Mission Relevance

An accurate and comprehensive nuclear database allows the prevention and deterrence of global nuclear proliferation

- β-decay following fission events provides detectable signatures to identify fission products and their respective yields.
- Measurements rely on precise knowledge of β-decay observables

This work looks along the A=111 mass decay chain
- Fission fragments that populate the "valley" in thermal fission product yields
- Yield increases as neutron energy increases in induced fission
- Provides direct forensic signature for presence of fast neutrons

Background

Fission products undergo β− decay and subsequently emit gammas to reach stability
- The fraction of γ rays of a certain energy emitted during this process is known as the γ branching ratio or intensity (BR)
- Fission product yields (FPY) can then be found based on the measured number of characteristic γ rays (Nγ):

\[ FPY = \frac{N_\gamma}{BR_\gamma} \]

\[ BR_\gamma = \frac{N_{\text{FPY}}}{N_{\text{FPX}}} \]

- Many long-lived isotopes have large (3%-30%) uncertainties in their γ-ray intensities contribute to the absolute uncertainty for FPY measurements

Our work aims to provide precision measurements (known to <1%) of the γ branching ratios from long-lived fission products, specifically in \(^{111}\text{Ag}\).

Sample harvested at California Rare Isotope Breeder Upgrade (CARIBU) at Argonne National Laboratory (ANL)
- Fission products from \(^{235}\text{U}\) spontaneous fission source collected into beam
- Beam is then accelerated and filtered through isobars for mass purification
- Relevant fission products implanted on a 200 nm thick carbon foil
- \(^{111}\text{Ag}\) purity in extracted sample approximately 99.94%

Experimental Approach

Precisely calibrated HPGe detector coupled with 4r gas counter provides β-γ coincidence analysis
- HPGe absolute efficiency known to 0.2% over 5−1400 keV
- Source placed in gas detector mounted at various distances from face of HPGe detector:
  - 151 mm from HPGe cap
  - 51 mm from HPGe cap with plastic medium for background suppression

Preliminary Results and Future Work

Using the gamma branching ratio formula where \(N_\gamma\) is the β-γ coincidence peak area, \(N_{\text{FPX}}\) is the total number of β-particles detected, and \(e_{\gamma}, e_{\text{FPX}}\) are the γ-ray, β-particle, and β-γ coincidence detection efficiency (respectively):

\[ \frac{\gamma-\text{ray detection efficiencies provided by CYLTRAN simulations of the TAMU HPGe detector}}{\beta-\gamma coincidence detection efficiencies provided by Geant4 simulations of the 4r gas counter} \]
- Close to 100% detection efficiency

Future work
- Multiple experiments to determine BRs, using this method have been carried out for \(^{152}\text{Ce}, ^{147}\text{Nd}, ^{140}\text{Ce}\), and \(^{136}\text{Ce}\)
  - Future experiments will look at \(^{181}\text{Tb}, ^{180}\text{Sb},\) and \(^{110m}\text{Cd}\) in the interest of reducing uncertainty in medical isotope diagnostics, FPYs, and r-process calculations

Use of nuCARIBU facility for sample implantation
- Replace 252Cf spontaneous fission source in CARIBU with actinide foil source for neutron-induced fission
- More reliable source of fission products

Local experimental setup at LLNL Nuclear Counting Facility with 4r gas counter and BeGe detector for γ-γ spectroscopy

Efficiency Calculations

\[ \gamma-\text{ray detection efficiencies provided by CYLTRAN simulations of the TAMU HPGe detector} \]
\[ \beta-\gamma coincidence detection efficiencies provided by Geant4 simulations of the 4r gas counter \]

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