Cross-Correlation Breakdown of BC-420 Plastic Scintillators

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Introduction and Motivation

- Sustained fission chains in an assembly and the ability to detect events are of interest in nuclear nonproliferation, safeguards, criticality safety, and emergency response.
- Cross-correlation (CC) analysis is a tool typically implemented for understanding fission particle energy and time-correlated behaviors.
- Langevin approach to interpreting californium source driven noise analyses may not adequately estimate subcritical neutron multiplication factors.
- Langevin approach is based on detection of the first neutron, but with CC we can quantify how often neutrons begin a coincidence gate.

We analyze the simulated cross-correlation breakdown of Li-6-glass-faced BC-420 plastic scintillators, to evaluate subcritical neutron multiplication models.

Cross-Correlations

- Used to look at the multiplicity and identify spontaneous fission
- Four interactions can be detected: (n, n), (p, p), (n, p), (p, n)
- Each correlation has a time difference, $\Delta t = t_{start} - t_{stop}$

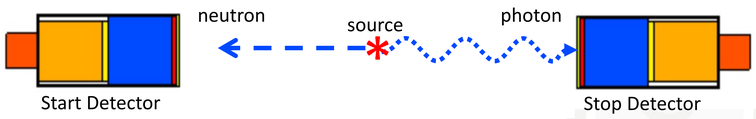

Fig. 1. Example Cross-Correlation for a photon-neutron (n, p) correlation detection

Simulation

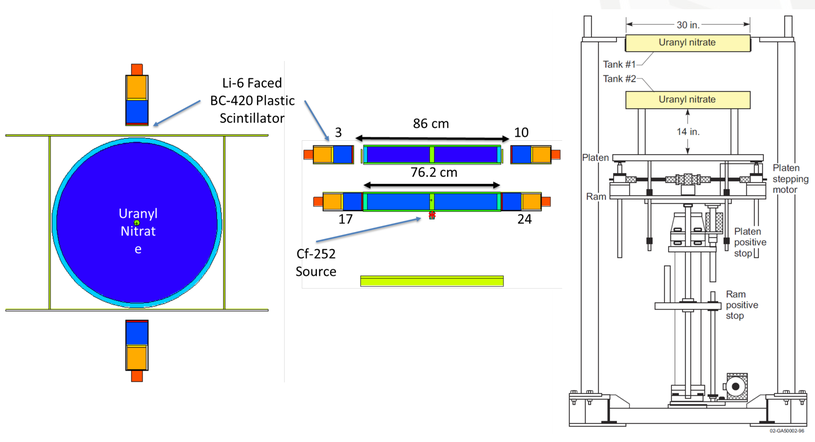

Fig. 2. (Left) MCNP Simulated and (Right) Sketch of Planet Assembly Machine with two 93.1% enriched uranyl nitrate filled WINCO tanks, using a Cf-252 source and four Li-6 faced BC-420 plastic scintillators

This work was funded in-part by the Consortium for Monitoring Technology and Verification under Department of Energy National Nuclear Security Administration award number DE-NA0003920

Post-Processing and Analysis

- Benchmarks simulated with MCNPX-PoliMi using various cases including:
  - Two 180° and 100 cm separated BC-420 detectors with Cf-252 source
  - Planet Assembly with two uranyl-nitrate **filled** WINCO tanks and 4 detectors
  - Planet Assembly with two **empty** WINCO tanks and 4 detectors
- Simulated collisions in detectors are processed using MPPost, a detector response post-processing software, to obtain the cross-correlations and pulse heights for each scenario.

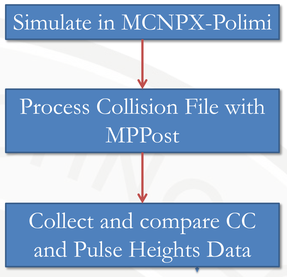

Fig. 3. Process of simulating and post-processing

Results

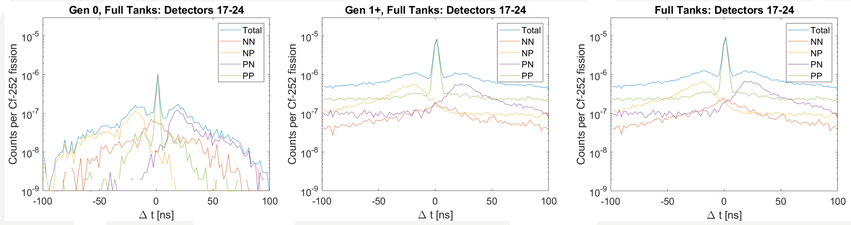

Fig. 4. CC breakdown by (Left) only source particles, (Middle) only particles from multiplication, and (Right) all particles for the Planet Assembly with filled WINCO tanks at 15.24 cm separation (k_{eff}=0.94)

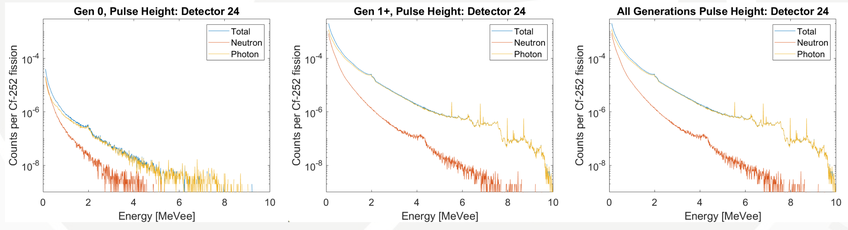

Fig. 5. Breakdown of Pulse Height by (Left) only source particles, (Middle) only particles from multiplication, and (Right) all particles for WINCO tanks also separated at 15.24 cm

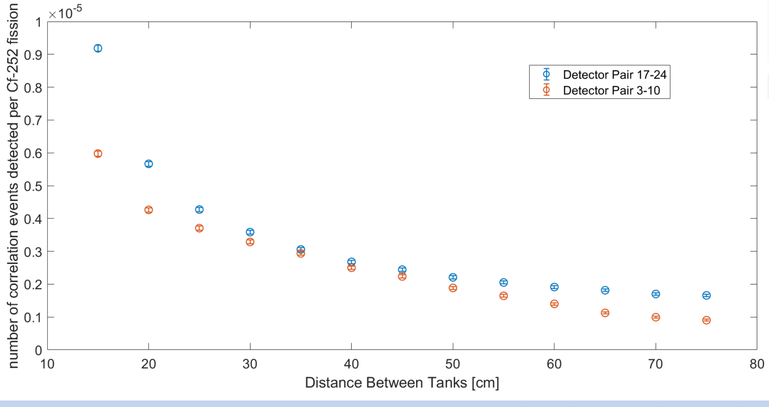

Fig. 6. Number of neutron-neutron correlation events detected per Cf-252 fission as a function of tank separation

Results Continued

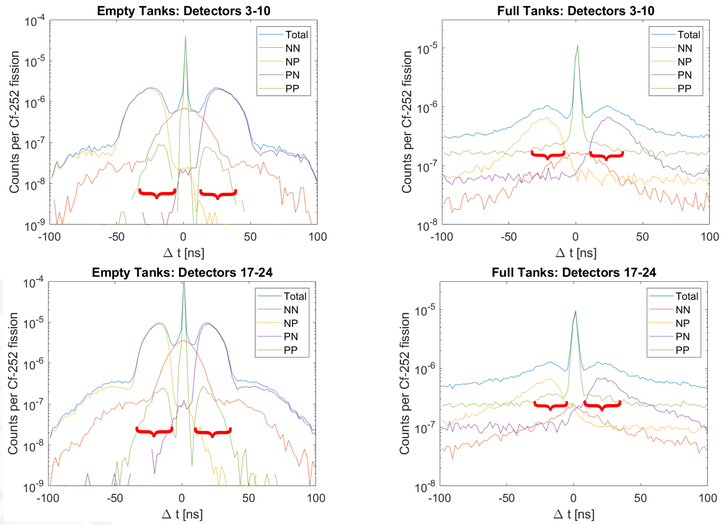

Fig. 7. Comparison of CC for (Left) empty tank detector pairs and (Right) full tank detector pairs. It can be seen that photon-photon region in the red brackets is, to some degree, visible in all CC

Conclusion and Future Work

- Photon-photon CC are more prevalent, especially in a multiplying assembly.
- Frequency of neutron-neutron correlations are lowest regardless of assembly.
- Photons from inelastic fast neutron scatters in the detector contribute to the frequency at larger time differences in photon-photon cross-correlations, but are minimized in multiplying assemblies.
- Future: Analyze assemblies at lower criticality and determine the contribution of (alpha, n) reaction in uranyl nitrate.

Impact

- Understanding of increasingly subcritical assemblies allows better material accountancy and can help identify smuggling of small masses
- Development of this work also aids in developing better neutron multiplicity models, which in turn help criticality safety studies.
- MTV: Collaboration with Oakridge and Los Alamos national labs has driven me to continue my career into graduate school

References

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