Detection of Fast Neutrons during Photon Active Interrogation

C. A. Meert[1]*, A. J. Jinia[1], Andrew Panter[1], Aaron MacDonald[1], H. S. Kim[2], S. D. Clarke[1], D. D. Wenztzloff[2], S. A. Pozzi[1]
[1]Department of Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor, MI
[2]Department of Electrical and Computer Engineering, University of Michigan, Ann Arbor, MI
Sara Pozzi, pozzisa@umich.edu *Presenting Author, cmeert@umich.edu
Consortium for Monitoring, Technology, and Verification (MTV)

Introduction and Motivation

- Photon active interrogation can induce photonuclear reactions in HEU to produce more detectable signatures compared to passive detection.
- **Goal**: Develop high-confidence techniques to detect prompt neutron signatures during photon active interrogation.
- **Expected Impact**: this project will improve the deployability of active interrogation systems by using a commercial 9-MeV linear accelerator (linac) and developing new techniques.

Mission Relevance

- Active interrogation systems support the detection of concealed special nuclear material.
- Increasing the deployability of active interrogation systems will improve the ability to interdict illicit special nuclear material.

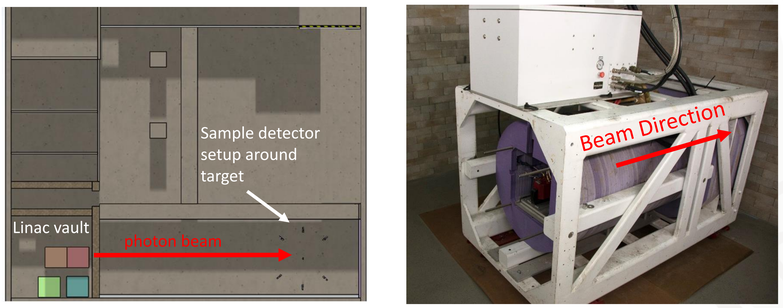

Fig. 1: Lab space, dimensions: 20 m × 15.7 m (Left) and linac in concrete vault (Right)

References:

1. C.A. Meert et al, "Neural Network-Based Algorithm for Fast Neutron Detection in a Pulsed High-Photon Field," INMM Annual Meeting, Palm Desert, CA, USA, July 14-18, 2019.

Technical Approach

- **Summary:** Interrogate depleted uranium (DU), detect neutron signatures with several techniques
- **^{3}He and stilbene analysis:** charge integration
- **^{4}He analysis:** time-over-threshold method
- **Neutron activation analysis:** count decays of activation products post-interrogation with HPGe

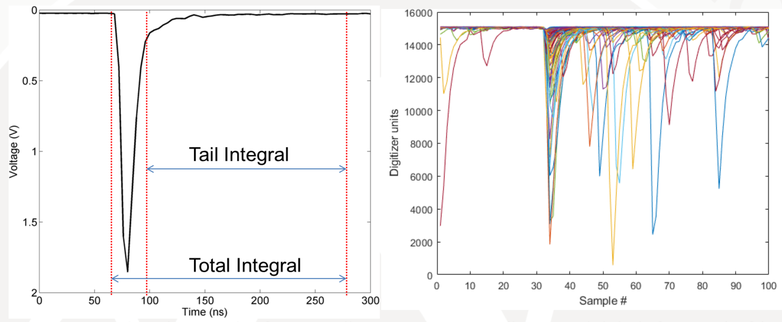

Fig. 2: Example voltage pulse from a stilbene organic scintillator, with labels for PSD (Left). Example pile-up pulses in stilbene during DU interrogation (Right).

Results

- **^{3}He:** >>2σ increase in neutrons, but detector is experiencing pile-up every linac pulse (≈45 Hz).
- **^{4}He:** >1σ increase in fast neutrons, >2σ in thermal neutrons. Confidence could be improved by implementing waveform analysis.
- **103 cm^3 Stilbene:** Desirable detection efficiency, but pile-up cleaning removes many potential neutron signals[1].
- **0.216 cm^3 Stilbene:** Reduced detection efficiency, but lower pile-up chance. PSD parameter optimization required.
- **Neutron activation:** Strong activation observed ***only*** during DU interrogation (*See poster #23 by Andrew Panter).*

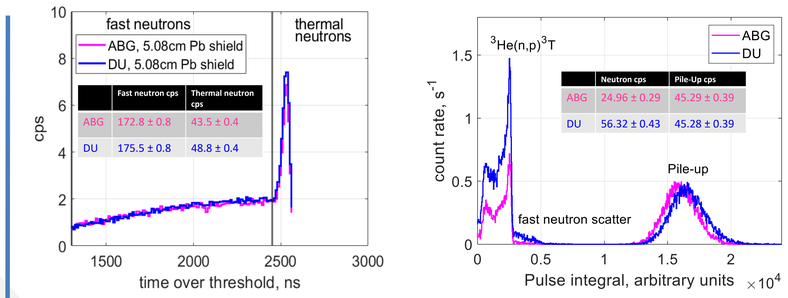

Fig. 3: Recorded spectra during photon interrogation with and without DU, for ^{4}He (Left) and ^{3}He (Right)

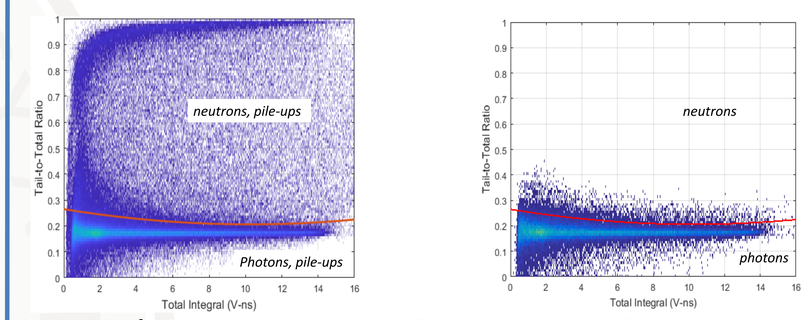

Fig. 4: 103 cm^3 stilbene detector results during DU active interrogation. Before (Left) and after (Right) pile-up cleaning

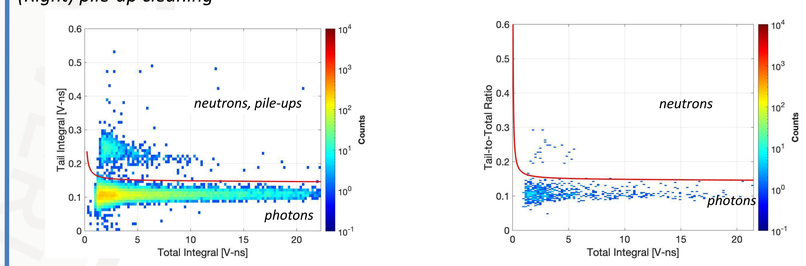

Fig 5: 0.216 cm^3 stilbene detector results during DU active interrogation. Before (Left) and after (Right) pile-up cleaning

Conclusions

- Several detection techniques have been tested; stilbene continues to be the most effective detector for photon active interrogation
- Neutron activation analysis can supplement detection methods due to its high photon rejection capability
- **Next Steps:** Optimize stilbene PSD parameters, analyze stilbene data with machine learning-based algorithm *(see poster #19 by Tessa Maurer)*

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. This work is also funded in-part by the Domestic Nuclear Detection Office of the Department of Homeland Security through the Academic Research Initiative Award Reference number 2016-DN-077-ARI106.

National Nuclear Security Administration