Measurements of Prompt Fission Neutron Correlations in ^{252}Cf

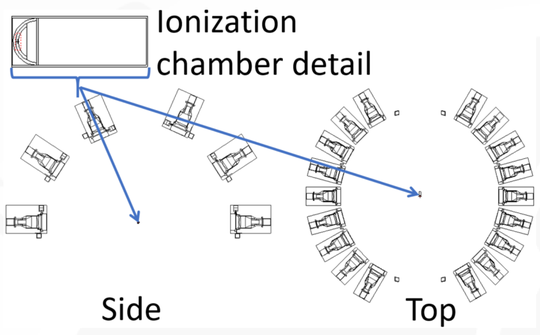
P. Schuster[a], M. Marcath[a], S. Clarke[a], P. Talou[b], M. Devlin[b], R. Haight[b], S. Pozzi[a]
[a] University of Michigan, [b] Los Alamos National Laboratory
PI: Prof. Sara Pozzi, pozzisa@umich.edu
Consortium for Verification Technology (CVT)

Abstract

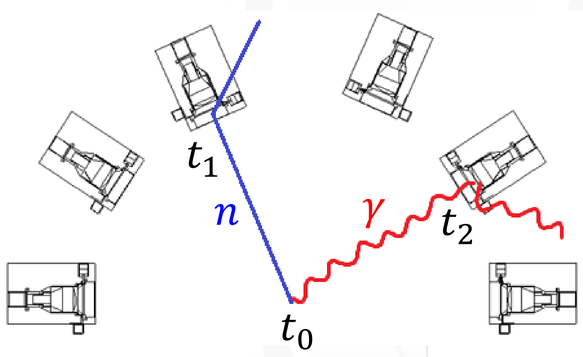
Nuclear fission is a complex de-excitation whereby an unstable heavy nucleus splits into two, or more, smaller fragments, releasing radiation mostly in the form of neutrons and gamma rays. Accurate models for simulating fission neutron and gamma-ray emission are vital for designing new safeguards and nonproliferation systems. Present models are often limited in detail or incorrect for important isotopes of plutonium and uranium. New fission models based on theory, including CGMF and FREYA, are in development and improve our ability to accurately predict the fission emissions of key isotopes, but they have not been fully validated with correlated data. We have performed experiments at Los Alamos National Laboratory using the Chi-Nu array of 54 organic scintillator detectors of prompt neutrons and gamma rays from spontaneous (252Cf) and neutron-induced (235U) fission. These measurements are compared to simulations in which the fission event generator is varied between MCNPX-PoliMi, CGMF, and FREYA. Our analysis gives particular focus to correlated particle events.

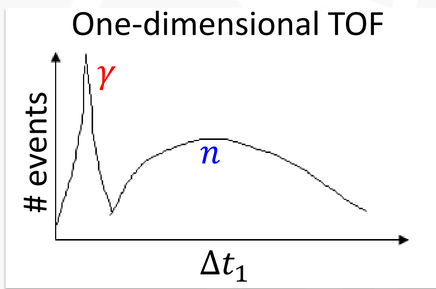
Measurements and simulations

- Chi-Nu array at LANL LANSCE facility with 54 detectors
- Liquid scintillator with 1.6 ns timing resolution, PSD for n-γ classification
- 124 hours of data, full waveforms
- Particle transport with MCNPX-PoliMi
- Vary fission event generator: CGMF, FREYA, MCNPX-PoliMi



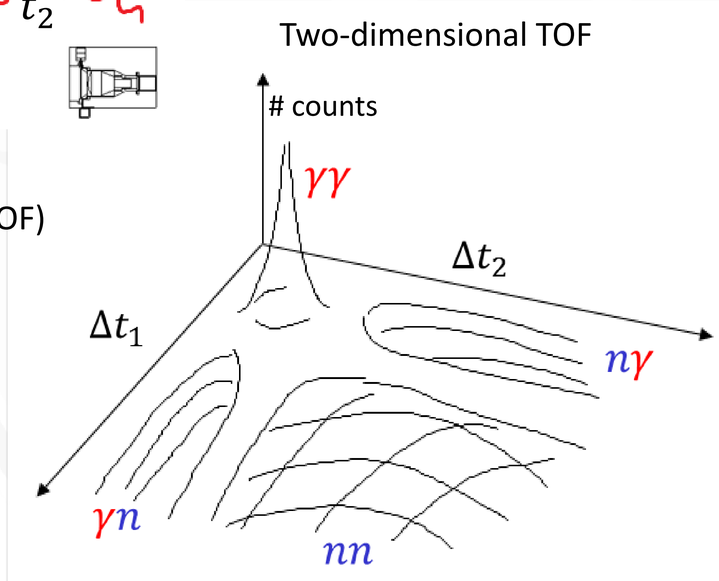
The bicorrelation distribution

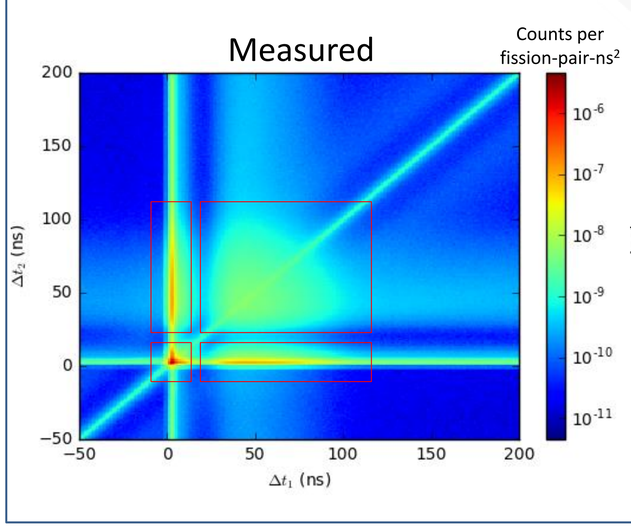


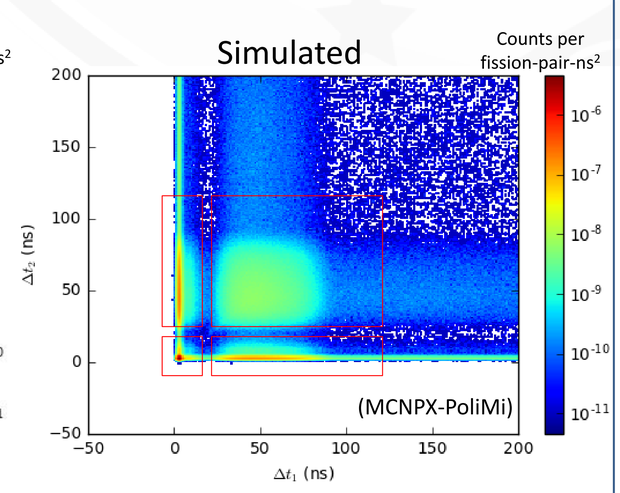


Calculate the time-of-flight (TOF) to each detector:

$$\Delta t_1 = t_1 - t_0$$
$$\Delta t_2 = t_2 - t_0$$







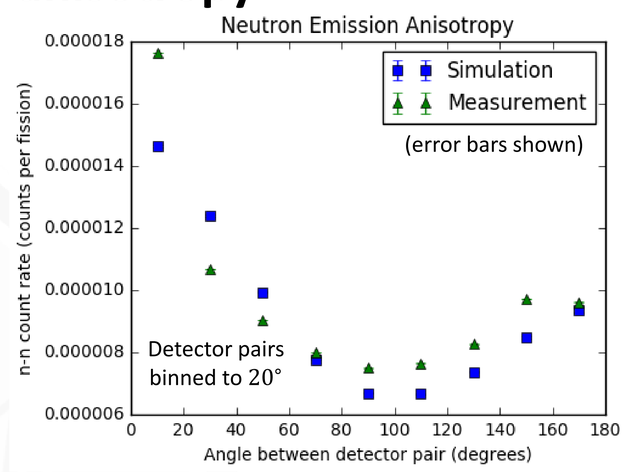
Quantifying magnitude of anisotropy

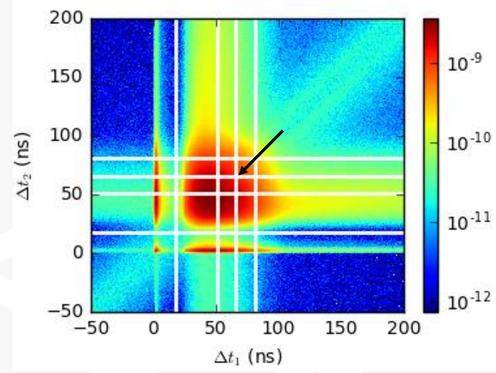
Count rate vs. angle

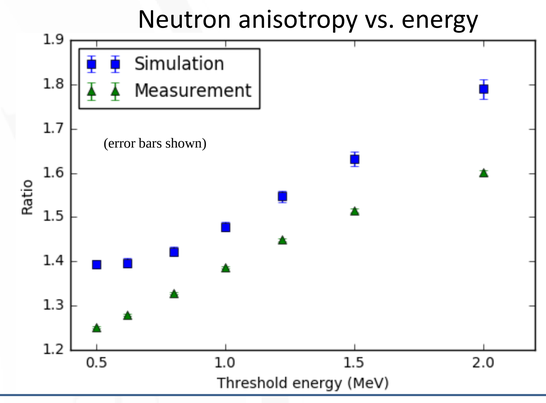
- Calculate n-n count rate for detector pairs at different angles
- Neutrons > 0.72 MeV

Anisotropy vs. energy

- Vary neutron energy threshold
- Calculate: Ratio $= \frac{\#\text{ counts at } 180°}{\#\text{ counts at } 90°}$

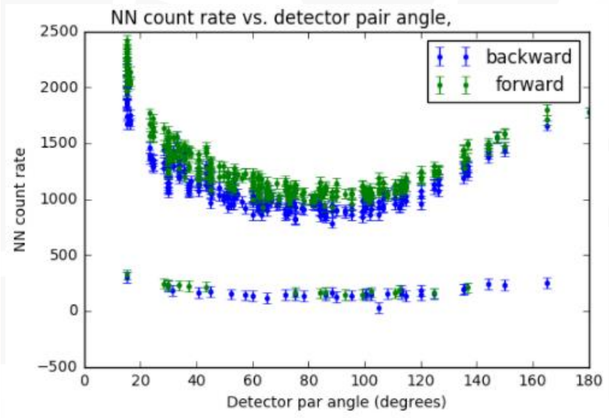


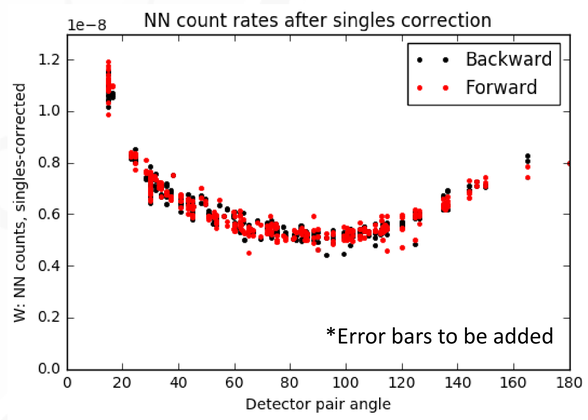




Correcting for solid angle, efficiency effects

- Significant variability in count rates vs. angle (error bars statistical)
- Divide by singles rates to account for efficiency, solid angle: $W = \frac{D_{i,j}}{S_i * S_j}$
- Investigate effects of fission chamber attenuation (pairs backward of chamber will be more attenuated)





Conclusions

We have performed unique, information-rich measurements on prompt fission emission. This provides an opportunity to validate new fission models and investigate poorly-characterized physics. We have demonstrated observable trends for ^{252}Cf spontaneous fission including the emission anisotropy.

Future work includes analysis of already-collected data from ^{235}U measurements and new measurements of ^{239}Pu and ^{240}Pu. We will also investigate the new fission models CGMF and FREYA.

View our work at https://github.com/pfschus/fission_bicorrelation

This work was funded in-part by the Consortium for Verification Technology under Department of Energy National Nuclear Security Administration award number DE-NA0002534

National Nuclear Security Administration