Response of a new pad-based neutron detector developed for coded aperture thermal neutron imaging

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ABSTRACT: A new coded aperture thermal neutron imager system is being developed at Brookhaven National Laboratory. The camera utilizes a position-sensitive "He-filled ionization chamber, in which an anode plane is composed of an array of pads with independent acquisition channels. The charge is collected on each of the individual 5x5 mm² anode pads, (4x8 in total, corresponding to 24x24 cm² sensitive area) and read out by application specific integrated circuits (ASICs). The new design has several advantages for coded-aperture imaging applications in the field, compared to the previous generation of wire-grid based neutron detectors. Among these are its rugged design, lighter weight and use of non-flammable stopping gas. The pad-based readout occurs in parallel circuits, making it capable of high count rates, and also suitable to perform data analysis and imaging on an event-by-event basis. The spatial resolution of the detector can be better than the pixel size by using a charge sharing algorithm. In this paper we will report on the development and performance of the new pad-based neutron camera and describe a simulation software tool developed to model the response of the detector in order to optimize the pad geometry and achieve a sub-pixel resolution.

The completed pad detector and the new pad detector based coded aperture camera. The detector "plug and play", the high voltage power supply and control electronics are all integrated. The camera is powered by a 24 V power brick and controlled by a laptop computer via Gigabit Ethernet.

The detector pad board consisting of 5x5 mm pads could have more than one configuration. In the presently implemented offset configuration, every second pad-row is offset by 2.5 mm. The figure below displays three neutron events marked "A", "B" and "C". The longer arrow in each case illustrates the proton path lengths, whereas the shorter arrow is the triton path. Depending on the neutron hit location the interaction can generate charge on one ("A"), two ("B"), or even three ("C") pixels. The right panel on the figure displays the measured waveform components for the three scenarios.

We have developed a simulation package to model the detector response as a function of He and stopping gas pressure and pad board geometry. The proton and triton range as a function of gas pressure and composition is modeled by Monte Carlo (MCNPX) calculation.

In the simulation the randomly oriented proton-triton charge distribution is placed in the active area of the detector and propagated through the weighting field and generates pulses on the detector pads.

Calculated proton range in various gas mixtures. In 2.5 bar He and 0.5 bar CF₄ the range is ~ 4 mm. Using this mixture more than one pad will respond, so a weighted average location can be computed.

Calculated weighting potential for a quarter pad (left), and simulated pulse shape for a B type event, where the charge is shared between two pads.

Simulated response of neutrons randomly distributed along a vertical line at 0 pixel (left). The right panel displays the same response after the center of weight of each event is calculated.