Neutron Energy-Multiplicity Correlations from the Spontaneous Fission of Cf-252

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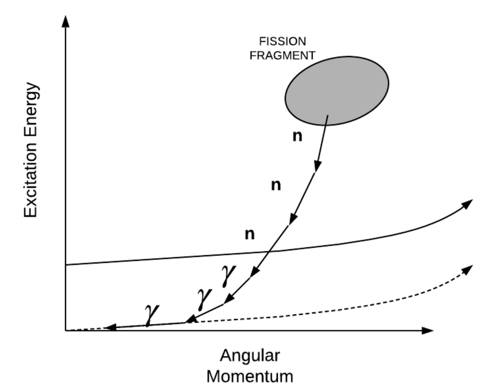
Mission Relevance

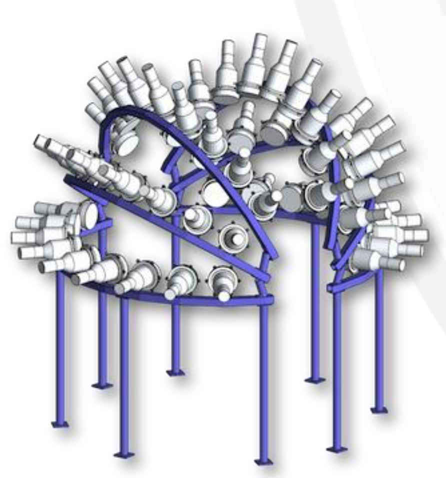
In order to prevent nuclear proliferation, we need radiation detectors to accurately identify and characterize Special Nuclear Material (SNM). Current methods of characterization, can be improved by including analysis of energy-multiplicity correlations following fission.



Introduction and Motivation

Correlations in fission signatures contain information regarding the fission process and the sample itself. Current characterization methods assume no correlations between the energies and multiplicity of the emitted radiation; however, models of fragment de-excitation suggest these correlations exist. Our goal is to quantify these correlations and leverage them to characterize SNM. We focus on neutron correlations only.

Fission event generators FREYA and MCNPX-PoliMi were used for simulating the measurements taken at Los Alamos Neutron Science Center.



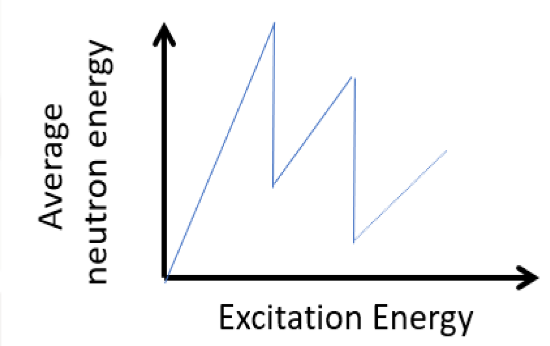
Based on de-excitation models used by the fission event generators, we divide the energy-multiplicity correlation into two contributions: **fragment initial conditions** and **energy competition**.

Technical Approach

We characterize these contributions by considering:

Mean Neutron Energy

$$\langle E \rangle = \frac{1}{N}\sum_{i=1}^{N} E_i$$

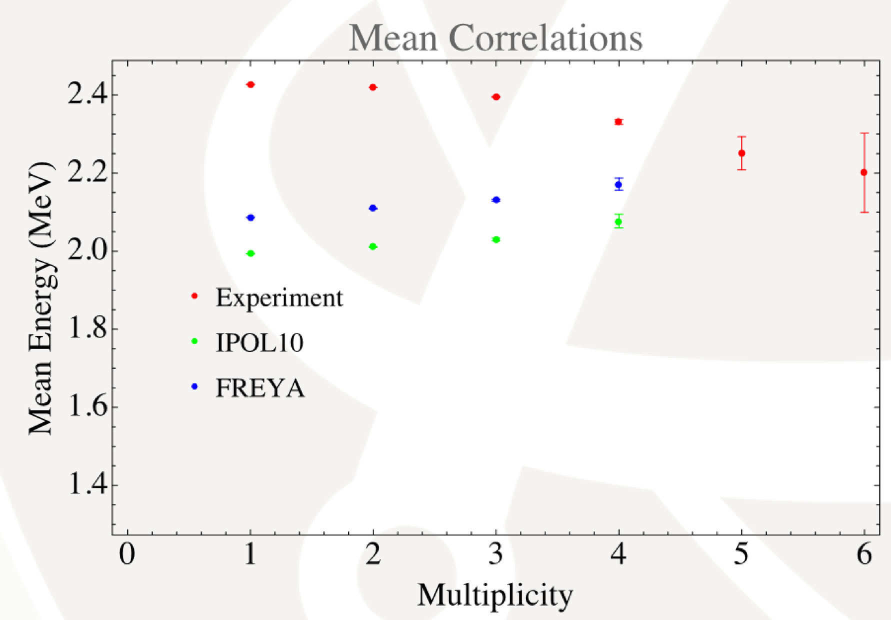


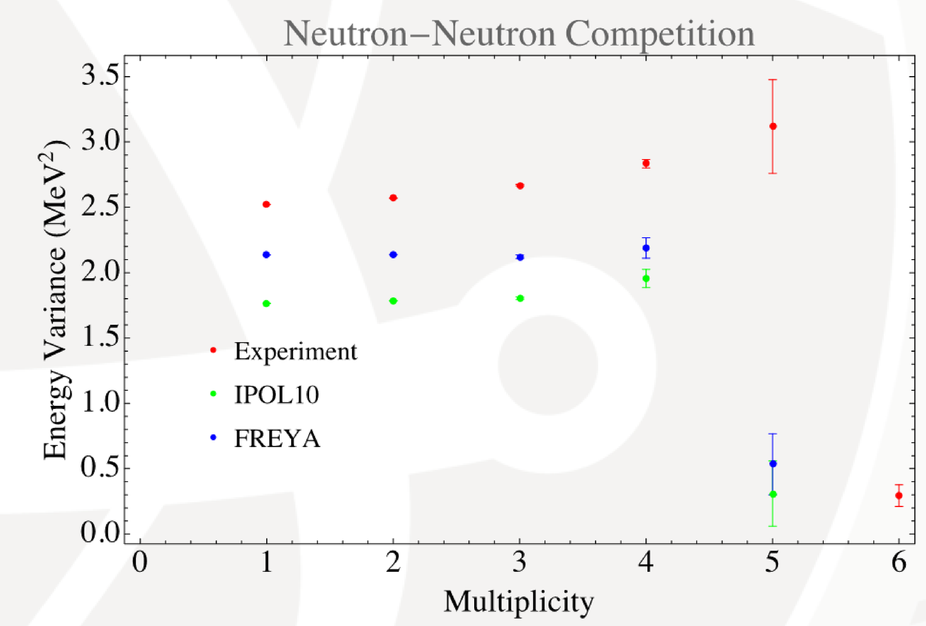
Neutron Energy Variance

$$\frac{\sigma^2(E_{TOTAL})}{N} = \sigma^2(E) + (N-1)cov(E_i, E_j)$$

We obtain correlations due to fragment initial conditions and energy competition through the slopes of these relationships.

Results





Experimental results indicate a negative correlation due to the fragment initial conditions, while the simulated results indicate the opposite.

Correlations in uncorrelated simulations indicate a systematic bias that increases neutron energy as multiplicity increases.

Difference in Spectra:

We are currently investigating the difference in the average energy between the experiment and simulation

- Room Return contributions in the simulated data.
- PSD effects and classification of background

Conclusion

Further analysis is needed to fully quantify these effects on the total neutron energy-multiplicity correlation. Current focuses are

- Removal of cross talk and room return events in the simulated data.
- Effects of correlated background on misclassification.

Expected Impact

Experimental investigations of energy-multiplicity correlations will expand our analysis of fission signatures.

Analysis of these correlations can then be used to more accurately characterize the sources or materials that create these signatures; thus enhancing capabilities of nonproliferation.

Next Steps

There is room to expand this study to include photons emitted following fission.

Additionally, we know that relativistic effects on the isotropic fragment emission results in energy-angle correlations. These correlations lack experimental verification as well.

These correlations arise from a positive energy bias along the direction of motion of the fission fragment.

National Nuclear Security Administration

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