Modernizing the Fission Basis: Short Lived Fission Product Yield Measurements in $^{235, 238}$U & ^{239}Pu

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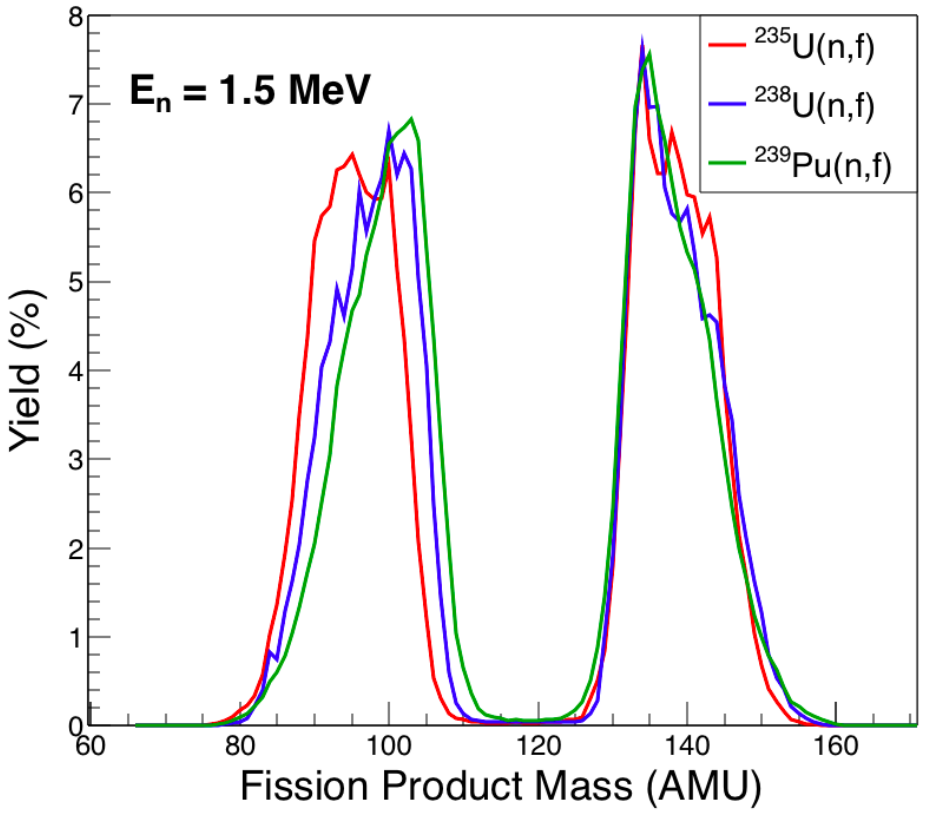
Fission Product Yields (FPYs)

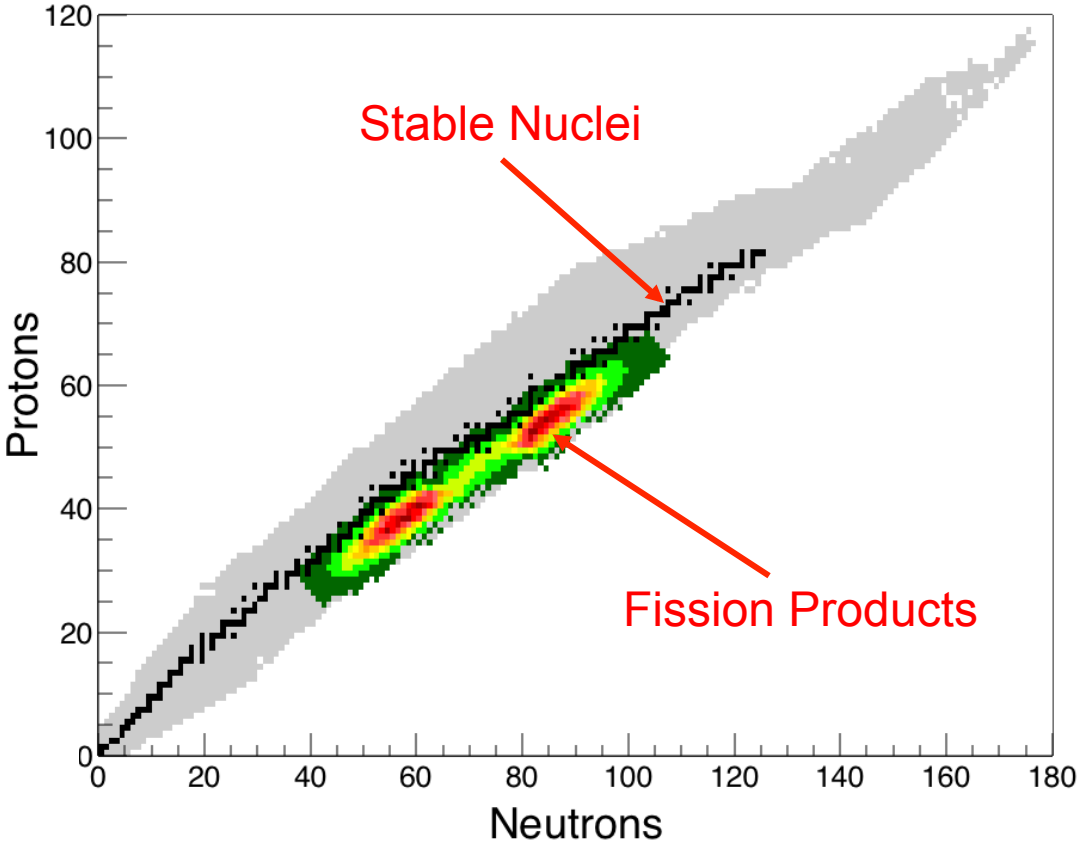
- Shape and energy evolution of FPY mass distribution is a sensitive probe of the fission process
- Need for high-precision FPY data
  - Stockpile Science
  - Nuclear Energy
  - Nuclear Forensics
  - Antineutrino Anomaly
  - Benchmark for Microscopic Fission Models

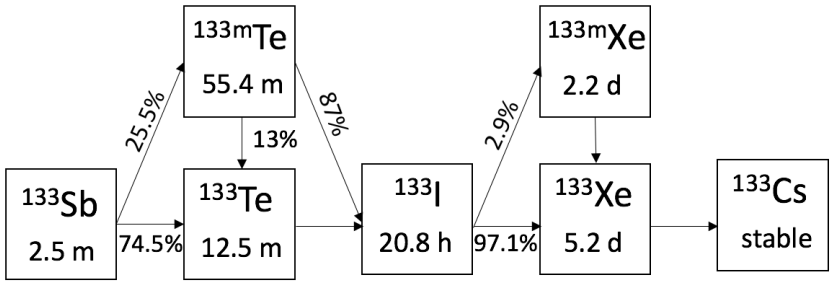


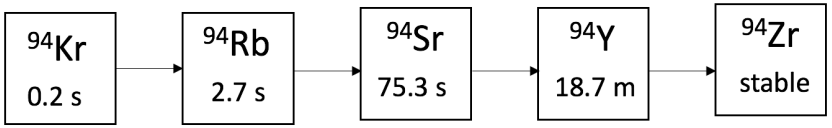
Data from T.R. England and B.F. Rider, LA-UR-94-3106 (1994)

Fission Product Yields Landscape

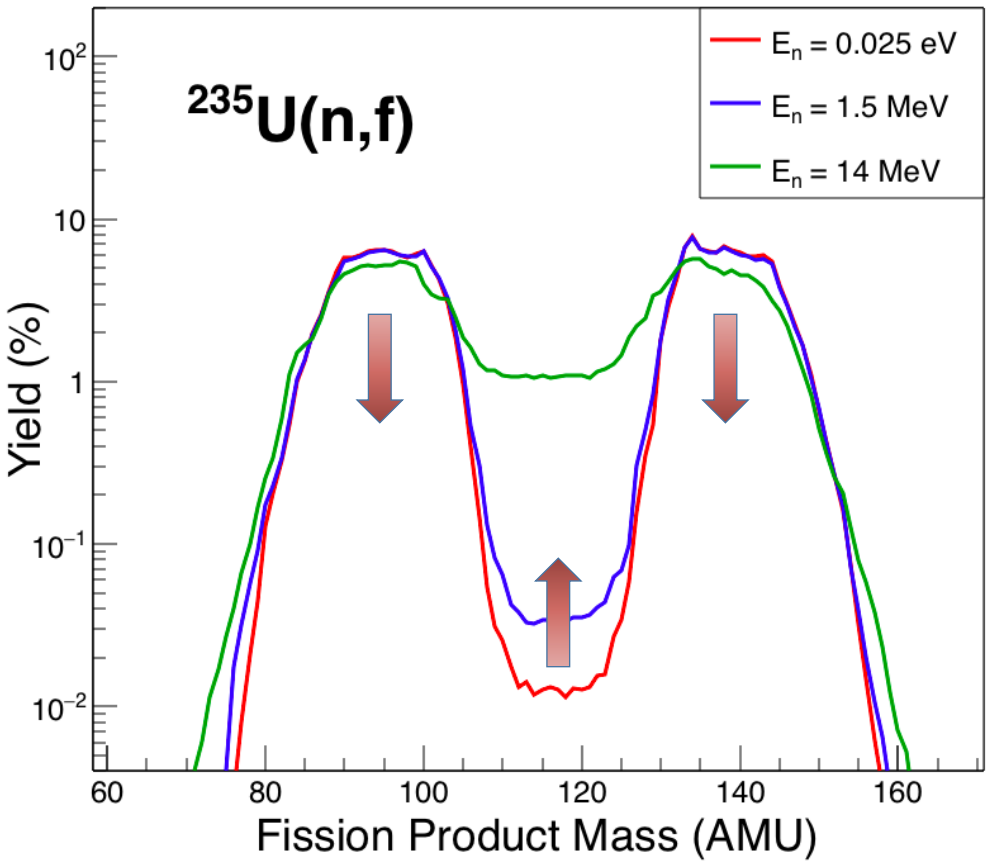
- Neutron-rich fission products β-decay to stability
- Identify with E_γ and $t_{1/2}$
- Determine cumulative & independent yields





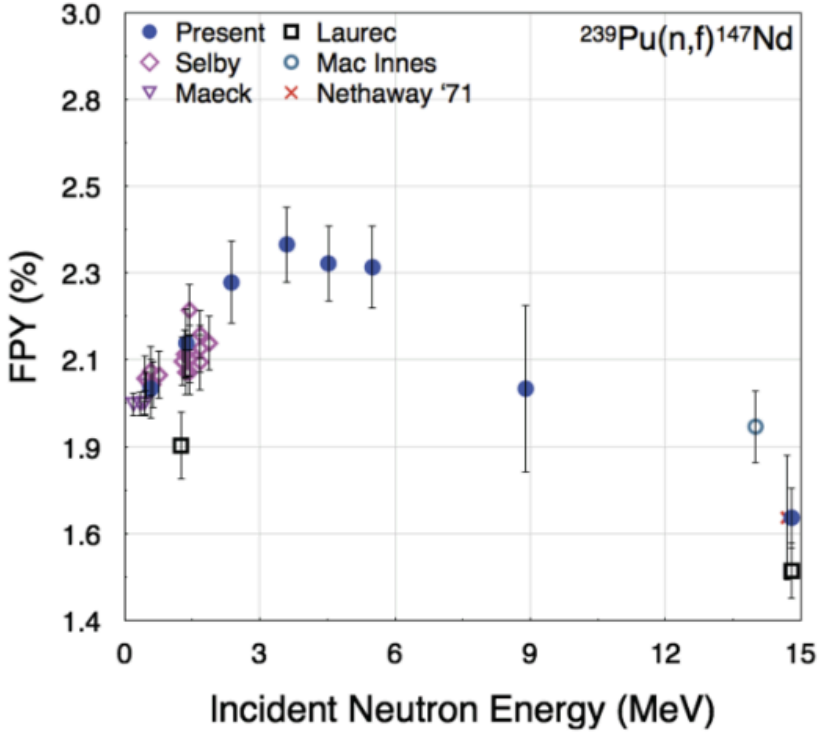


FPY Energy Dependence



Data from T.R. England and B.F. Rider, LA-UR-94-3106 (1994)

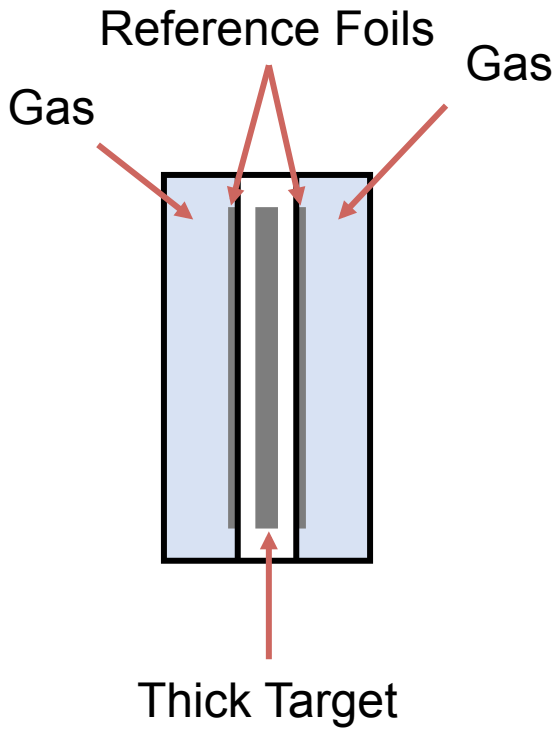
- Positive trend from 0-4 MeV observed in some high-yield fission products
- Needs theoretical explanation

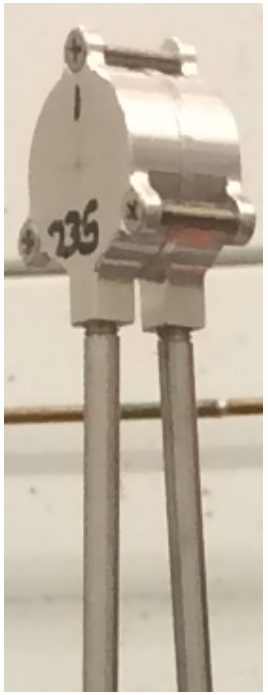


M.E. Gooden et al. Nucl. Data Sheets 131, 319, (2016)

Dual Fission Chamber

- Precise fission counting
- Eliminates need for knowledge of neutron flux and fission cross section
- FC efficiency = 98.5±1.5%

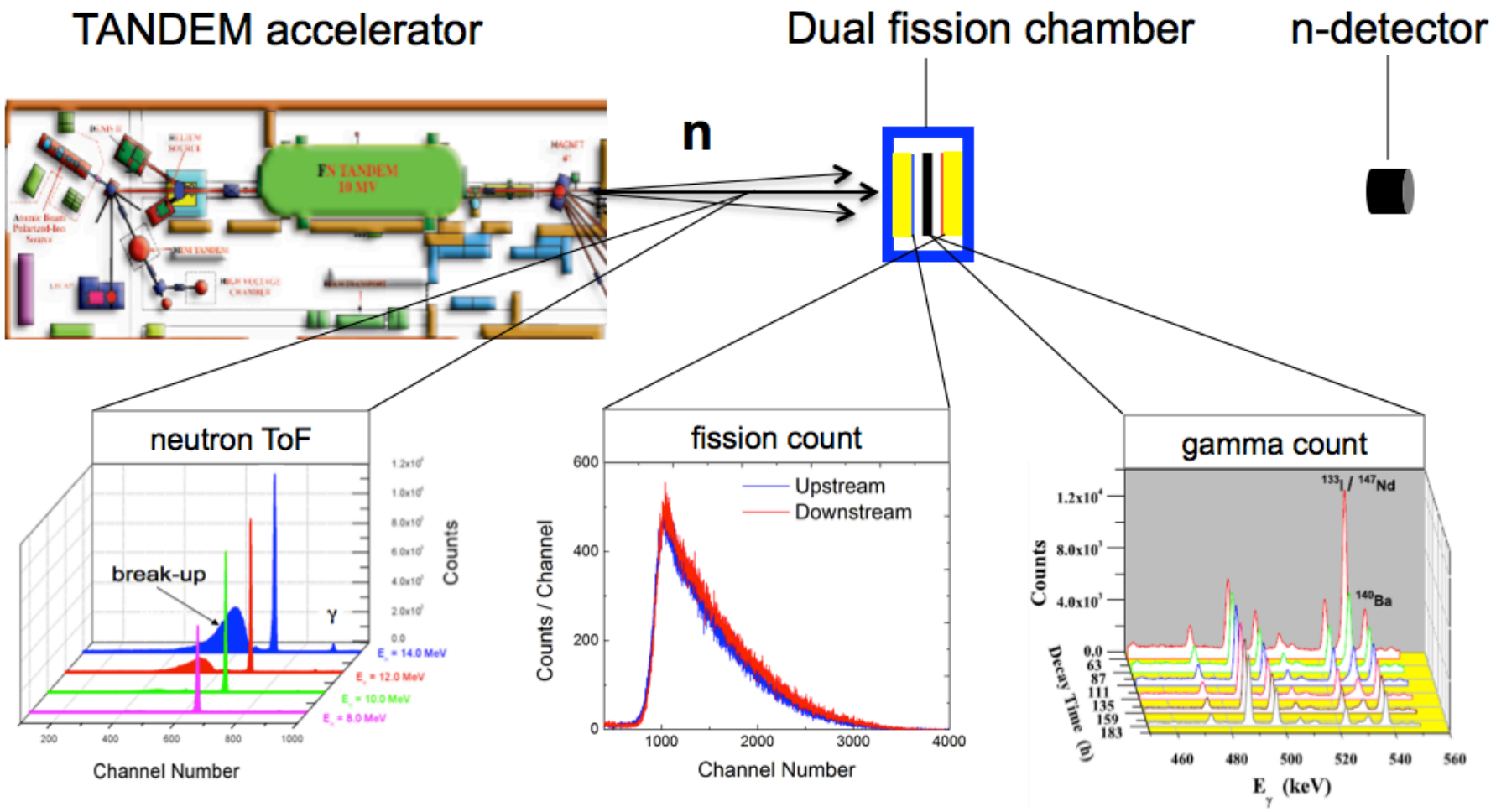




$$FPY \propto \frac{1}{\sigma(n,f)\phi(E_n)} \Rightarrow FPY \propto \frac{M_{thin}}{M_{thick}}$$

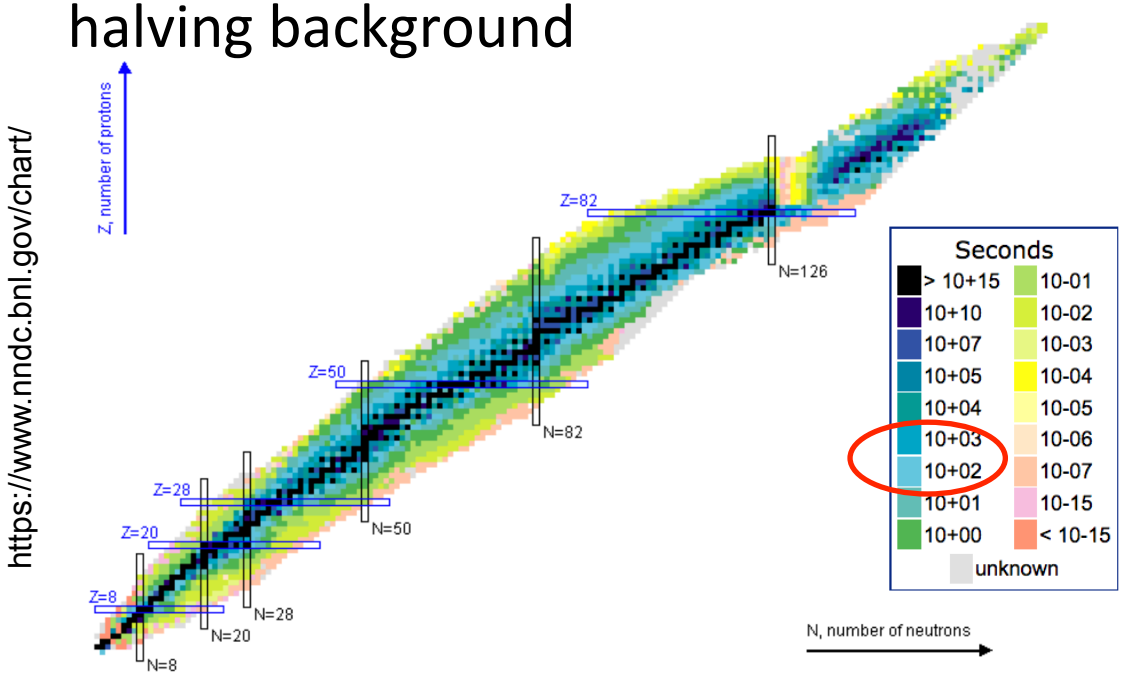
C. Bhatia et al. Nucl. Instr. Meth. A 757, 7, (2014)

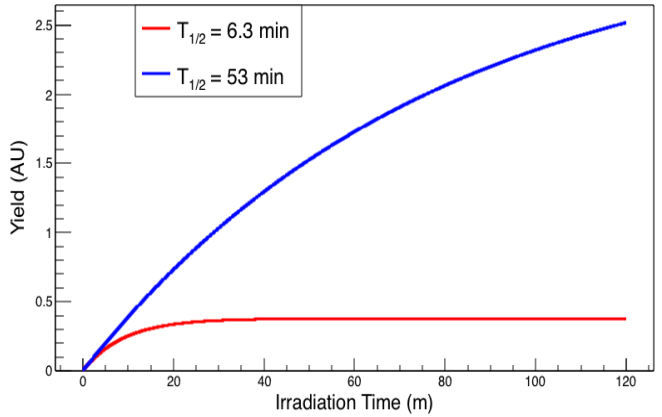
TUNL-LANL-LLNL FPY Measurements



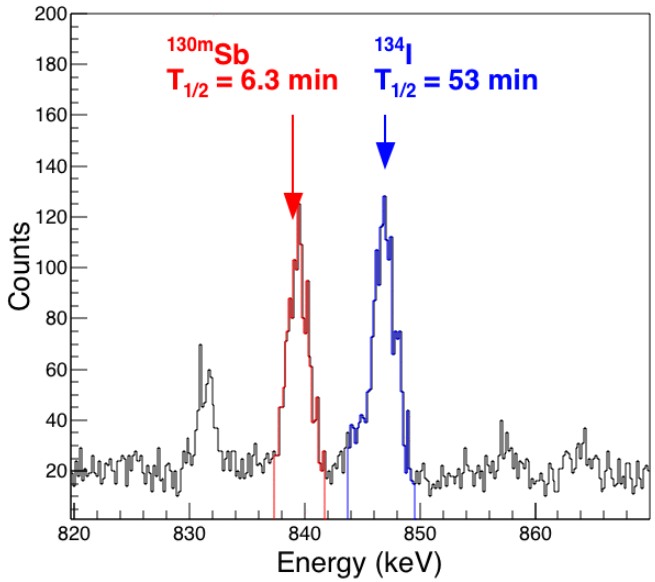
Short Lived FPY Measurements

- Expose to neutron beam for 1 hr, begin counting immediately after (<5 min) and count continuously for 3-4 days
- Reduce activity from long lived FPs, halving background

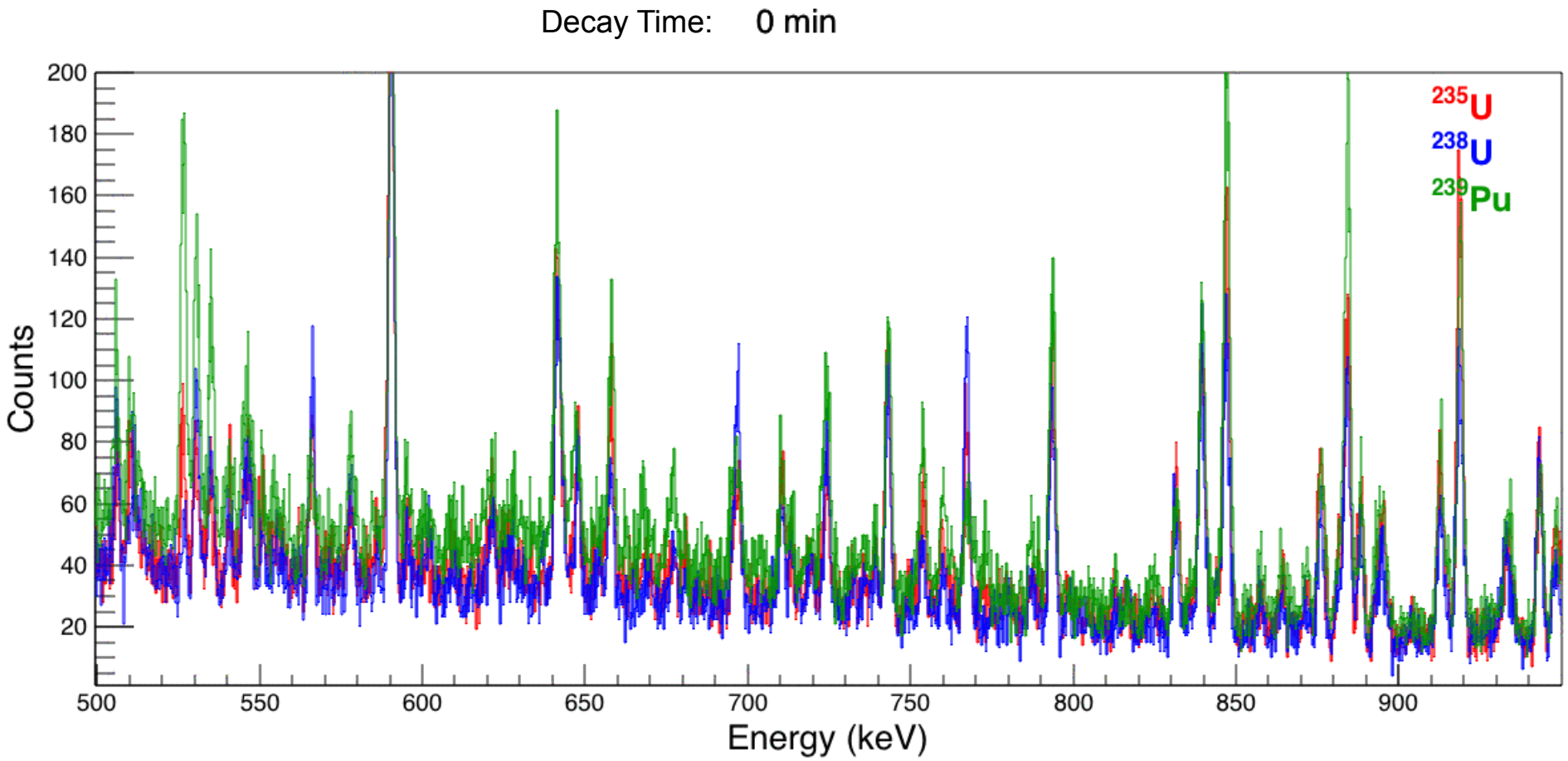




Decay Time: 0 min

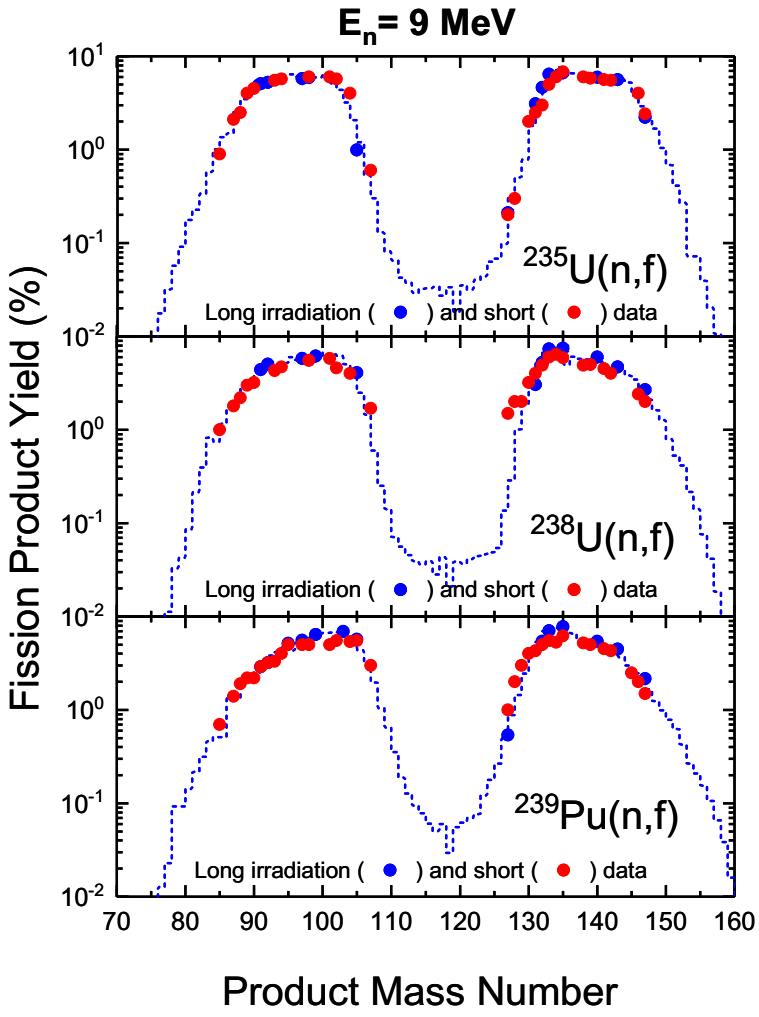


FP Spectra from Fission at E_n = 9 MeV



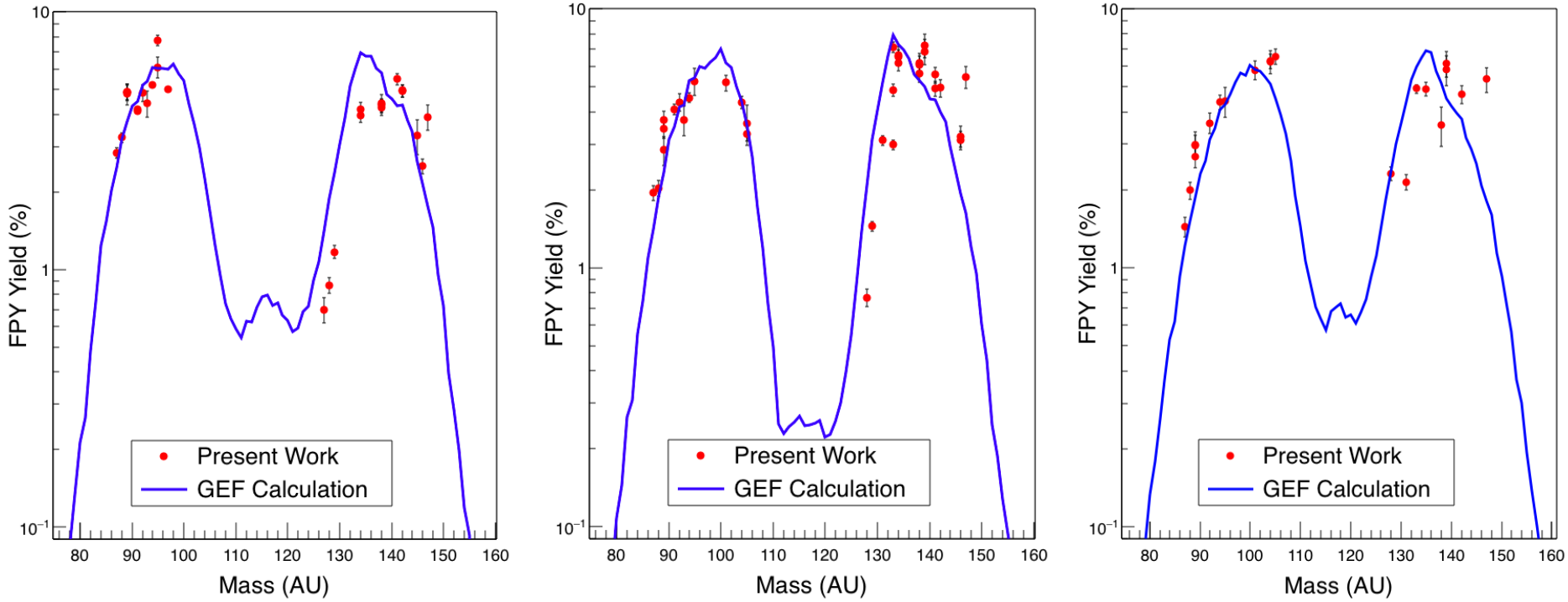
FPY Mass Distribution: Long + Short Irradiation

- Self-consistent, systematic approach to measuring FPYs
- Long-lived (days or weeks)
- Short-lived (minutes or hours)
- Constrain the mass distribution



Preliminary Results from E_n = 9 MeV

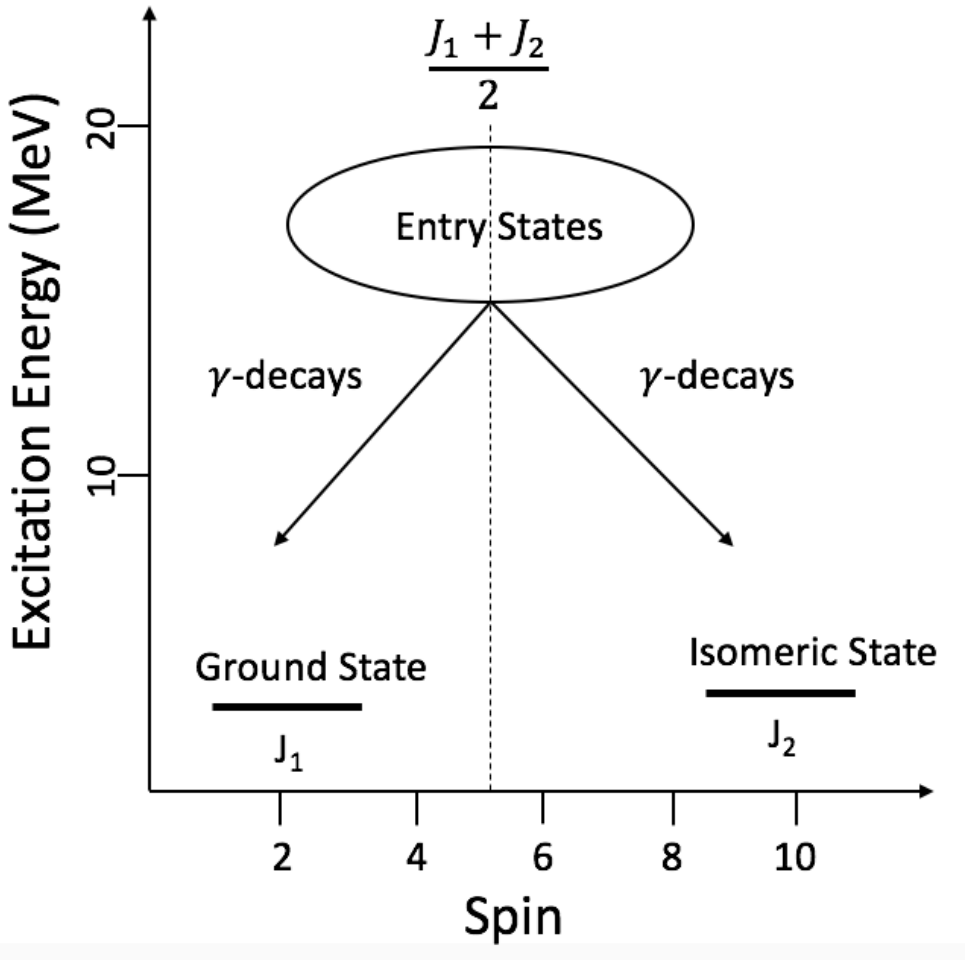
^{235}U ^{238}U ^{239}Pu



Current data only includes “simple” cases (i.e. no long lived parent nuclei)
More to come with further analysis!

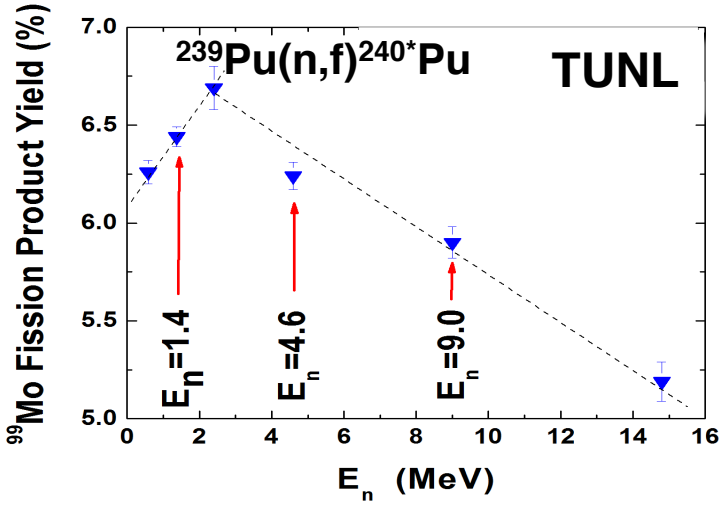
Isomeric Ratios of Fission Products

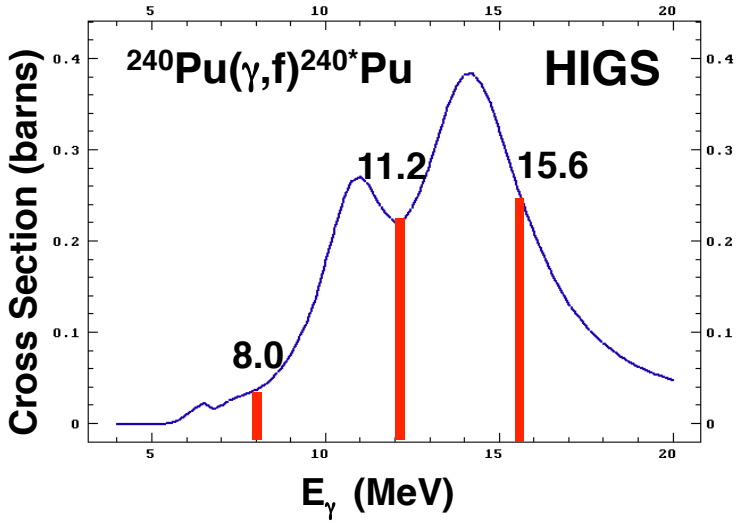
- Ratio of isomeric to ground state FPY given by angular momentum of fission fragment
- Candidate nuclei in short lived data
  - ^{133}Te, ^{134}I, ^{135}Xe
- Future measurements at more energies will yield energy evolution of $J_{fragment}$



Bohr Hypothesis Test - Photofission of ^{240}Pu

- ^{239}Pu(n,f) and ^{240}Pu(γ,f)
  - Same compound nucleus:^{240*}Pu
  - Match excitation energies
- ^{240}Pu(γ,f) with HIGS γ-ray beams
  - Monoenergetic (~3% FWHM)
  - Intense (~10^8 γ/s on target)
- Current progress
  - Fission chamber being fabricated
  - Two electroplated ~30 µg/cm^2 ^{240}Pu targets being fabricated
  - 200 mg ^{240}Pu activation target ready
  - HIGS beam available FY18





Concluding Remarks

- FPYs are a sensitive probe of the fission process
- Focus on short-lived FPs to extend mass distribution, fragment momentum
- Planned ^{240}Pu(γ,f) measurements will test Bohr hypothesis
- Thanks to collaborators!
  - A.P. Tonchev[1], W. Tornow[2,3], F. Krishichayan[2,3], S. Finch[2,3], M. Gooden[4] and J. Wilhelmy[4], R. Henderson[1], N. Schunk[1], R. Vogt[1]
  - [1]LLNL, [2]Duke University, [3]TUNL, [4]LANL