Fast Neutron Detection in a High-Photon field using Organic Scintillators

C. A. Meert[1], C. A. Miller[1], S. D. Clarke[1], S. A. Pozzi[1]

[1] Department of Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor, MI

PI: S.A. Pozzi, pozzisa@umich.edu

Consortium for Verification Technology (CVT)

Goals & Objectives

- Optimize shielding design for fast neutron detected count rate with organic scintillators in a high-gamma field.
    - Previous work demonstrated the use of artificial neural networks (ANNs) to recover information, but the addition of shielding will enable deployment in radiation environments with higher photon rates.
- Inform upcoming experiments to be conducted at the University of Michigan.

Mission Relevance

- This project aims to develop new pulse processing algorithms for radiation detection applications.
- The resulting methods could be deployed to improve the fidelity of measurements for a wide spectrum of safeguarding and verification applications by reducing information loss due to pile-up.

Introduction

- Information loss due to pulse pile-up interferes with radiation measurements, especially when using pulsed sources. Preserving neutron information is essential to safeguarding special nuclear material (SNM).
    - Fission products in spent fuel, and AmLi used for fresh fuel inspections can make high-photon environments resulting in pile-up.
- The pulse shape discrimination (PSD) ability, efficiency, and low cost of stilbene make it an ideal candidate for this application.
- Pile-up will erroneously increase neutron counts.
    - At high rates, pile-up will result in higher pulse tail integrals, imitating neutron pulse shapes. Using shielding to reduce overall photon counts will mitigate this effect.

Characterizing the Lab

- We simulate the Detection for Nuclear Nonproliferation (DNNG) linear accelerator (linac) facility, using MCNPX-PoliMi.
    - We use a Varian M9 linac as an intense photon source to induce photoneutron emissions in SNM or typical cargo material targets.
- High photon background is expected from environmental scattering and linac shielding materials in the lab space.
- Lab simulations demonstrate neutron signal greater than lab scattered and linac shielding material production.

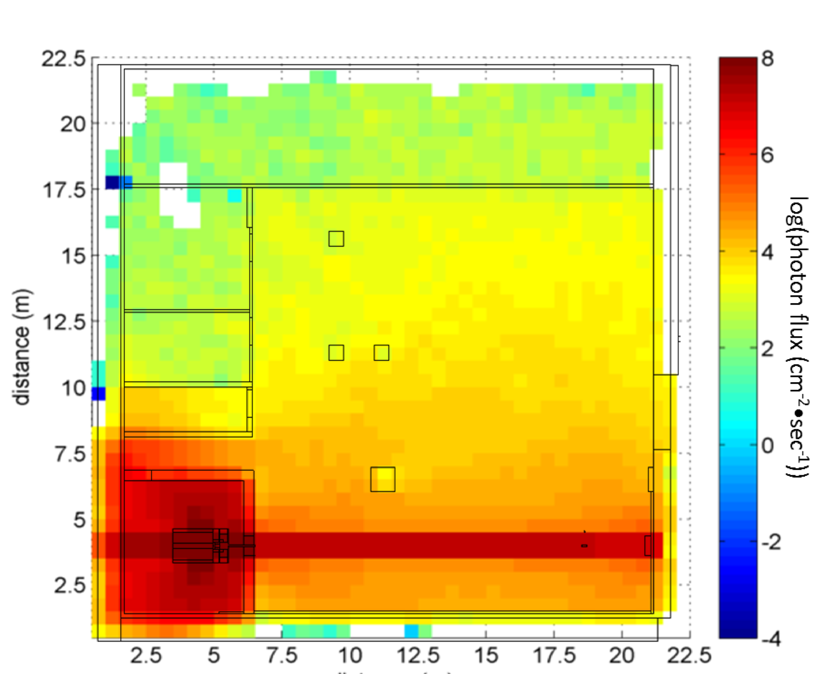


Fig. 1: Simulated photon flux in the lab space during linac operation at 25 Hz.

Fig. 2: DNNG linac inside the vault.

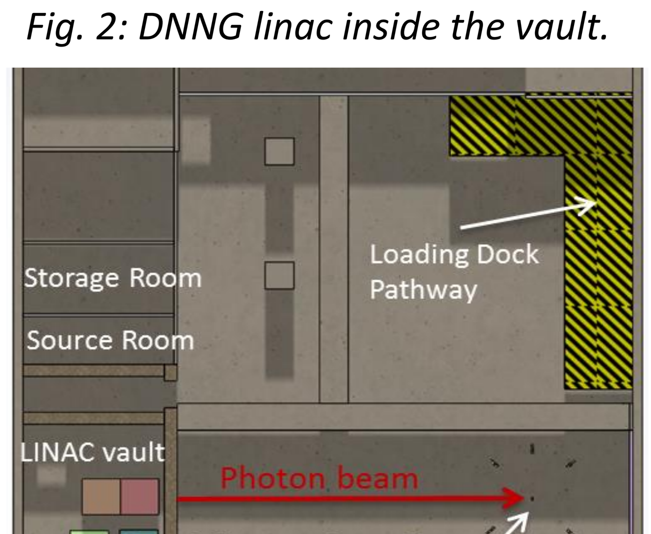


Fig. 3: DNNG linac lab space. Lab dimensions are 20 m × 15.7 m.

Results

- Shielding is optimized to minimize pile-up; shielding must attenuate photons with minimal attenuation of the neutrons incident on the detector.
- Optimal shielding was determined to be 2 inches of lead. Carbon steel was considered for shielding, but is less effective for photons attenuation with detrimental signal neutron attenuation.
- Lead irradiation measurements were conducted fall 2018 to demonstrate neutron production and to test traditional PSD.
- Detector shielding was increased to 4" of lead to reduce pulse rate such that neural net algorithm training sets could be developed.

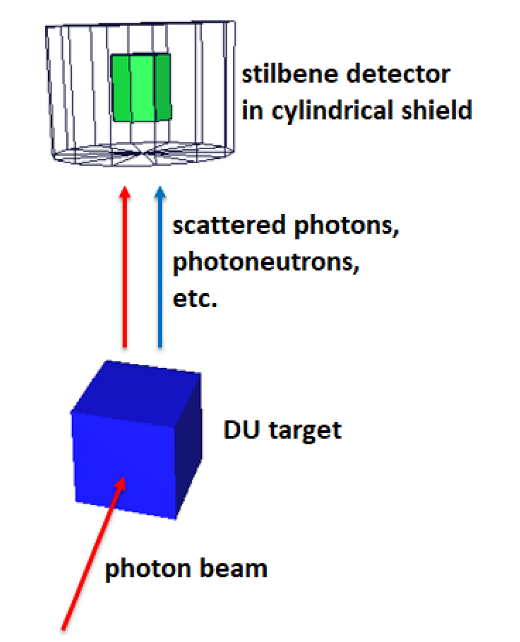


Fig. 4: Isolated detector model

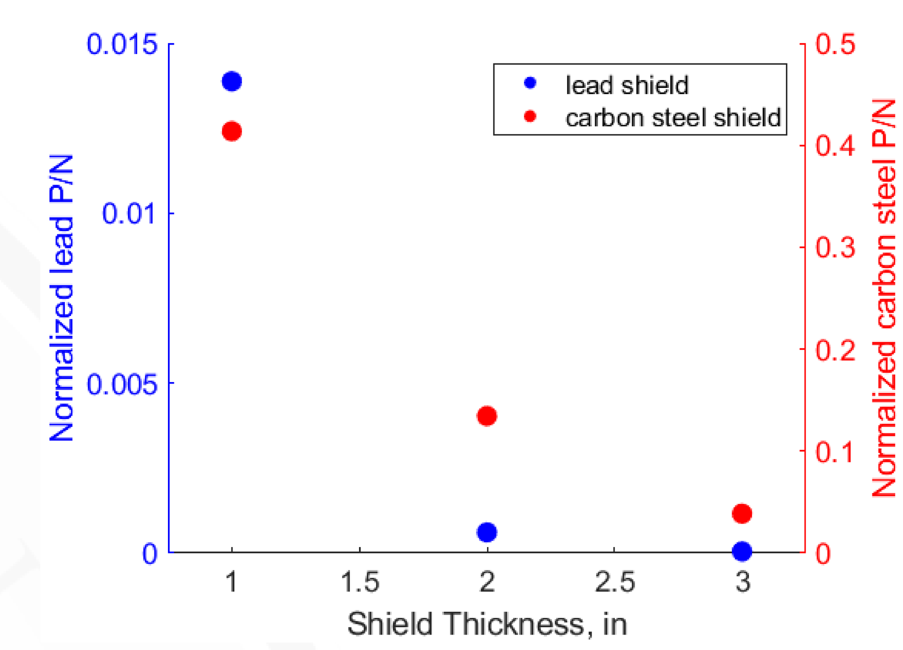
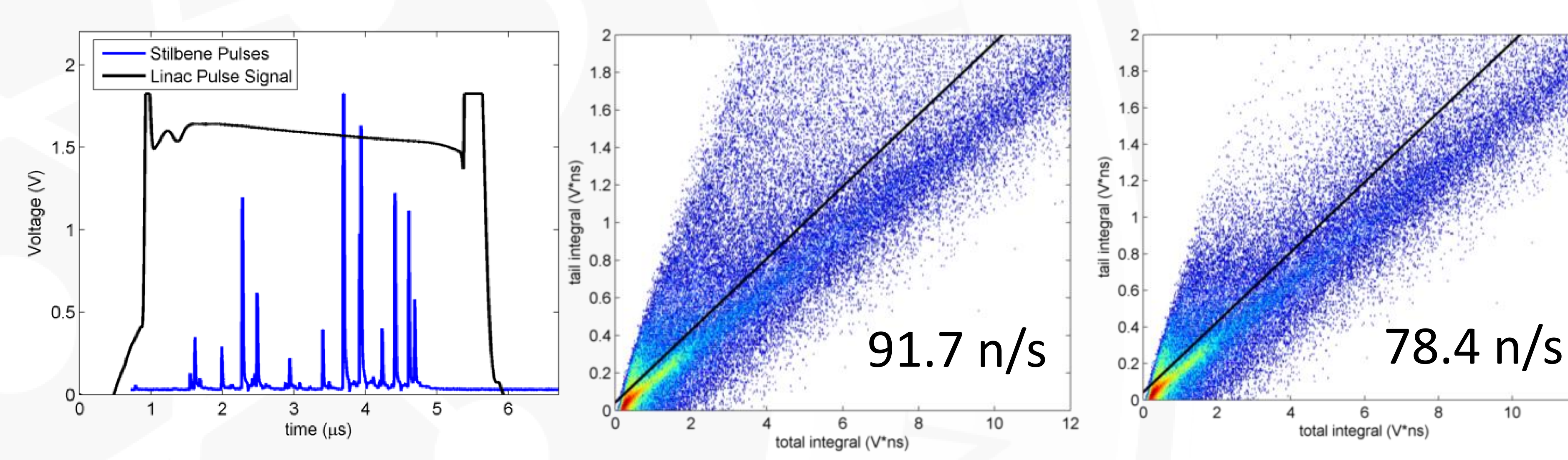


Fig. 5: Normalized photon/neutron results for detector shields using 4 inch cube depleted uranium target. P/N is normalized to the bare detector case.



(a) (b) (c)

Fig. 6: Sample pulse structure with stilbene pulse train and trace of linac magnetron current (a). 2000 cm3 lead target interrogation PSD tail-total integral plots measured with a 5.08 cm Ø x 5.08 cm stilbene detector before (b) and after (c) fractional pulse height double pulse cleaning

CVT Impact

- DNNG has developed new relationships with Niowave, Inc., a company in Lansing, MI specializing in superconducting accelerators.
- Cameron Miller interned at Lawrence Berkeley National Lab working on monoenergetic photon sources. Work contributed to a national lab technical report and a publication which was presented at the Symposium on Radiation Measurements and Applications.

Discussion & Conclusions

- Without detector shielding, measurements detect few neutrons because pile-up results in clipped pulses.
- Detector shielding was used to reduce count rates sufficiently such that an ANN-based algorithm could be used for processing.
    - ANN training sets will need to be created using collected data.
- Experiments will be used to develop pulse processing methods to recover neutron pulse information from pile-up events.
    - Results will inform the design of improved safeguards and active interrogation techniques.
    - The resulting methods would improve spectroscopic techniques for many radiation detection applications.

This work was funded in-part by the Consortium for Verification Technology under Department of Energy National Nuclear Security Administration award number DE-NA0002534, And in-part by the US Department of Homeland Security, Domestic Nuclear Detection Office, Academic Research Initiative under Grant No. 2016-DN-077-ARI106.

National Nuclear Security Administration