Toward development of fast neutron portal monitors

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Smuggling of fissile material into the United States is a major national security issue. Current portal neutron monitors primarily rely on thermal neutron detectors and require expensive materials such as ^{3}He gas. Besides significant cost of ^{3}He gas, another disadvantage is the loss of information about the direction for the measured neutrons. If fast neutrons are detected before thermalisation then momentum vector can be recovered and may be used for point-like source identification. Techniques have been developed to challenge these limitations in the past [1], but still require complex detection systems. Currently, we are developing a novel technique of fast neutron detection. It is a collaborative effort with the mathematics department. By developing an array of hydrocarbon scintillators (p-terphenyl, the brightest organic scintillator with excellent PSD properties) in an arrangement that optimizes the probability of a neutron scattering in two scintillators (double scattering events), we hope to achieve better sensitivity to elevated neutron flux from a point-like source. Primarily, this technique preserves information of the incoming neutron direction which allows for source location reconstruction using the techniques proposed by our colleagues [2,3].

As a prelude to the development of this detector apparatus, simulations of the setup were done with the Monte Carlo software MCNP [4]. Simulations were conducted with sampled neutron background libraries and real fission spectra for isotopes of interest. Results from the simulations were used as preliminary data sets for the development of the location reconstruction techniques provided by the mathematics group. Initial testing has provided positive results for the algorithm with successful location recovery for all data sets.

A key factor in the design of the detector apparatus involves the choice of light detector. An attractive option is silicon photomultiplier (SiPM), because of its small footprint, low bias requirement and flexible configuration. We have tested two brands of SiPMs: a Hamamatsu S-13360 and the other a C-Series SensL.

Initially, testing was done for a single Hamamatsu SiPM in order to observe neutron and gamma waveforms from p-terphenyl using a ^{252}Cf source. While waveforms were observed, they were significantly smaller than expected (10mV amplitude scale). For accurate waveform analysis, we would need amplitudes on the 100mV scale. Various attempts were made in order to determine the cause of the small signals and to amplify the signals. The amplification lead to distortion of the signal preventing reliable pulse-shape discrimination.

The C-Series SensL SiPM were tested next. Similar results were found initially, but after reviewing alternative methods in [5], it was found that biasing the SiPM on the cathode (instead of the anode) produced a signal in the 100mV-1V scale. Similar tests were done using the Hamamatsu SiPMs, but to no avail. Further testing of the SensL SiPMs were done to compare directly with [5] with the only major difference being the scintillator used.

Parallel to the testing of the light detectors, an analysis code was developed. An integral part of the analysis includes pulse shape discrimination (PSD). Utilizing the properties of the waveforms, we are able to distinguish between the neutron and γ-events. Two main techniques were used: a simple method of calculating the charge (integral) and the amplitudes of the waveforms and a method involving a tail charge and total waveform charge [5]. While both techniques are still under development, preliminary PSD was done for both Hamamastu and SensL SiPMs, an example is shown in Fig. 1. So far, PSD with SiPM cannot compete with PSD that we are achieving with photomultiplier tubes. Further tests and developments are under way.

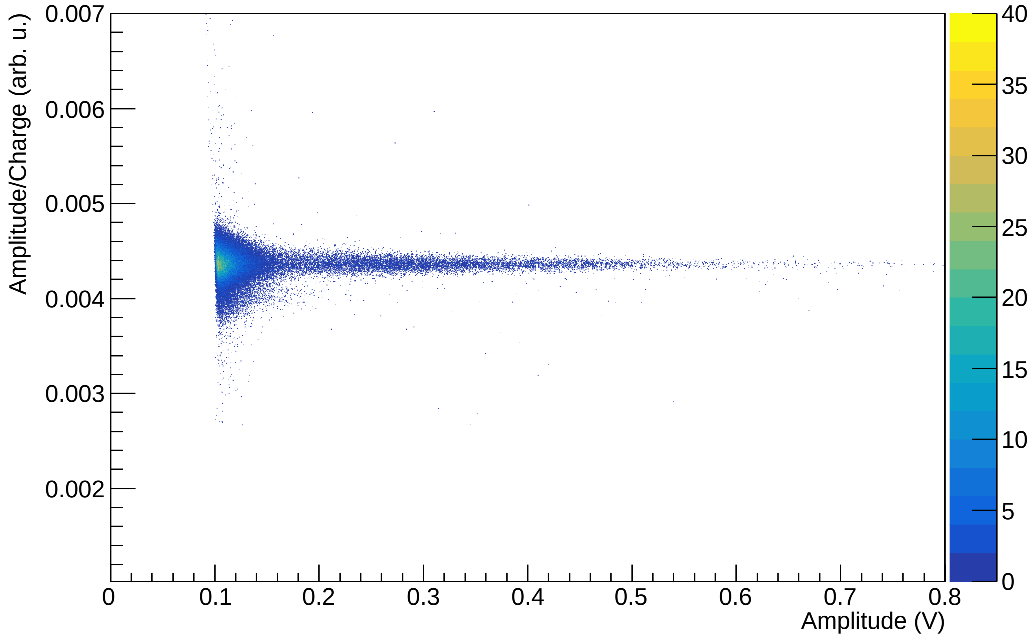

FIG. 1. Preliminary pulse shape discrimination using the amplitude over charge method and the C-Series SensL SiPM. A clear gamma-ray band is visible around 0.0045 (y-axis) and extends from 0.1 to past 0.8 V. Another band is visible around 0.004 (y-axis) that corresponds to neutron waveforms. Discrimination for this case is not ideal and new techniques (both physical and computational) are being looked at in order to enhance our PSD abilities.

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