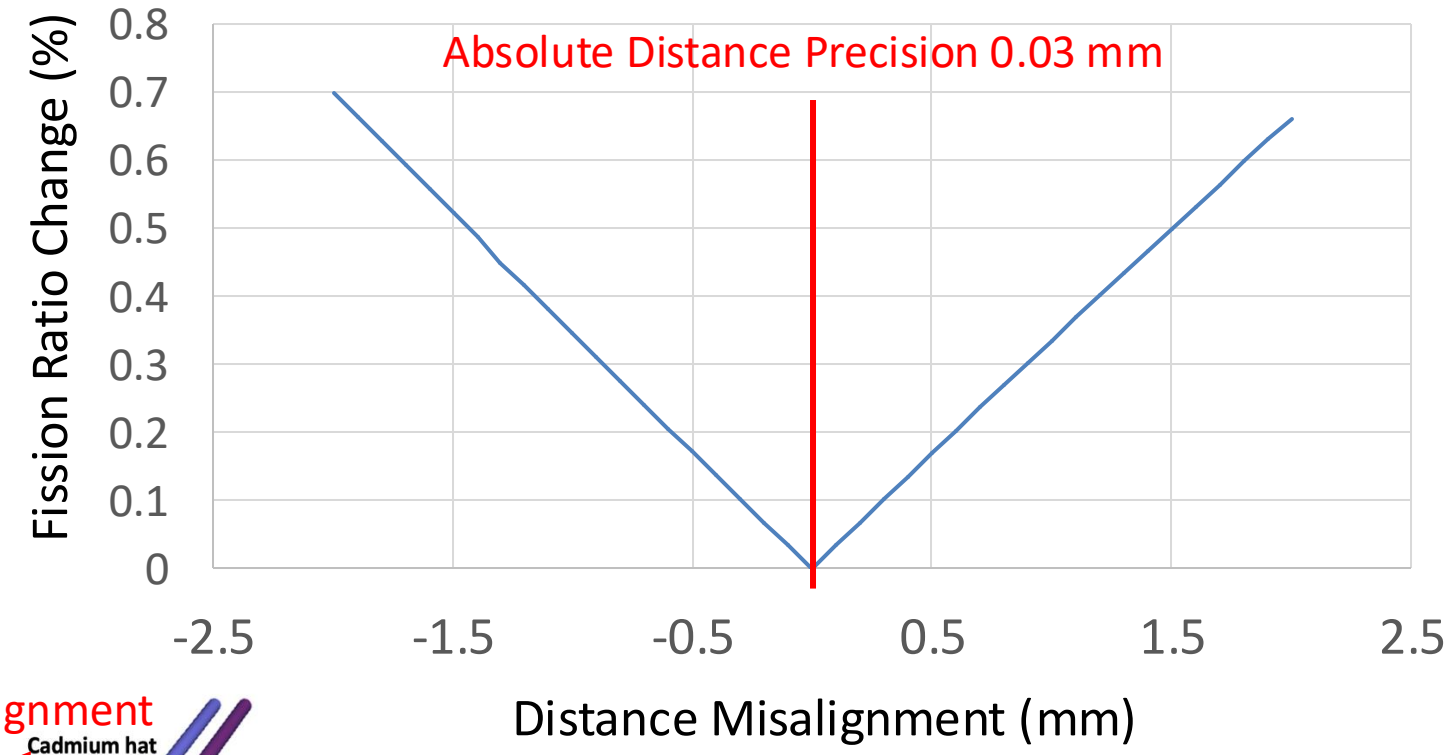
MCNP Calculations Confirm Limited Sensitivity to FC Radial Offset



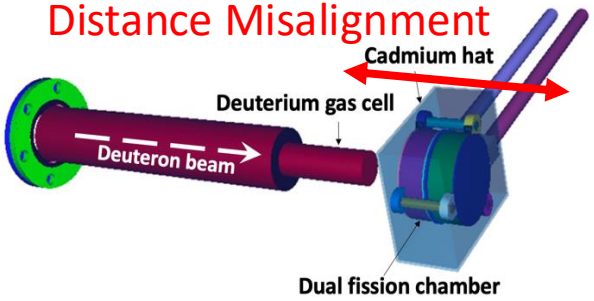
Lateral Misalignment



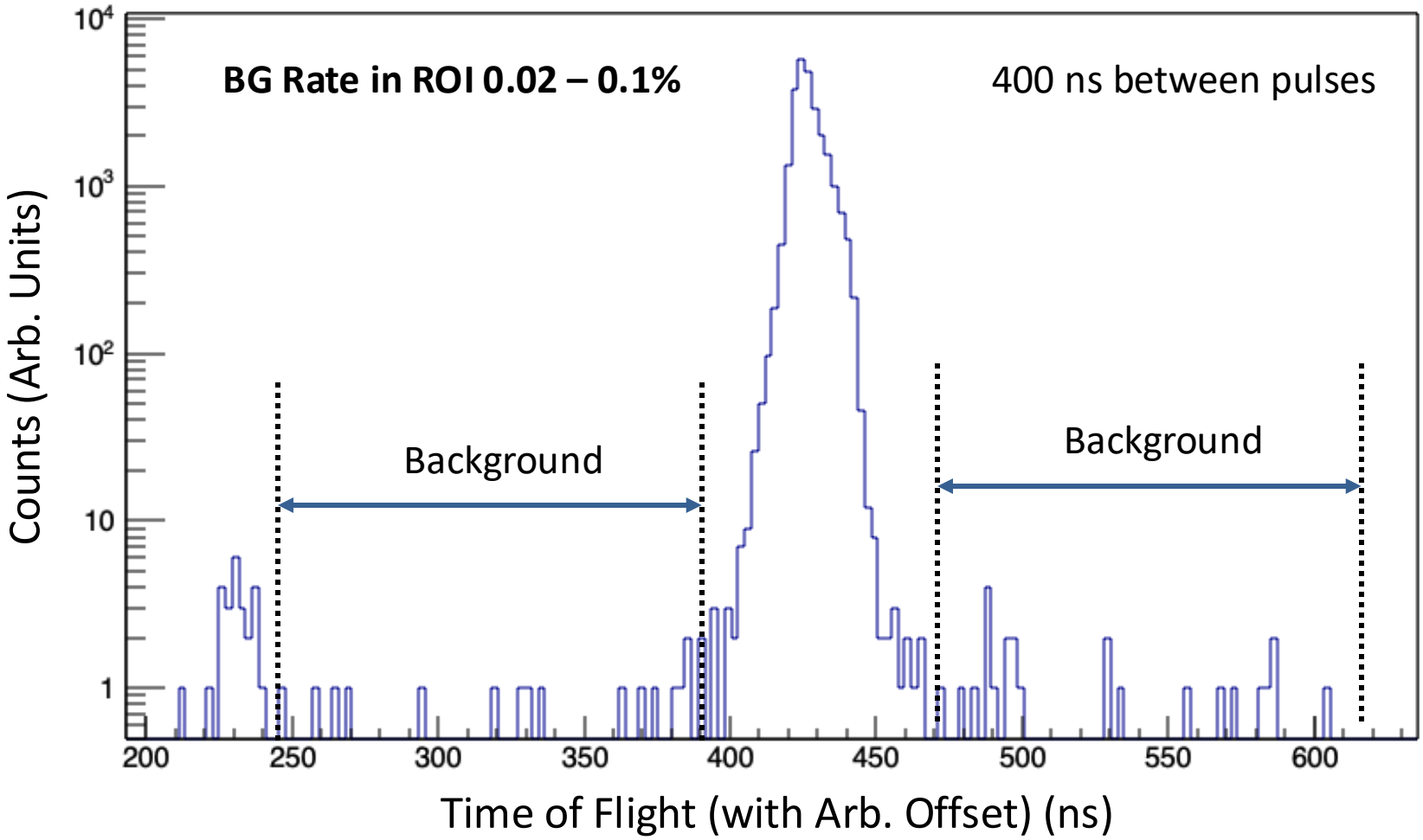
MCNP Calculations Quantify Sensitivity to FC Distance Offset



Distance Misalignment



Fission Chamber ToF Confirms Low BG/Room Return



Fission Cross-section Ratio Equation

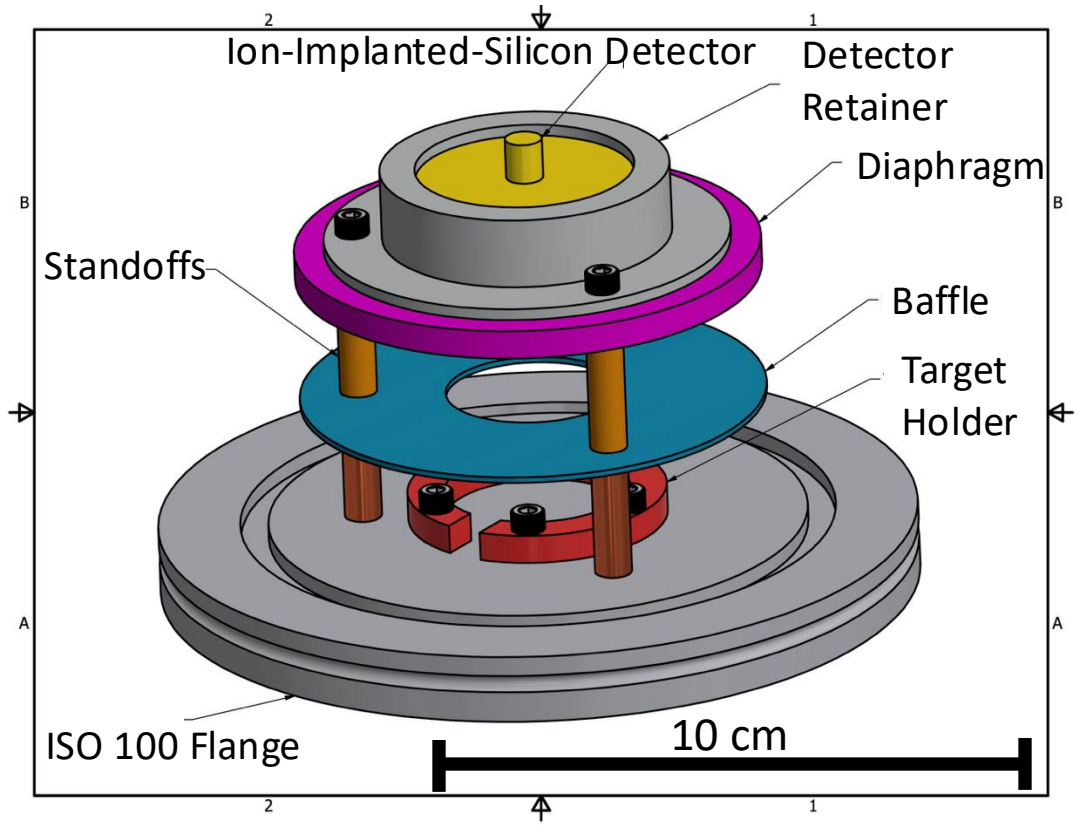
$$\frac{\sigma(U8)}{\sigma(U5)} = \frac{N(U5)}{N(U8)} \sqrt{\frac{U8_{meas\uparrow}}{U5_{meas\downarrow}} \frac{U8_{meas\downarrow}}{U5_{meas\uparrow}} \frac{\epsilon_{U5\uparrow}}{\epsilon_{U8\downarrow}} \frac{\epsilon_{U5\downarrow}}{\epsilon_{U8\uparrow}}}$$

Number of atoms in the target

Measured fission counts in the Upstream (↑) and Downstream (↓) orientation

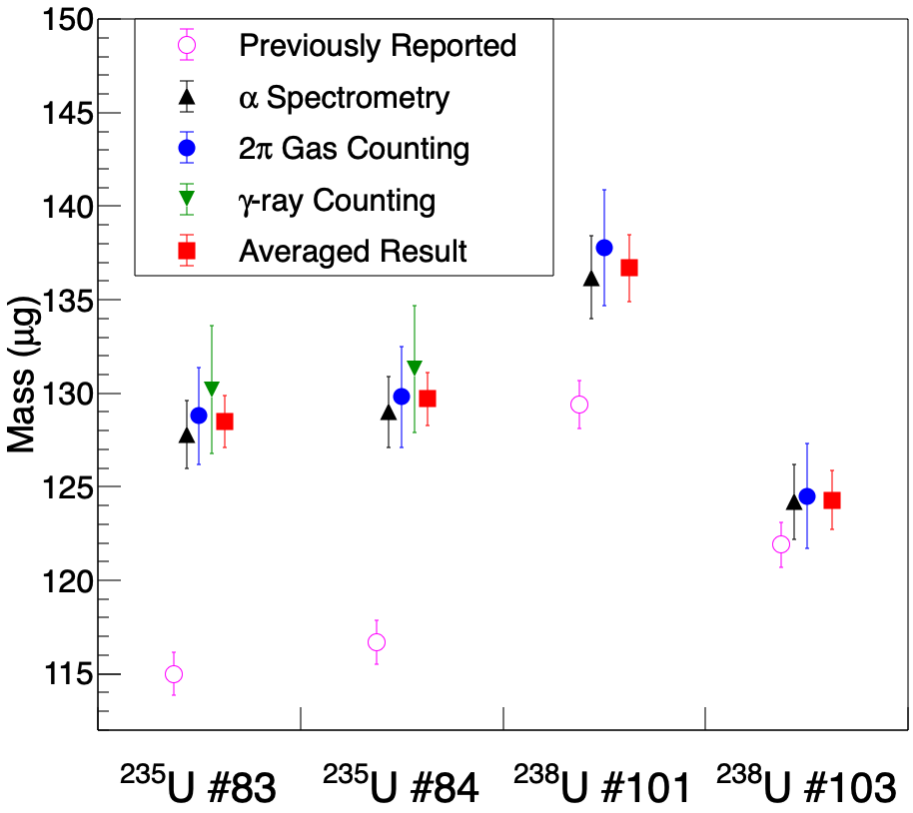
Kinematic Boost Efficiency (GEANT4) Upstream (↑) and Downstream (↓)

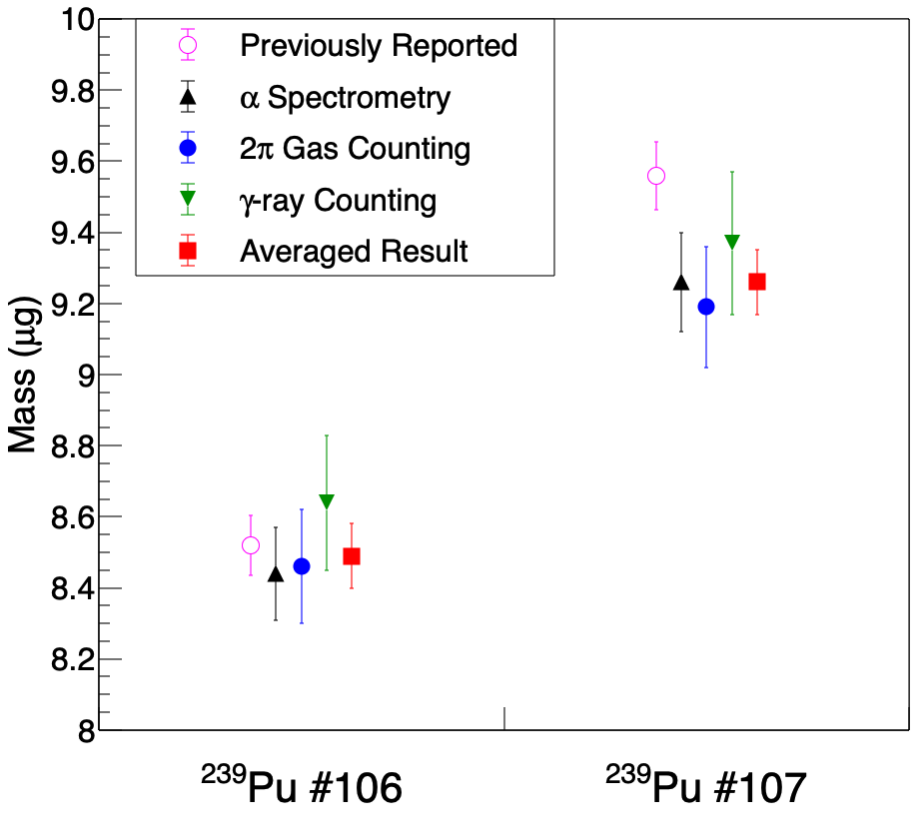
Atom Ratios Measured with a Dedicated Alpha Spectrometer



J. A. Silano *et al.*, Nucl. Instrum. Methods in Phys A **1063**, 169234 (2024).

Verification of Alpha Spectrometer Mass Measurements





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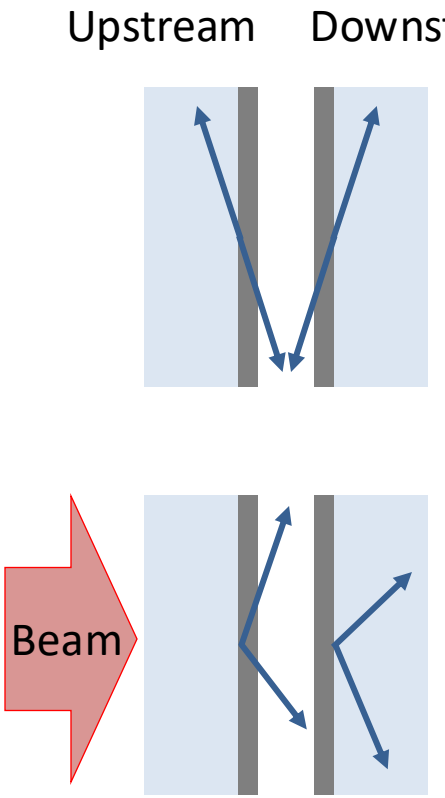
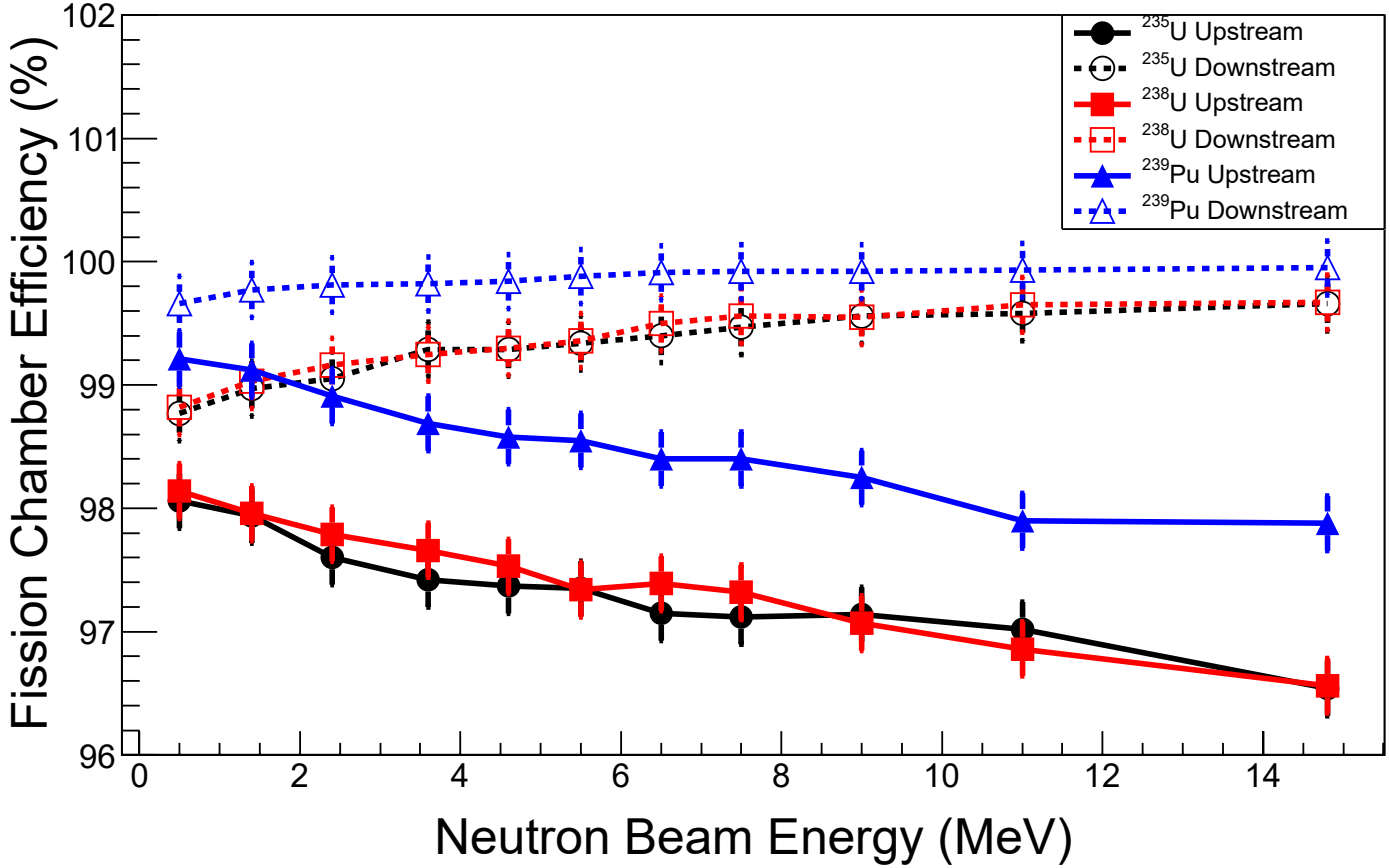
Number of atoms in the target

Measured fission counts in the Upstream (↑) and Downstream (↓) orientation

Kinematic Boost Efficiency (GEANT4) Upstream (↑) and Downstream (↓)

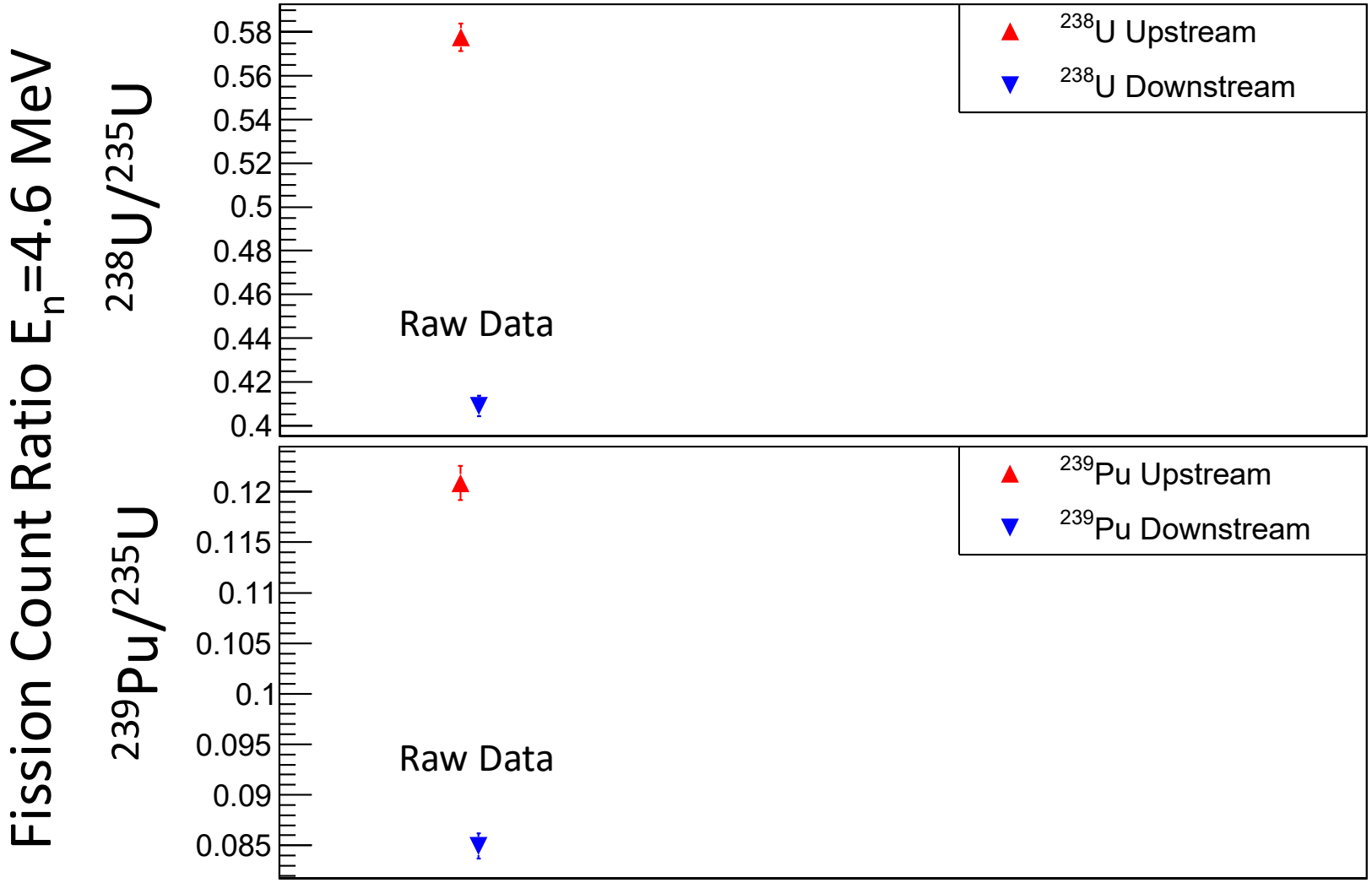
Kinematic Boosting Correction Factor



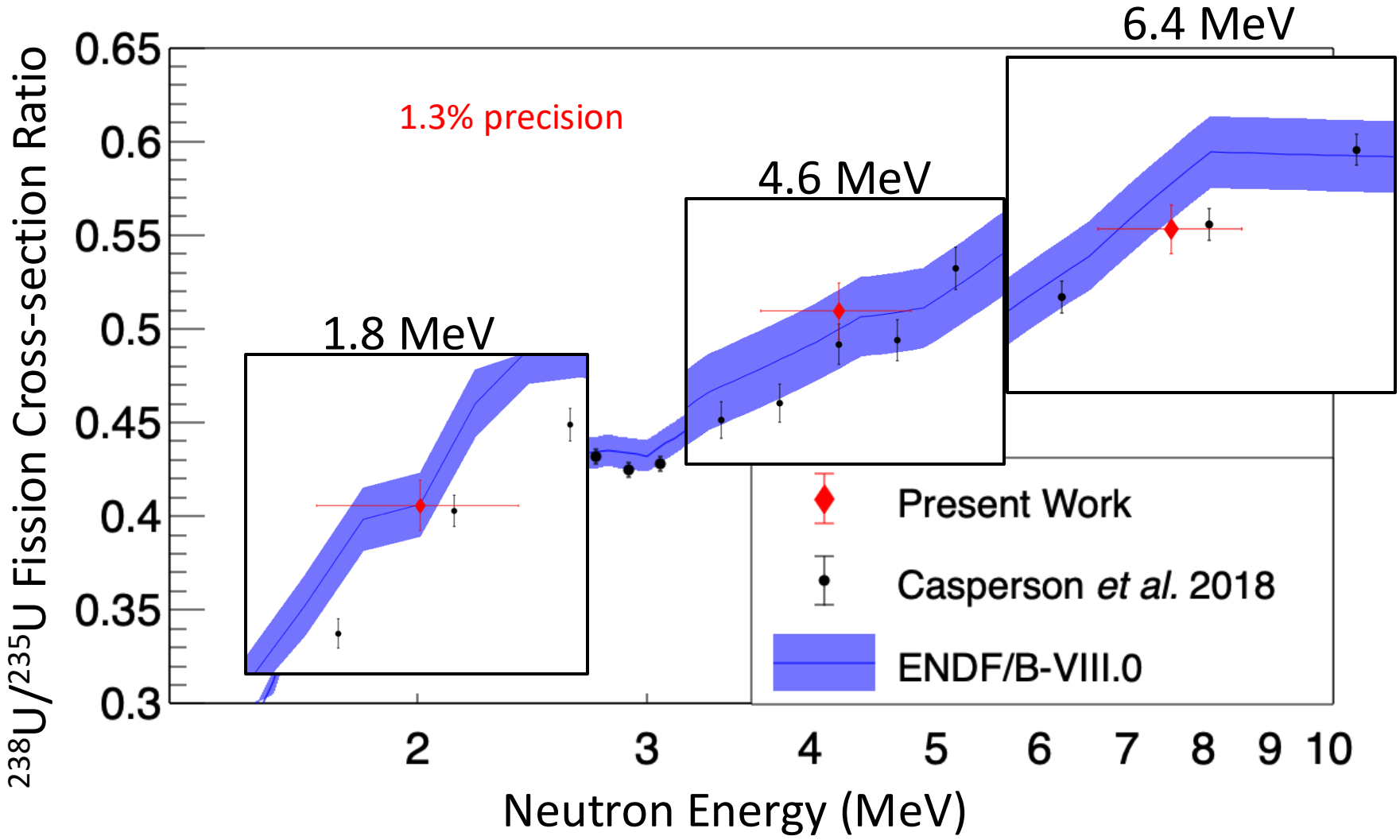


FREYA: R. Vogt and J. Randrup, Nucl. Instrum. Methods Phys. Res. A **954**, 161225 (2020).

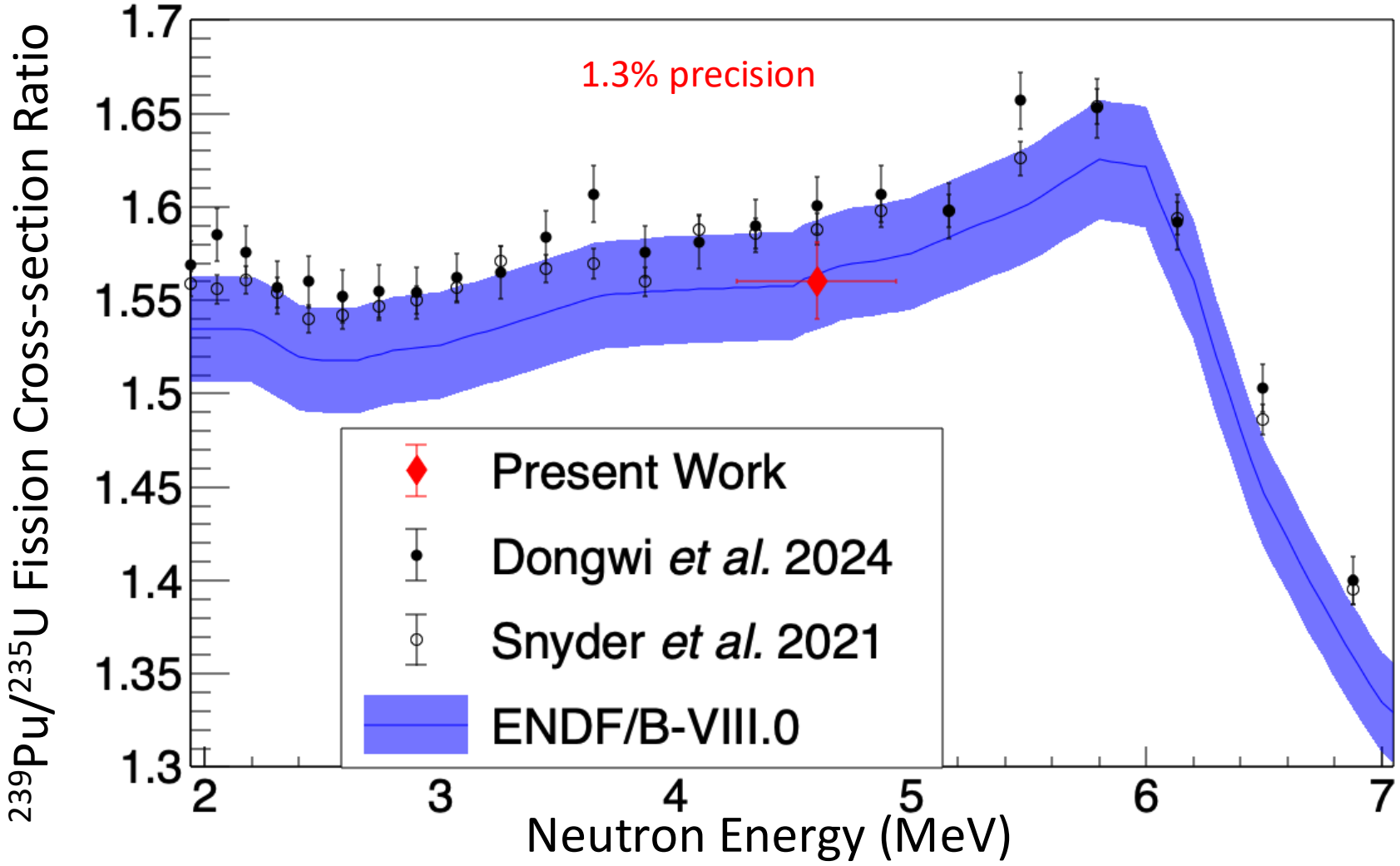
Simulation Corrections Completely Account for Upstream/Downstream Systematics



$^{238}U/^{235}U$ Cross-section Ratio Results

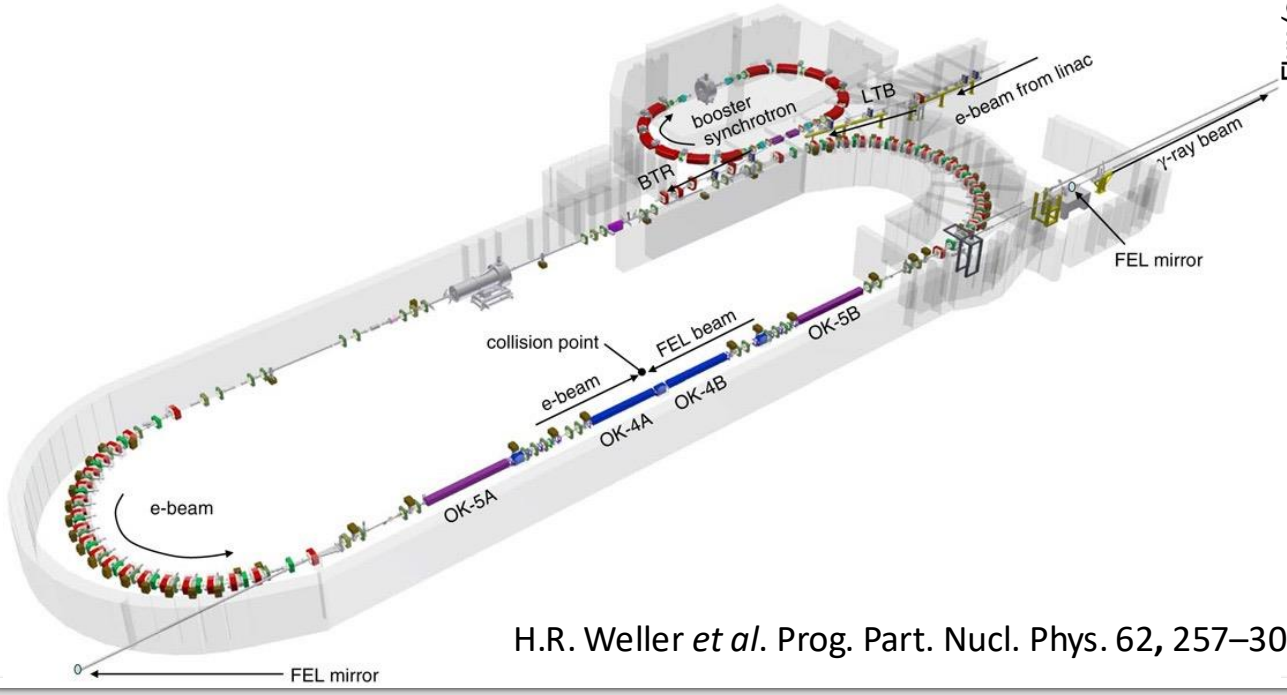


$^{239}Pu/^{235}U$ Cross-section Ratio Results

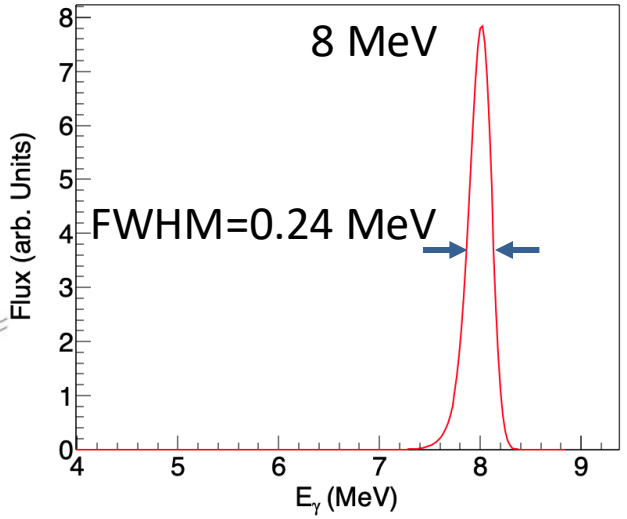


Next Step: Photofission at the High Intensity γ-ray Source (HIγS) Facility

- Beam energy: 7-18 MeV
- Energy spread: 3% FWHM
- Flux on target: $5 \times 10^7 - 10^9$ γ/s



Example γ-ray Beam Spectrum



H.R. Weller *et al*. Prog. Part. Nucl. Phys. 62, 257–303 (2009)

Photofission Across the GDR

- Simultaneous measurement of photofission cross sections for ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu
  - Absolute CS (4-6% precision)
  - CS Ratios (1.6-3.2% precision)
- 74 hours of PAC approved beamtime
- 7 MeV ≤ E_γ ≤ 18 MeV
  - 0.25 MeV steps