Toward the development of a next generation fast neutron portal monitor

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The non-proliferation of fissile materials is an important goal for global security. Current generation neutron portal monitors mainly utilize ^{3}He detector counters to detect thermal neutrons. A shortage of ^{3}He has made this technique expensive. Also, the neutron thermalization prevents the use of thermal neutron sources, that can otherwise be employed for active interrogation that is especially useful for detection of ^{235}U. Additionally, all of the directionality information from the neutrons is lost in the thermalization process. Taking inspiration from the Gamma-Ray Burst Monitor [1], we are developing a fast neutron detector that will surpass these limitations. By utilizing a large array of small (2.5cmx2.5cmx2.5cm) p-terphenyl scintillators we can distinguish ambient background neutrons from source neutrons and we can also localize a fissile source. Detecting fast neutrons preserves directional information while also minimizing the sensitivity limitations from the ambient neutron background. The development of this detector is a collaborative effort between the Cyclotron Institute, the department of mathematics, the department of statistics and Washington University. The focus of this report is Monte Carlo simulations of the proposed detector configuration for security applications.

The double neutron scattering technique described in the previous report, [2], was found to be inefficient because of the low frequency of events above a reasonable detector threshold. The new concept was introduced and the simulations have indicated that the downfalls of the previous design can be alleviated. By creating a large array of the p-terphenyl crystals (~2 mean free paths thick) we can continuously sample the ambient neutron background on one half of the detector while measuring neutrons coming from a fissile source on the other half. Each of the crystals are attached to EJ-282 wavelength shifters which have photomultiplier tubes attached at the end. We can readout each of the scintillators to get the neutron flux in each crystal which allows us to determine the direction of the source regardless of the location with respect to the detector. Utilizing multiple of these detectors will provide a powerful apparatus in the detection of fissile materials. Fig.1 is a visualization of the assembled detector array.

Simulations are being conducted in MCNP6 [3] with a Watt fission spectrum sampled ^{235}U+n source and a realistic ambient neutron background taken from data obtained near New Orleans. Simulations have provided encouraging results. Using a basic analysis technique of looking at the number of neutrons scattering per layer of scintillators as a function of the penetration depth, we can clearly identify presence of a localized neutron source. Fig. 2 shows an example of what the simulated

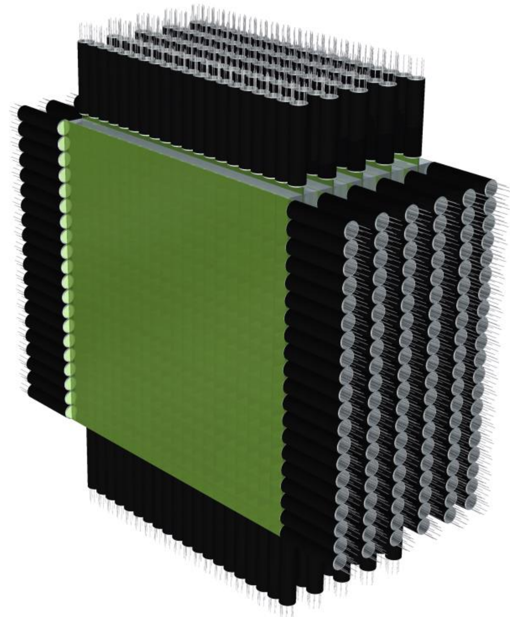

FIG. 1. CAD drawing of the assemble neutron detector. Ideally the source would be emitting towards the exposed face of the apparatus. The black cylinders are the photomultiplier tubes, the green sheets are the EJ-282 wavelength shifters, and the grey cubes are the para-terphenyl scintillators.

data looks like. From this figure, it is clear that for certain source strength it is easy to differentiate the source and the background neutrons.

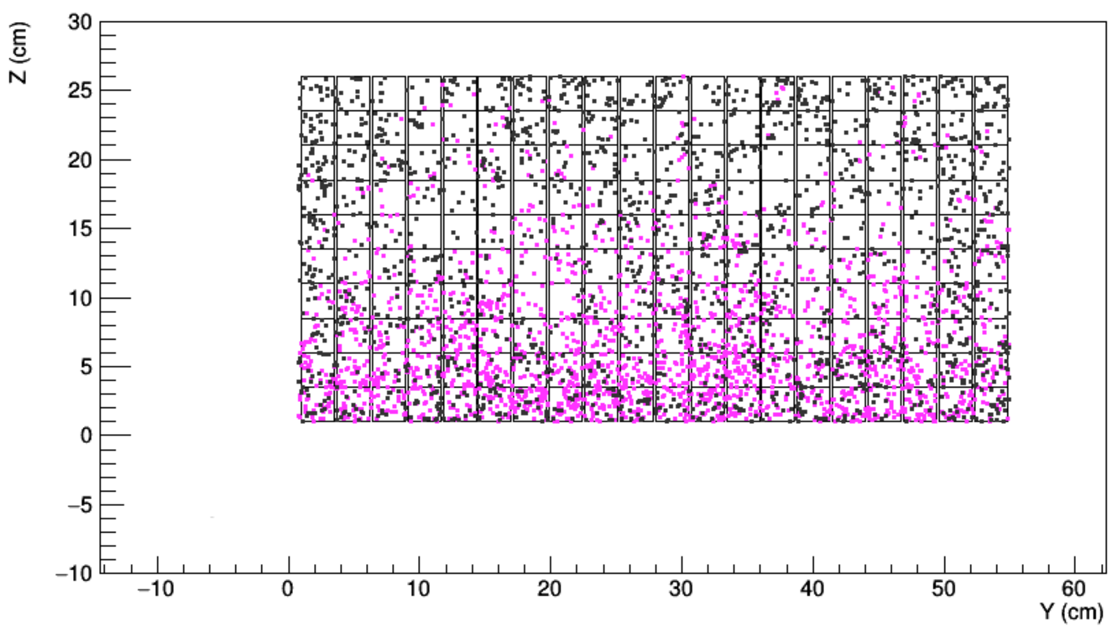

FIG. 2. Example of the MCNP6 simulation data. The square segments are para-terphenyl cubes projected onto a y-z plane. The black dots are neutron scattering events from the ambient neutron background and the magenta dots are neutron scattering events from the ^{235}U+n source. The source is located at negative one meter along the z-axis.

Current progress is being made to determine the minimum source strength that we can accurately identify. To do this we have two parallel methods in progress: one is a statistical model and the other is a deep learning technique. Both of these methods utilize the neutron flux in each crystal, allowing for source recognition regardless of source location.

[1] C. Meegan *et al.*, Astrophys.l J. **702**, 791 (2009).

[2] E. Aboud *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2017-2018), p. IV-79.

[3] T. Goorley *et al.*, Nucl. Tech. **180**, 298 (2012).