Pulse Height Spectra Analysis of a Neutron Energy Tuning Assembly

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Abstract

Neutron spectrum shaping is a novel method that can be used to generate synthetic debris for nuclear forensics applications. An energy tuning assembly (ETA) was previously designed and built for the purpose of irradiating samples with a combination of a thermonuclear and a prompt fission neutron spectrum for production of synthetic debris for the technical nuclear forensics at NIF. Initial bench-marking of the ETA performance was performed at the Lawrence Berkeley National Laboratorys 88-Inch Cyclotron using 33 MeV deuteron breakup on tantalum as the neutron source. This research analyzes detector responses collected from three EJ-309 detectors used to characterize the ETA generated neutron field. Full waveform data from the source and ETA modified field were taken. A signal processing chain was developed to reduce the full waveform data into a neutron only pulse height spectrum to unfold the measured neutron energy spectrum.

1 Introduction

Previous research developed a novel approach to designing neutron energy tuning assemblies (ETAs) to create customizable neutron spectra using existing facilities to address capability gaps that exist for many applications [1]. One such application is the creation of synthetic debris for post-detonation technical nuclear forensics (TNF) missions, specifically the creation of realistic synthetic fission and activation products that provide the characteristic "fingerprint" used to aid in the attribution of weapon's origin [2, 3]. An ETA was designed to modify the National Ignition Facility (NIF) neutron source to have the spectral characteristics required to produce synthetic debris. This research aims to benchmark the performance of the ETA to facilitate future experiments on NIF.

2 Experimental Set-up

The 88-Inch Cyclotron at LBNL is a variable energy, high-current, multi-particle cyclotron capable of accelerating deuterons up to a maximum energy of 65 MeV with maximum currents on the order of 10 particle-μ A. For the ETA experiments, a beam was designed to have a neutron spectrum that is peaked near 14 MeV – NIF-relevant energies thereby probing the same interaction mechanisms – and has as limited a high energy component as possible ($\sim$ 0.5% of the total fluence is above 20 MeV). This was accomplished using a 2H+ beam accelerated to 33 MeV and directed at a tantalum breakup target. The deuteron beam was run at a current of $\sim$ 100 nA during the source beam irradiation and $\sim$ 2 μA during the ETA irradiation. The beam was directed along the Cave 0 beam line and optically aligned using a phosphor located in the Cave 01 beam box, as shown in Figure 1. A Faraday cup located inside the cyclotron vault was equipped with a 4 mm thick tantalum breakup target plunged along the Cave 0 beam line [4]. The tantalum target is backed by a 14.5 mm thick copper cooling assembly with a 38 mm radius cutout centered on the tantalum target. The resulting neutrons and photons entering the experimental area were collimated by $\sim$ 3 m of concrete and $\sim$ 1.5 m of sand bags encasing the beam pipe, producing a high contrast, open-air neutron beam in the Cave 02 experimental area.

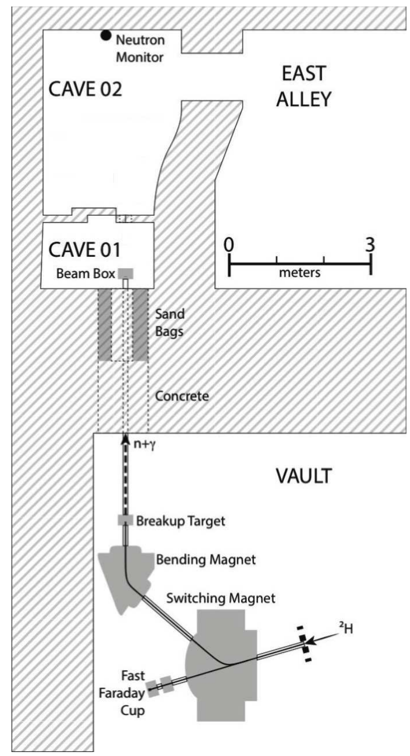

Fig. 1. Schematic representation of the 88-Inch Cyclotron vault and beam line to Cave 0. The Cave 0 experimental end station is comprised of two enclosures, Cave 01 and Cave 02, separated by a lead-lined door outfitted with a beam port.

A cross-sectional view of the ETA designed for TNF applications is shown in Figure 2. The outer diameter is 280 mm, the overall length is 240.2 mm, and the central sample cavity is 8.93 mm high with a diameter of 53.1 mm.

The ETA was fielded in Cave 02 and planed at beam line center (BLC) and 693.6 cm from the front face of the breakup target ($\sim$46.4 cm from the Cave 02 side of the Cave 01/Cave 02 wall shown in Figure 1). Three EJ-309 detectors were arranged around the ETA to measure the ETA modified neutron field. All were aligned in height with BLC and placed at angles of 0°, 45°, and 90° with respect the the incident beam.

3 Results

The ratio of neutrons to gammas is $\sim$1:1 for 33 MeV deuteron breakup on a Ta target thereby requiring the use of

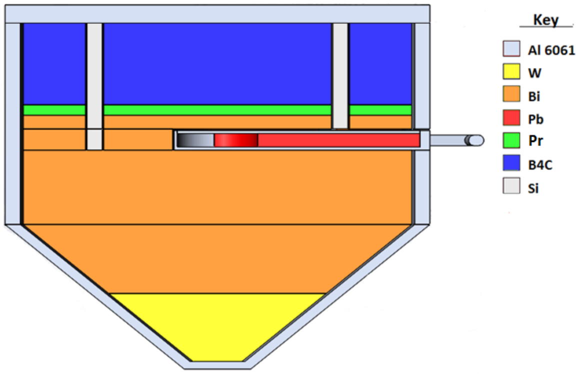

Fig. 2. Final ETA design [1].

pulse shape discrimination (PSD) to separate out the detector neutron response. To improve discrimination at low pulse height (PH) events near the software threshold, optimization of the PSD parameters for the tail-to-total, tail-to-peak, and 90-10 methods were performed for each detector channel and data set. An example optimized PSD plot obtained for the detector at 0° with the ETA using the tail-to-peak method is shown in Figure 3.

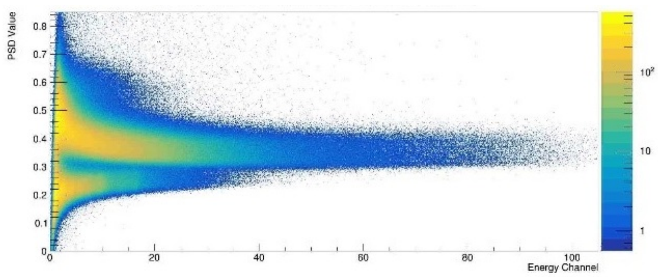

Fig. 3. Uncalibrated PSD Histogram for the detector at 0° with the ETA in place. The peak window used was 20 ns, and the tail window was 56 ns with a start off-set of 28 ns.

A slice of Figure 3 at the PH cutoff (channel 1305) is shown in Figure 4. Fitted cuts are developed to separate the neutron and gamma contributions resulting in the PHS shown in Figure 5 for the three detectors with the ETA in place.

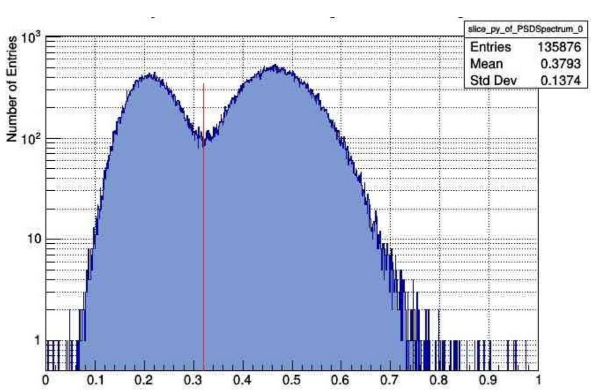

Fig. 4. PSD histogram near PH software threshold.

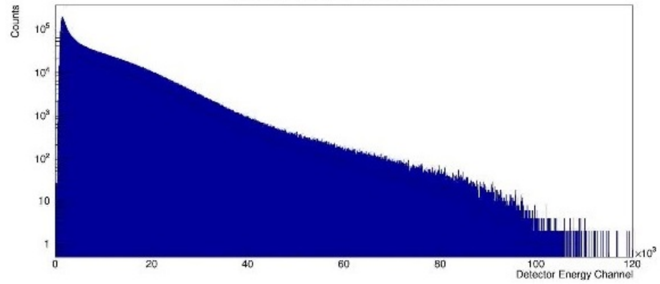

Fig. 5. PHS for the ETA measurements and all detectors.

4 Future Work

Analysis of this data is ongoing. It is anticipated by the conference that the PH unfolding will be complete and neutron energy spectra for the source beam and ETA modification at all detector positions will be presented. Additionally, comparisons with existing full-scale simulations to assess the ability to model ETA performance will be shown.

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