Detection of Fast Neutrons during Photon Active Interrogation

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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 photofission neutrons in active interrogation scenarios.
- **Expected Impact:** This project will demonstrate the ability to use prompt photofission neutron signatures and organic scintillators to detect special nuclear material.

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.

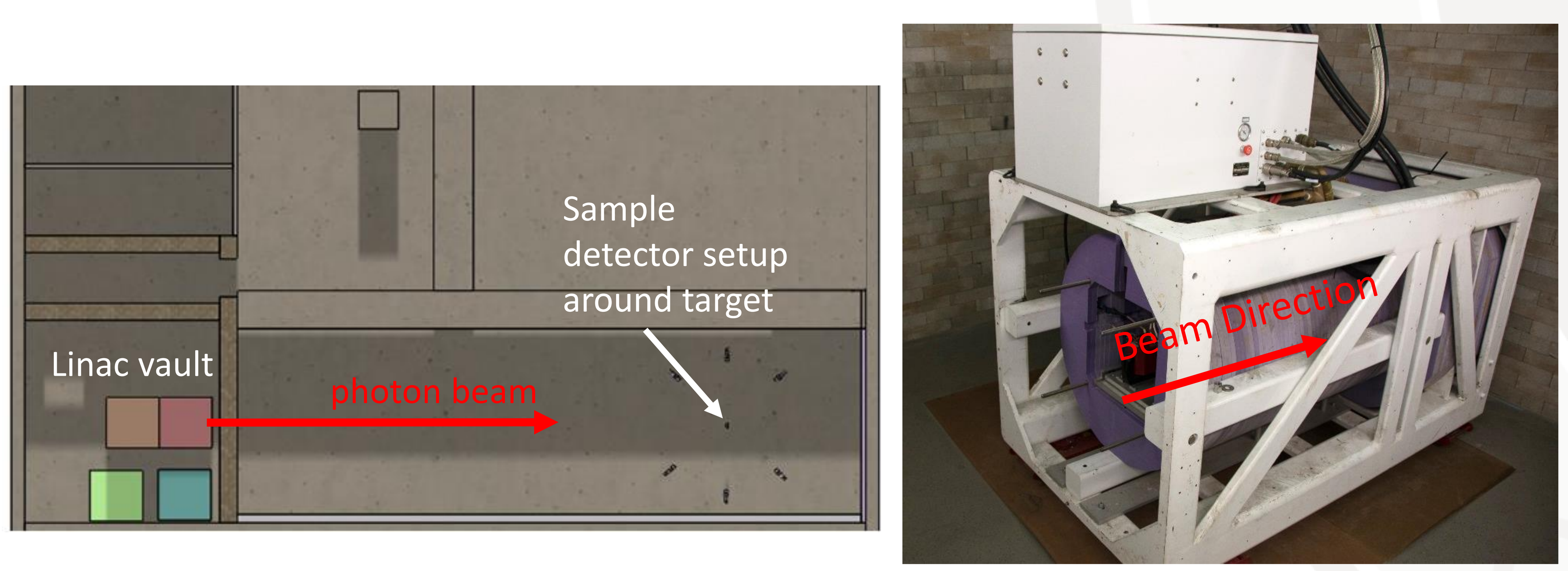

Fig. 1: *Lab space, dimensions: 20 m × 15.7 m (Left) and linac in concrete vault (Right)*

Reference:

C. A. Meert, A. T. MacDonald, A. J. Jinia, W. M. Steinberger, S. D. Clarke, S. A. Pozzi. "Photoneutron detection in active interrogation scenarios using small organic scintillators." Symposium on Radiation Measurement Applications, Virtual. May 19 – 28, 2021. Accepted to IEEE TNS, 03/0

Technical Approach

- **Experiments:** Interrogate depleted uranium (DU) with a 9-MeV linear accelerator (linac, Fig. 1), detect prompt photofission neutron signatures with stilbene organic scintillators.
- **Analysis:** Pulse shape discrimination (PSD) by charge integration (Fig. 2) with time-gating to measure only prompt neutrons emitted during a linac pulse.

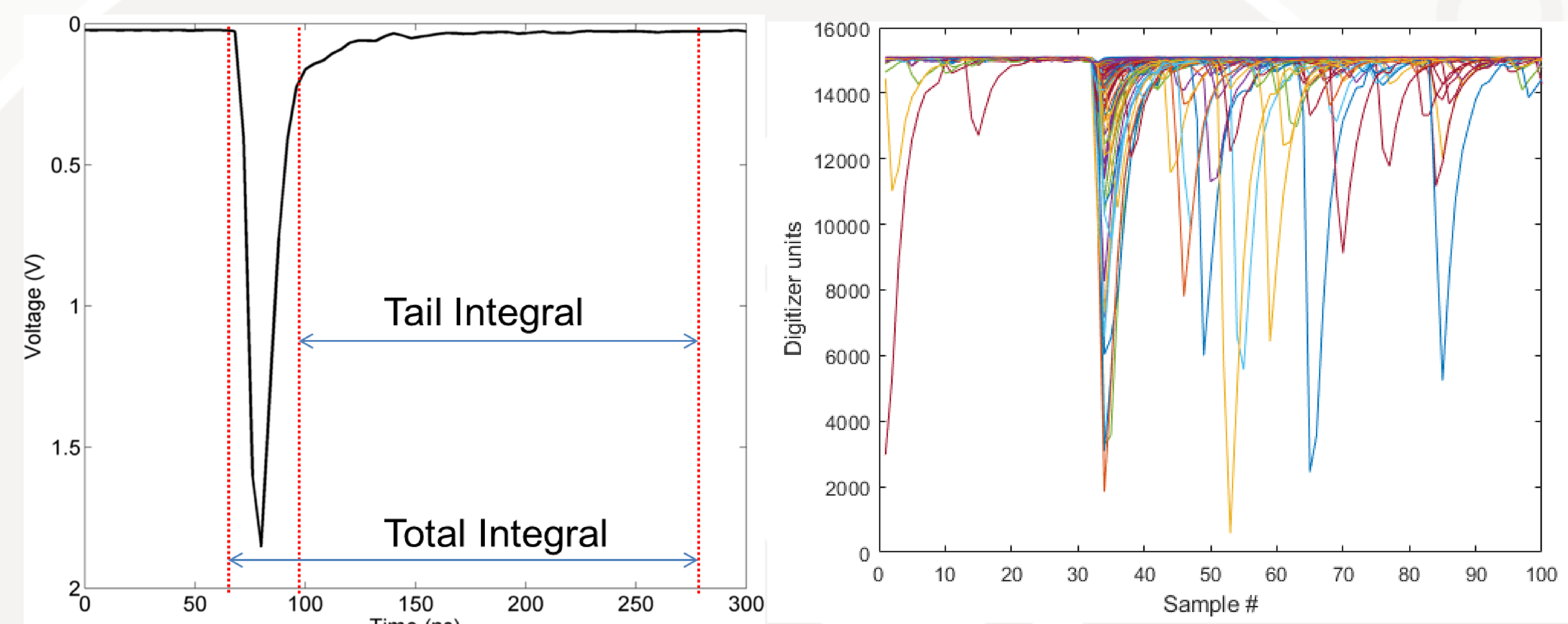

Fig. 2: *Example voltage pulse from a stilbene organic scintillator, with labels for PSD (Left). Example pile-up pulses in stilbene during DU interrogation (Right).*

Results

- **5.08-cm cylinder stilbene:** Detector overwhelmed, causing significant signal loss via pulse pile-up. No defined neutron band in the PSD plot (Fig. 3).
- **0.6-cm cube stilbene:** Pile-ups are successfully cleaned from the collected data. Sparse neutron band (Fig 4). **Net neutron count rate >2σ above active background within 5 minutes of measurement (Fig. 4-5).**

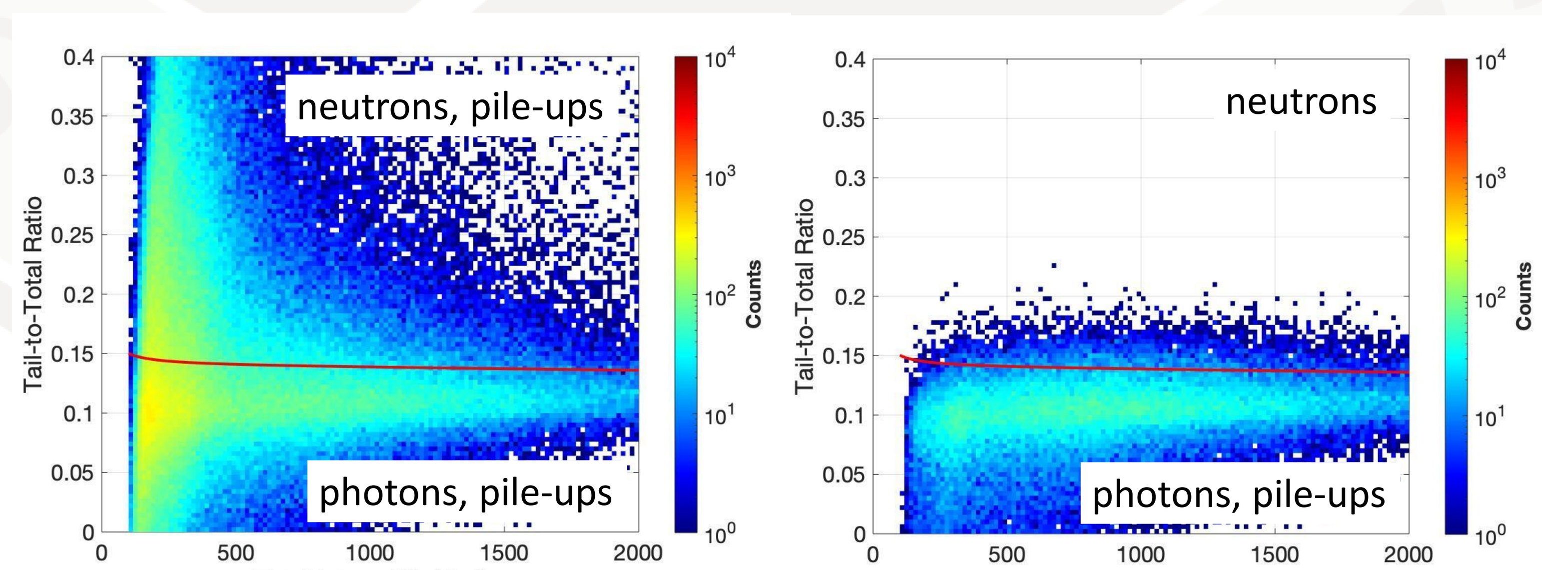

Fig. 3: *5.08-cm stilbene detector results during a 1-hr DU interrogation, with the detector 4 m from the target location. Before (Left) and after (Right) pile-up cleaning.*

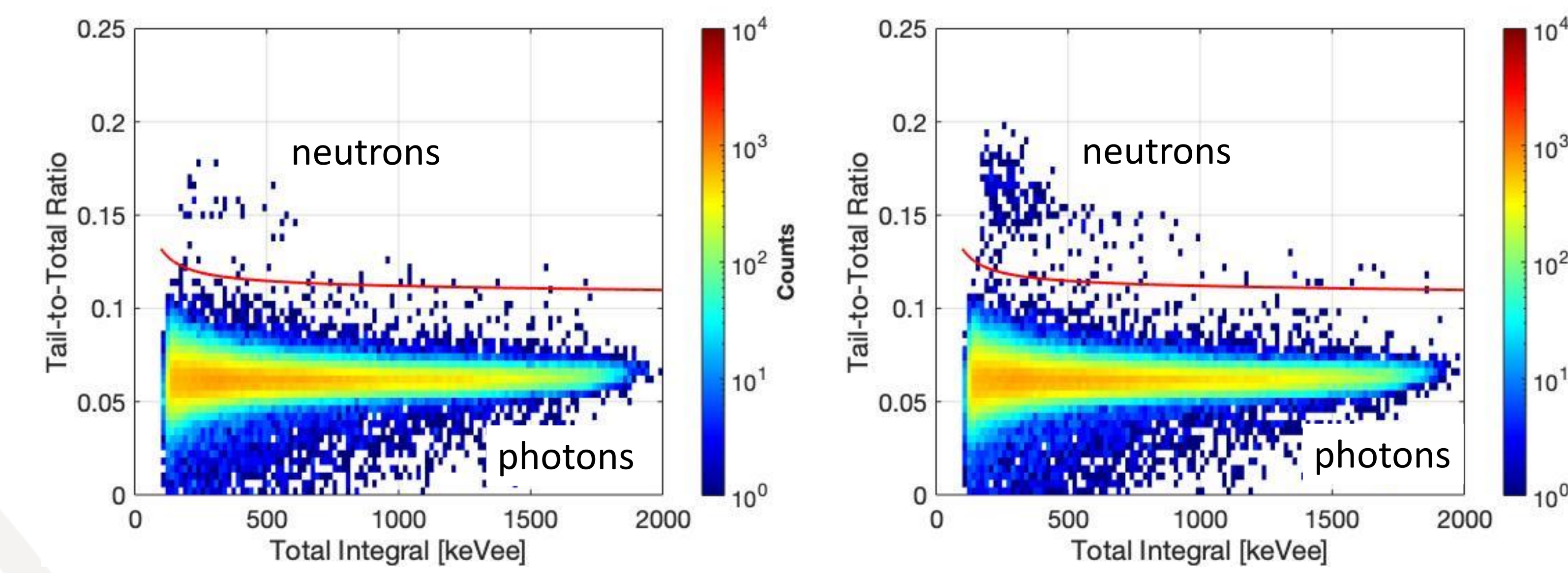

Fig. 4: *0.6-cm stilbene detector pair results, with detector 1 m from target location. Measurement without target (Left), and during a 1-hr DU interrogation (Right)*

- Required time to detect the DU could be reduced by increasing linac duty factor, or by adding more detectors to the array

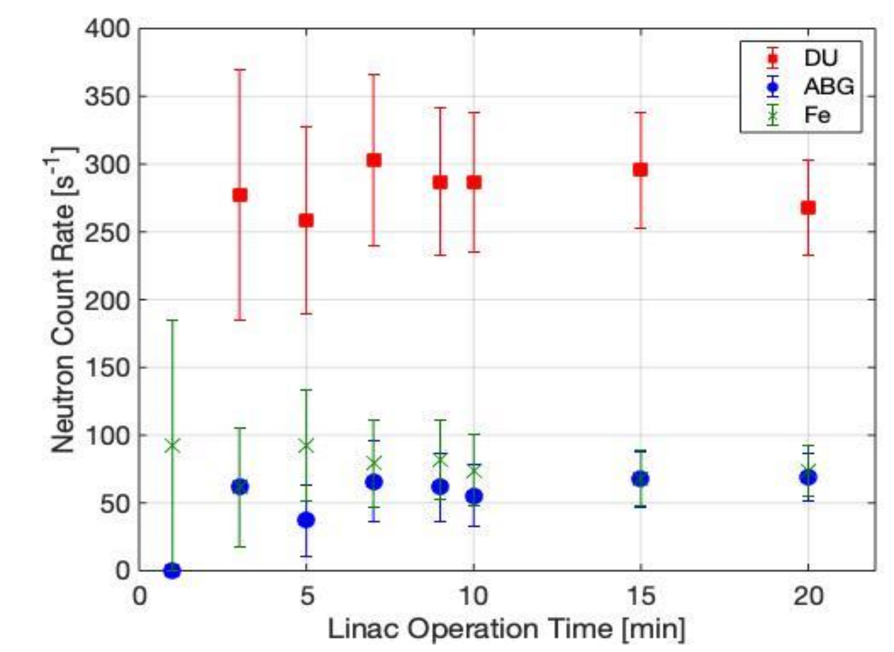

Fig. 5: *0.6-cm stilbene time-dependent neutron count rate comparison*

MTV Impact

- Networked with MTV-associated national lab researchers
- Workshop presentations solicited feedback from subject matter experts
- Organized collaborative experimental campaigns

Conclusions

- Reducing detector size reduces pile-up rate, significantly improving fast neutron detection capability during active interrogation.
- Arrays of small-volume detectors can detect prompt photofission neutrons in the active interrogation environment.
- **Next Steps:** Analyze stilbene data with machine learning-based algorithm. Investigate silicon photomultiplier arrays use.

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