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Summary Paper - MCNPX Simulation Study of STRAW Neutron Detectors

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BACKGROUND

A novel prototype fission meter is being designed at National Security Technologies, LLC, using a thin uniform coating (only 1 micron thick) of ^{10}B as a neutron converter inside a large array of thin (4 mm diameter) copper tubes. The copper tubes are only 2 mils thick, and each holds the stretched anode wire under tension and high voltage. The tubes are filled with proportional counter gas (a mixture of 90%/10% of Ar/CO_2). The tubes operate in proportional counter mode and attract mobile charged particles (α's) created in the nuclear interaction $^{10}B(n, {}^4He)^7Li$. However, a single tube has about 1/7th the sensitivity of a ^3He tube. Modeling is required to determine if enough such tubes could be placed in a neutron detection assembly of the current size to give comparable sensitivity to ^3He. Detectors lined with ^{10}B lie between ^3He and $^{10}BF_3$ proportional counters and fission chambers in terms of neutron detection efficiency and gamma ray insensitivity. The mean free path of thermal neutrons in ^{10}B is about 18 μm. It takes about 60 μm of ^{10}B layer to completely stop thermal neutrons, but the energetic α-particles generated in the reaction have a range of only 3.3 μm in ^{10}B environment—hence the thin layer of boron coating on the copper tube. The prototype design is shown in Figure 1. It consists of two panels of three staggered rows of 500-mm-long, 4-mm-diameter straws, with 20 in each row, embedded in 30-mm-thick high density polyethylene (HDPE).

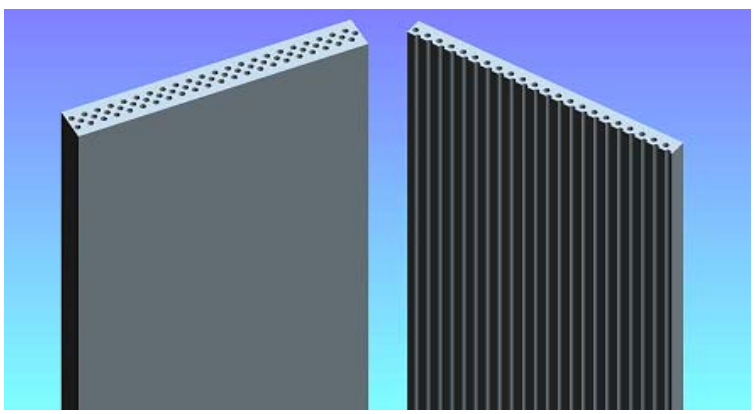

Figure 1. Sectional view of the two panels of 60 straws, each embedded in a 30-mm-thick HDPE matrix.

PROJECT OBJECTIVE AND DESCRIPTION

The project demonstrates a new application of thin neutron and gamma converter technique (1 micron thin ^{10}B coated copper tube). It exploits fast timing from multiple straw detectors to count multiplicity of both gamma and neutrons from fissioning materials. The objective is to find a near-term replacement of ^3He gas in neutron detection and measurement (with a very large neutron detection area). All the solid-state detectors developed thus far are small and inefficient. The thin size of the straws provides imaging

capability with high enough resolution for radiation emitting sources. The prototype will provide the first aerial neutron detection system with directional sensitivity.

MCNPX RESULTS

A large number of MCNPX calculations covering substantial design parameter space of straw multiplicity detectors have been performed and will be presented. The efficiency of thermal neutron detection of this proposed detector will be compared to that of the commercially available Fission Meter and Detective-EX (both manufactured by ORTEC) [Figure 2]. Pulse height spectra originating from the charged particles created in the nuclear reaction

$$^{10}B(n, {}^{4}He)\ {}^{7}Li^{*} + 2.310\ MeV\ (94\%) – \text{excited state}$$

$$^{10}B(n, {}^{4}He)\ {}^{7}Li + 2.792\ MeV\ (6\%) – \text{ground state}$$

will be examined, and the response to incident gamma rays will be demonstrated.

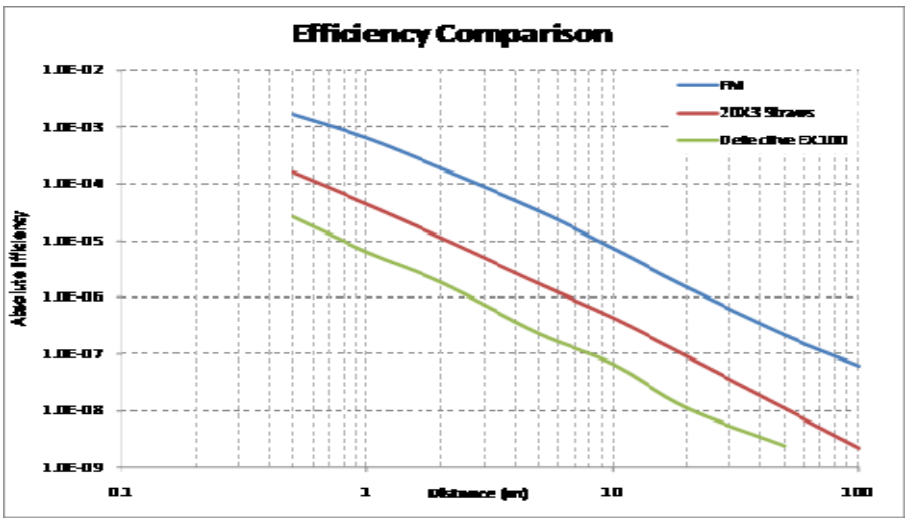

Figure 2. Absolute efficiency calculations for proposed straw detector, Fission Meter, and Detective-EX-100 (manufactured by ORTEC). Efficiency of a single panel of straws is shown.

The studies of semiconductor neutron sensors have demonstrated that ^{6}Li may be a better converter layer than ^{10}B; even though the thermal neutron absorption cross section in the case of ^{6}Li is about 1/4th of that in ^{10}B, the effective range of energetic charged particles are longer in the ^{6}Li medium (mostly ^{6}LiF) and therefore are more available to be drawn out to the anode wire in the proportional counters. Results of simulations of ^{6}LiF converter layers will be shown.

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