Toward the development of a next generation fast neutron portal monitor

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The non-proliferation of fissile materials is one of the most important fields in global security. Current generation neutron portal monitors mainly use a thermalization process that thermalizes the fast neutrons and counts them in a ^{3}He detector. A shortage of ^{3}He has made it increasingly rare and expensive. Special nuclear materials (SNMs), such as weapons-grade plutonium (WGPu) and high-enriched uranium (HEU), are dominated by non-spontaneous fissioning partners. This results in a spontaneous fission rate of 130 n/s/g for WGPu and a rate for HEU that is about four times lower than that of WGPu. As a comparison, ^{252}Cf, a common test source, has an emission rate of $2.1\text{x}10^3$ n/s/ng. A method of detecting these materials is to induce fission via a thermal neutron generator, which is referred to as active interrogation. Using an active interrogation technique, it is difficult or impossible to detect these SNMs using a thermal neutron detector. 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 (2x2x2 cm^3) para-terphenyl scintillators we can distinguish ambient background neutrons from source neutrons and we can also localize a fissile source. This method preserves directional information while also minimizing the sensitivity limitations from the ambient neutron background.

The uniformly most powerful Bayesian tests (UMPBT) [3] statistical model was used to determine the sensitivity limitations of our detector based off of Monte Carlo N Particle (MCNP6)

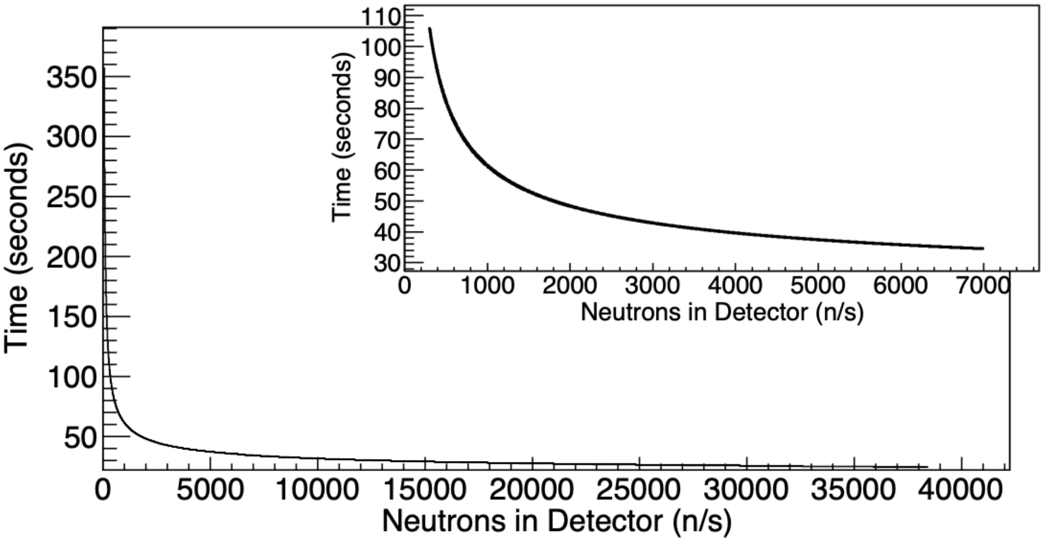

Fig. 1. Time vs source-neutron intensity entering the detector. The overlayed plot is a zoomed-in portion of the main plot to highlight the low-intensity region.

simulations that were conducted. The simulations were done using a ^{235}U+n Watt fission source and a measured ambient neutron background from New Orleans, Louisiana. A trend describing the time it takes for positive identification (with the confidence level of 1:1E6) with respect to the rate of neutrons being detected was formed with the model (Fig. 1).

Direct comparisons to current neutron portal monitors were done. The detector that was used as a comparison was the ^{3}He detector described in ref. [4]. An identical simulation was performed for both the ^{3}He detector and the proposed detector using passive interrogation of a ^{252}Cf source. For each of the simulations the efficiency of the detectors was calculated in terms of cps/ng. Table I shows the comparison of the efficiencies of the proposed detector and an assortment of current generation neutron portal monitors.

Table I. Comparison of neutron detection efficiency of the proposed detector and commercially-available detectors studied in Kouzes *et al.* [4]. The efficiencies labelled with a dagger were taken directly from ref. [4].

Detector Type	Efficiency (cps/ng)
Proposed Detector - Without UMPBT	12.0
^{3}He proportional detector (1 Tube)	3.0(2)†
BF$_3$ proportional detector (3 tubes)	3.7(2)†
Boron-lined proportional detector	3.0(2)†
Lithium-loaded glass fibers	1.7(6)†
Coated non-scintillating plastic fibers	2.0(1)†

A comparison of the proposed detector using the UMPBT model and the ^{3}He detector were done in terms of confidence levels. The confidence level was determined for various times of exposure to a ^{252}Cf source. For each of the times, a set of 50 MCNP6 simulations were conducted and the average number of detected neutrons from the source and background were calculated. Confidence levels for the ^{3}He detector were calculated based on the confidence intervals determined by the simulations. The simulation parameters were inputted into the UMPBT model to determine the confidence levels of the proposed detector. Fig. 2 shows the comparison of the confidence levels of both detectors for the times simulated.

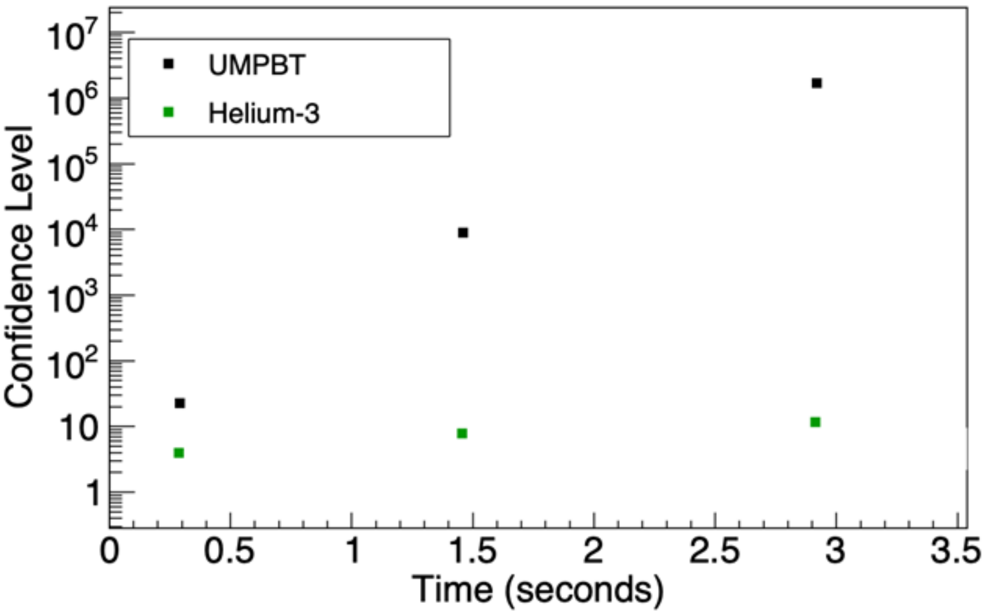

Fig. 2. Confidence levels in the form 1 in gamma, i.e. gamma = 10^6 corresponds to a confidence level of 1 in 10^6, which were calculated for a ^{3}He detector (green online) and the proposed detector using the UMPBT model (black). The confidence levels were derived from sets of 50 MCNP simulations with and without a source present. Comparison of the confidence levels shows a sensitivity comparison of the proposed detector to a standard ^{3}He detector.

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