Measuring Spin-Energy Correlations in Fission With Gammasphere

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Introduction and Motivation

As detection technology and techniques improve, nonproliferation instrumentation has become sensitive to increasingly complex signatures of fission. We strive to understand the origins of those signatures by measuring correlated fission fragments, neutrons, and gamma rays.

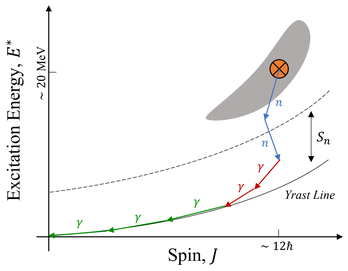

Fig. 1. Cartoon of fission fragment de-excitation (adapted from [1])

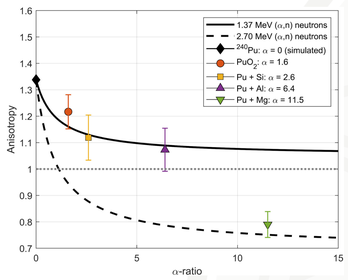

Fig. 2. Pu metal can be distinguished from oxides with neutron anisotropy [2]

Nuclear Data: Improving evaluated data libraries

Modeling Fission: More accurate signatures in simulations for instrument development for nonproliferation, e.g., **CGMF** (LANL), **FREYA** (LLNL)

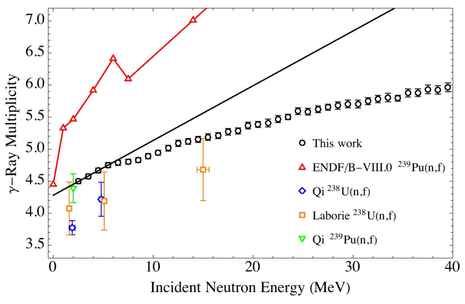

Fig. 3. Gamma-ray multiplicity of ^{239}Pu(n,f) as a function of incident neutron energy [3]

Technical Approach

Twin Frisch-Gridded Ionization Chamber (TFGIC)

- Designed and built with collaborators at Argonne National Lab (ANL) [4]
- Cf-252 spontaneous fission source inside
- Measures fragment masses and total kinetic energy (TKE) with the *2E* method [5]

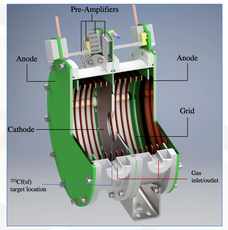

Fig. 4. CAD drawing of our TFGIC at ANL [4]

Gammasphere + FS-3

- Gammasphere: 110 HPGe spectrometers, arranged in 4π
- FS-3: Neutron- and gamma-ray-sensitive stilbene detectors
- Objective: combine with TFGIC to correlate fragment properties with neutron and gamma-ray emission

Fig. 5. Gammasphere at ANL

Spin-Energy Correlation Analysis

- *Coincidence finding*: Connect gamma rays and detected fragments
- *Doppler correction*: Correct measured gamma-ray energies for the Doppler shift based on fragment velocity and opening angle
- *Intensity balance*: Combine gamma-ray intensities and nuclear level scheme knowledge to determine spin distribution

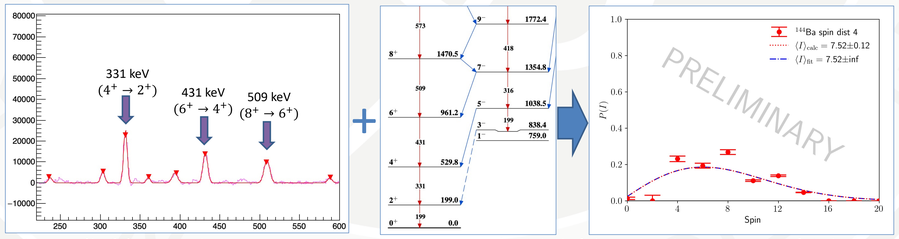

Fig. 6. (left) Doppler-corrected E_γ spectrum, (middle) level scheme, and (right) spin distribution for ^{144}Ba

Results

- We extracted the *spin sawtooth*—the shape of the average spin $\langle J \rangle$ as a function of fission fragment mass, as seen by Wilson et al. [6]

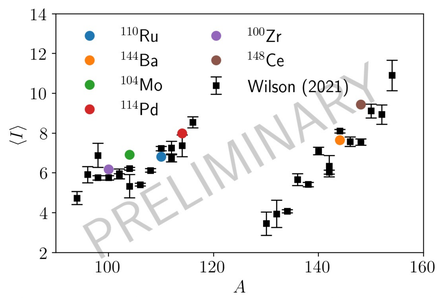

Fig. 7. Spin sawtooth, compared to Wilson et al. [6] in black

- We are extracting the average (post-statistical emission) spins of fragments as a function of total kinetic energy (TKE)
- These TKE curves aim to resolve the question in fission of the degree of correlations between spin and energy
- Target: May 2024

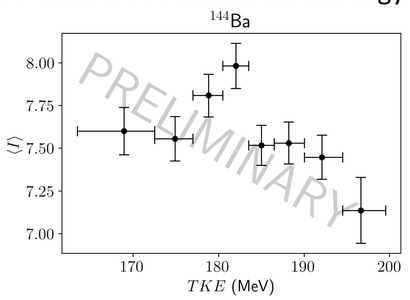

Fig. 8. Preliminary TKE dependence of average spin $\langle J \rangle$ for ^{144}Ba

Conclusion & Impact

- Our TFGIC+Gammasphere+FS-3 experiment will produce nearly model-independent results on spin-energy correlations in ^{252}Cf(sf)
- These results will (1) improve nuclear data and (2) help theorists improve predictive fission models to advance the NNSA's nuclear safeguards and nonproliferation mission by elucidating new signatures and correlations

Mission Relevance

- Improve fission gamma-ray nuclear data libraries, where experimental data is limited
- Discovering new signatures of fission could substantially improve nuclear material accountancy

MTV Impact

- Extensive collaboration with experimental scientists and engineers at Argonne National Lab
  - Constructing ionization chamber
  - Gammasphere experiment
- Collaborations with fission theorists at LANL (P. Talou, I. Stetcu, A.E. Lovell), LLNL (R. Vogt), and LBNL (J. Randrup)

References

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