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
- An artificial-neural-network-based pulse-shape-discrimination (PSD) algorithm will be used to decompose and re-classify piled-up pulses that result from the linac's large photon "flash".
- **Expected Impact**: this project will improve the deployability of active interrogation systems by using a commercial 9-MeV linear accelerator (linac) and readily manufactured PSD-capable stilbene organic scintillators

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

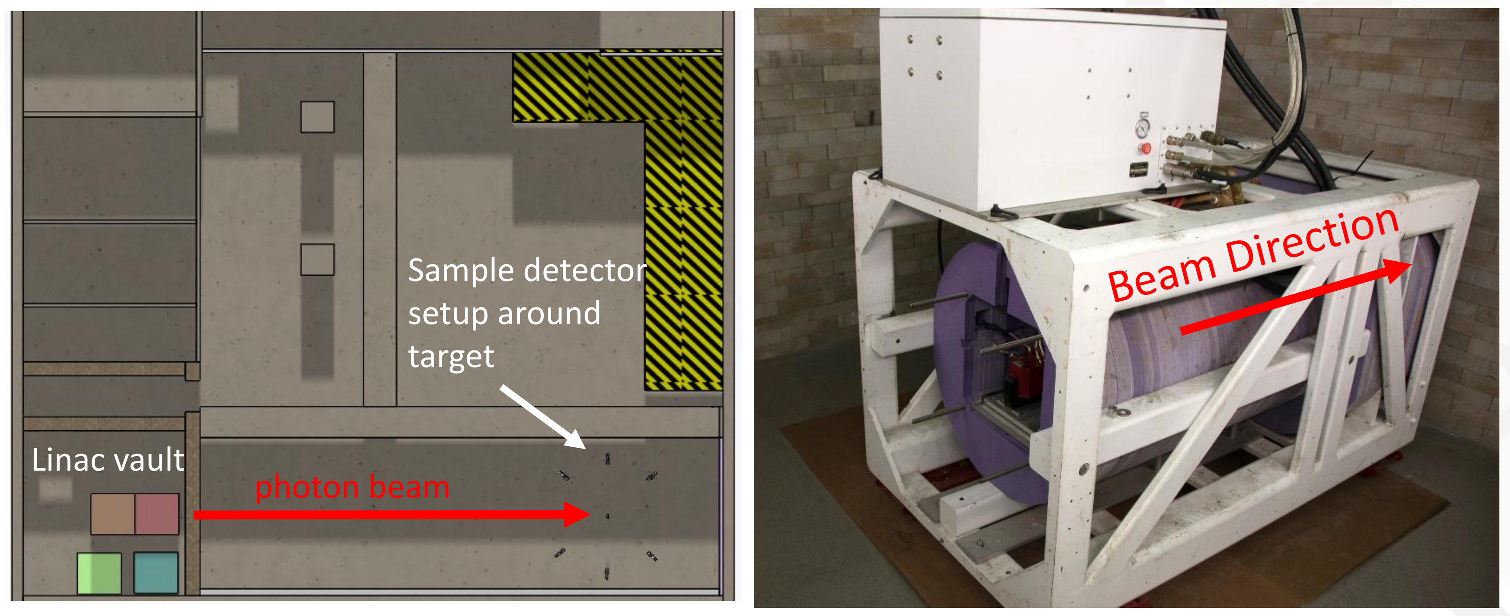

Fig. 1: Lab space, dimensions: 20 m × 15.7 m (Left) and linac in concrete vault (Right)

References:

1. C. Fu et al. (2018). "Artificial neural network algorithms for pulse shape discrimination and recovery of piled-up pulses in organic scintillators". Annals of Nuclear Energy, 120, 410-421.
2. 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

- The current ANN design can recover data from pulses separated by 60 ns or greater[1]
- We tested the ^{252}Cf-trained ANN on PuBe data
- We actively interrogated depleted uranium (DU) and analyzed data with both the ANN and traditional charge integration (CI) PSD[2]

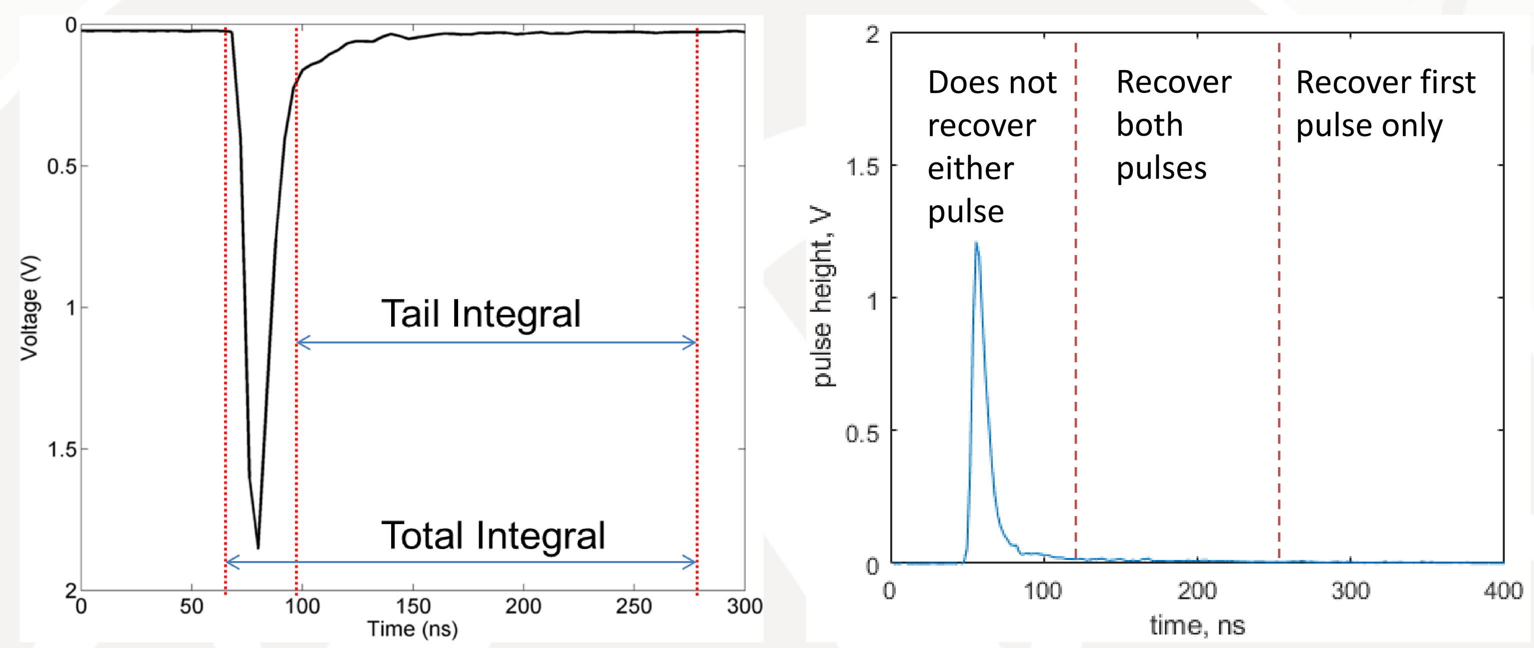

Fig. 2: Example voltage pulse from a stilbene organic scintillator, with labels for PSD (Left). The pulse recovery by the ANN is dependent on the separation time (Right).

Results

- ^{252}Cf-trained ANN accurately analyzed PuBe data
- ANN-attributed pulses appear in regions predicted by PSD
- ANN analysis recovered pulse information from pile-ups, increasing neutron counts compared to CI

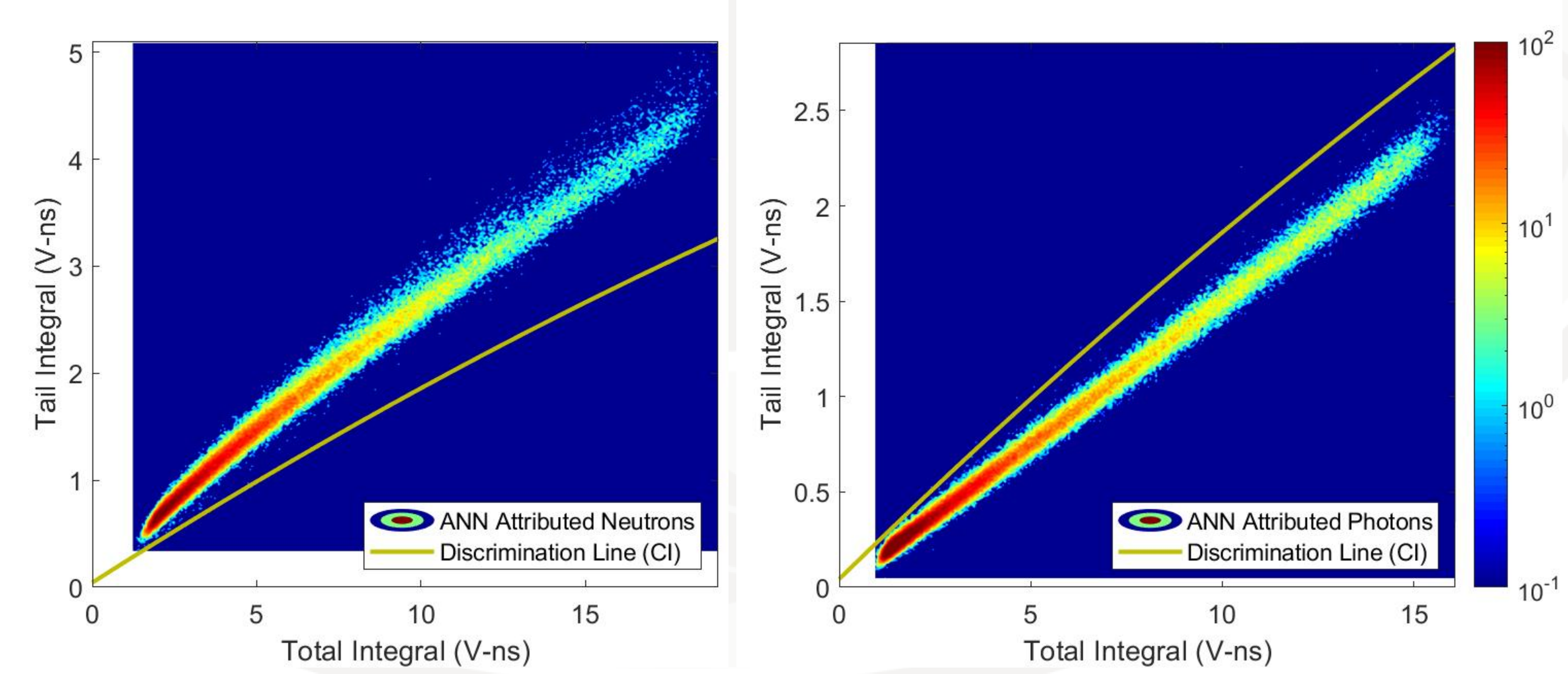

Fig. 3: ANN-attributed neutrons (Left). ANN-attributed photons (Right). The yellow line is the discrimination line used in CI PSD. The ANN successfully discriminated this PuBe data even though it was trained with ^{252}Cf only.

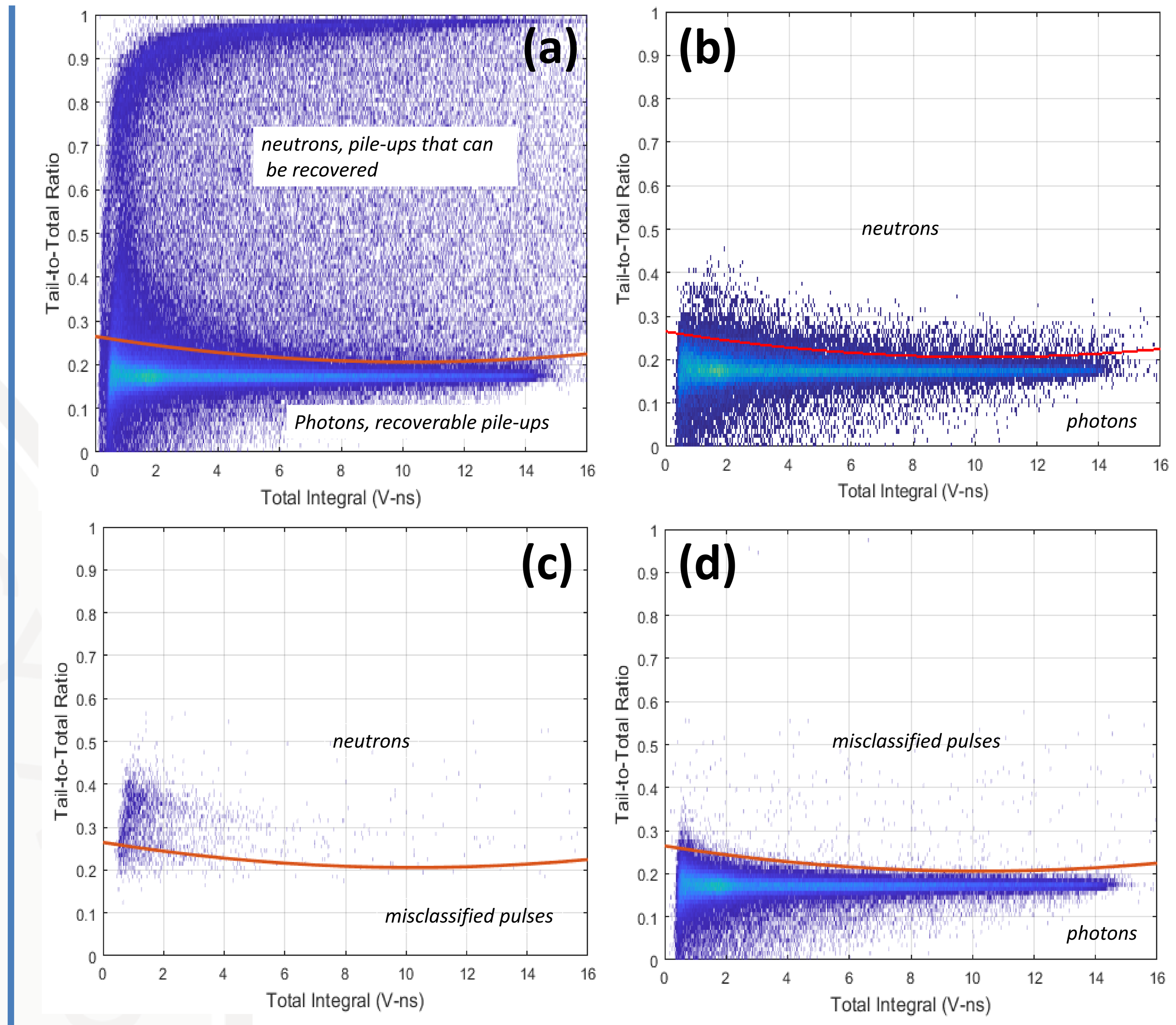

Fig. 4: Results for a 2" stilbene detectors during DU active interrogation. Comparing recoverable ANN data (a) to classifiable CI data(b) illustrates the potential advantage of ANN compared to traditional CI. ANN-attributed neutrons (c) and ANN-attributed photons (d) appear in the region predicted by CI PSD. The red lines are the discrimination line used in CI PSD.

Conclusions

- PuBe analysis demonstrates the robustness of the ANN to analyze radiation sources beyond it's training data
- Active interrogation results demonstrate the potential advantages of ANN-based PSD, and pulse recovery increased our neutron detection rates in comparison to traditional analysis methods
- **Next Steps**: Improved simulation models to provide ground-truth neutron detection rates, benchmark experiments with ^{3}He and inorganic scintillators

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