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Average neutron time-of-flight instrument response function inferred from single D-T neutron events within a plastic scintillator

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Abstract

The bulk ion-temperature and neutron reaction history are important characteristics of a fusion plasma. Extracting these from a measured neutron-time-of-flight (nTOF) signal, either by convolution or de-convolution methods, requires accurate knowledge of the instrument response function (IRF). This work describes a novel method for obtaining the IRF directly for single D-T neutron interactions by utilizing n-alpha coincidence. The t(d, α)n nuclear reaction was produced at Sandia National Laboratories' Ion Beam Laboratory using a 300-keV Cockcroft-Walton generator to accelerate a 2.5-μA beam of 175-keV D^+ ions into a stationary ErT_2 target. The average neutron IRF was calculated by taking a time-corrected average of individual neutron events within an EJ-228 plastic scintillator. The scintillator was independently coupled to two photo-multiplier tubes (PMT) operated in current-mode: a Hamamatsu 5946 mod-5 and a Photek PMT240. The experimental set-up and experimental results will be discussed.

The neutron diagnostic team at the Z-Facility is in the process of implementing new, dual-PMT nTOF detectors to constrain the physics relevant to the MagLIF concept [1,2].

- Burn average ion-temperature [3]
- Plasma B-field [4,5]
- Beryllium liner density
- Neutron yield [6]

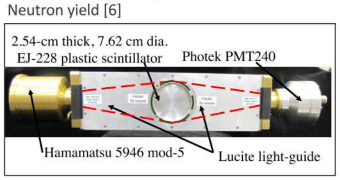

Fig. 1 Dual PMT nTOF detector

D-T neutrons produced at Sandia National Laboratories' Ion Beam Laboratory (IBL) are ideal for characterizing nuclear diagnostics and nTOF detectors[7].

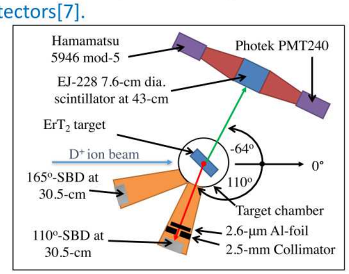

Fig.2 Schematic of the 300-keV Cockroft-Walton generator target area. Also shown are the two charged particle detectors at 110° and 165° and the nTOF detector under study at 64-degrees.

n-α particle coincidence establishes that a single neutron interaction has occurred within the scintillator.

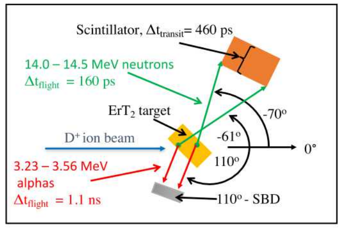

Fig. 3 Relevant kinematics for the t(d,α)n nuclear reaction as it is produced at the Ion Beam Laboratory

Particle coincidence is observed as a time-dependent Gaussian distribution.

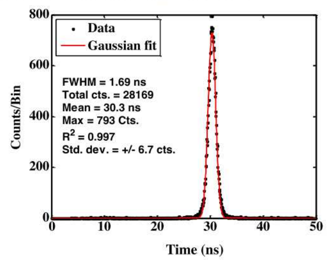

Fig. 4 The coincidence curve is the observed time difference between the detection of the neutron and alpha particle from the same reaction.

Waveforms produced from single neutron interactions within the scintillator are observed on a 3.5-GHz digitizer with 50-ps resolution.

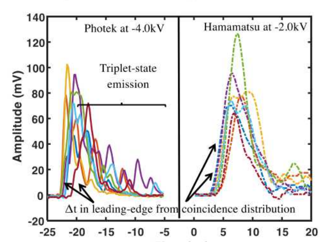

Fig. 5 Seven waveforms are shown for each the Photek (-4.0 kV) and Hamamatsu (-2.0 kV) PMTs to illustrate the range of data that was acquired. Data was shifted in time to show data simultaneously for both PMTs.

During post-processing each waveform is normalized to the leading-edge at 10% of the maximum amplitude.

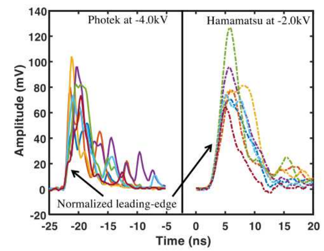

Fig. 6 Seven waveforms were normalized to the leading-edge at 10% of the maximum amplitude are shown for each the Photek (-4.0kV) and the Hamamatsu (-2.0kV).

The normalized data is averaged point-by-point and fit with an exponentially-modified Gaussian model.

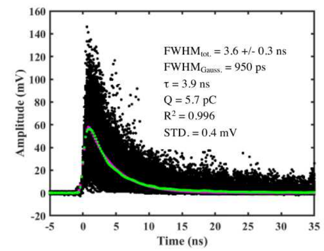

Fig. 7 1000 normalized waveforms shown with the average IRF and the best-fit model for the Photek-PMT240 at -4.0-kV

The average IRF was found for both the Hamamatsu 5946 mod-5 and the Photek PMT240 as a function of bias.

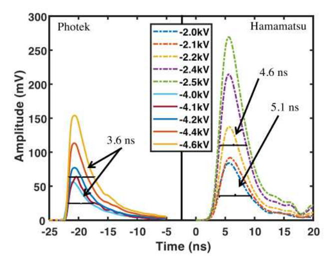

Fig. 8 Average IRFs shown for the Photek (solid lines) and Hamamatsu (dashed lines) PMTs as a function of bias

The measured IRF is convolved with simulated nTOF signals, with a variety of source conditions, and compared to the measured data.

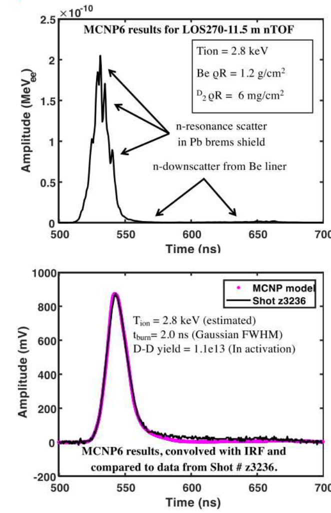

Fig. 9 An average IRF (Hamamatsu at -2.5 kV) was convolved with results from an MCNP6 model(above) of the LOS270-11.5 m detector and compared to data acquired on shot z3236.

Conclusions and Future Work

This work demonstrates a novel method for obtaining the IRF directly to single-event, D-T neutron interactions within a plastic scintillator. These IRFs can be convolved with MCNP6 results for a particular detector line-of-sight and used to constrain the temperature and beryllium liner areal density at the time of stagnation. Steps have been taken at the Ion Beam Laboratory to increase the sensitivity at which single events can be measured (amplitudes > 0.5-mV), which will allow us to calculate the average neutron sensitivity (pC/n).

References

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