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

FIESTA2017

September 19, 2017

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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

Fission Product Yields Landscape

- Neutron-rich fission products $\beta$-decay to stability
- Identify with $E_\gamma$ and $t_{1/2}$
- Determine cumulative & independent yields
FPY Energy Dependence

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


Dual Fission Chamber

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

TUNL-LANL-LLNL FPY Measurements

TANDEM accelerator

Dual fission chamber

n-detector

neutron ToF

break-up

Counts

Channel Number

fission count

Counts per Channel

Channel Number

gamma count

Counts

Decay Time (s)

Eγ (keV)

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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
FP Spectra from Fission at $E_n = 9$ MeV

Decay Time: 0 min

Energy (keV)

Counts
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

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 — $^{133}\text{Te}$, $^{134}\text{I}$, $^{135}\text{Xe}$
- Future measurements at more energies will yield energy evolution of $J_{\text{fragment}}$
Bohr Hypothesis Test - Photofission of $^{240}$Pu

- $^{239}$Pu(n,f) and $^{240}$Pu($\gamma$,f)
  - Same compound nucleus: $^{240*}$Pu
  - Match excitation energies

- $^{240}$Pu($\gamma$,f) with HIGS $\gamma$-ray beams
  - Monoenergetic ($\sim$3% FWHM)
  - Intense ($\sim$10$^8$ $\gamma$/s on target)

- Current progress
  - Fission chamber being fabricated
  - Two electroplated $\sim$30 $\mu$g/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 $^{240}\text{Pu}(\gamma,f)$ measurements will test Bohr hypothesis
- Thanks to collaborators!
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