Neutron Spectroscopy in High Gamma Background using Solid State Nuclear Track Detectors.

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INTRODUCTION

Measurement of neutrons in the high gamma background is difficult because of the extremely large number of photon events and the pulsed nature of the accelerator beam. The high instantaneous beam intensity hampers the use of detectors with active readout, because of pile–up effects in the electronics. It may also cause radiation damage to the detector. Hence, most of the active detectors and tracking type of detectors fails in measuring the neutron spectrum in high gamma background. As a solution to this, the passive neutron detectors are tested for measuring the neutron spectrum [1]. The CR-39 Solid State Nuclear Track Detector is one of the most popular track detectors among these. The CR-39 SSNTD an organic polymer . While a neutron collides on the hydrogen atom of the CR-39 material, the proton will recoil as a result of the elastic scattering. This recoiled proton makes scission of the long polymer chain of CR-39.

The characteristics of proton recoiled tracks are highly dependent upon the energy of recoiled protons, which is a function of incoming neutron energy and scattering angle. The diameter of the track depends on the stopping power at the depth. So the track diameter emerge as a function of the energy of proton stopping power and the range. This correlation is used in neutron spectroscopy based on CR-39. However, to visualize the track diameter, the scission radicals have to be removed from the bulk by chemical etching. The chemically etched tracks will be enhanced over the diameter, however it keeps the relationship between the energy of protons and the track diameter.

However, the major issue while using CR-39 based spectrum is basically the effect of unwanted tracks, under-etched tracks, and recoils produced by the collision of neutrons on other atoms. This contributes to a wrong estimation of the neutron spectrum. As a solution to the problem, a novel approach has been employed based on the morphological filter and particle discrimination gate for isolation of the true events. By this, the under and over etched tracks were excluded and selection of proton recoil events were achieved. The intrinsic efficiency of CR-39 has been attributed based on the elastic scattering cross-section. The experimentally measured spectrum has been reproduced with theoretical calculation and the low energy component has been accounted for.

MATERIALS AND METHODS

The neutron spectroscopic capability of the current method on CR39 SSNTD has been tested using the photoneutron generated by the Medical Linear accelerator. The bremsstrahlung photons were generated using a 10 MeV electron beam fired on the thick tungsten target. This photon beam is further fired on the thick lead + tungsten jaws producing the photoneutrons under the strong gamma background. The CR-39 SSNTD film was exposed to the Medical LINAC produced photoneutrons for an exposure time of 2 mins (corresponding to the monitor units of 1000MU). The exposed CR-39 films were etched under standard condition of 6N NaOH, at 60°C for 6hrs. This etched film image is captured using an optical microscope. Lower energy range of neutron spectra is limited to 0.7MeV due to the limitations in etching. The recoil tracks formed as the result of elastic scattering of neutrons were fitted with elliptical paraboloid, with the guidance of hough transform. The analysis has been done with the TRIAC-II code. This returns the major and minor axis of the elliptical tracks and also recoiled angle of a proton. Further, the brightness of each track, pointing to the depth of

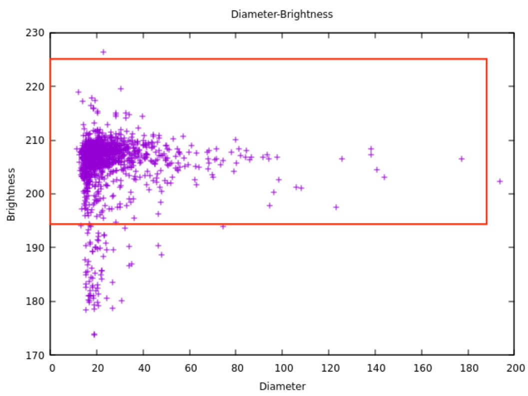

Figure 1: *The scatterplot showing correlating between track diameter and the brightness, along with the gate for isolating proton recoil events*

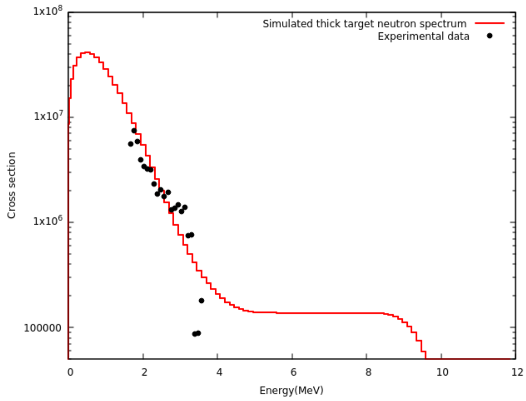

Figure 2: *Experimentally measured neutron spectrum with talys-1.96 supproted simulation of the thick target photoneutron spectrum from W-Pb target, induced by 10 MeV bremsstrahlung.*

the track is also estimated by the code. The major diameter and minor diameter have been averaged to obtain the equivalent circular diameter.

A 2D scatter plot of the track diameter- brightness has been made, and colonies corresponding to proton recoil tracks was identified and isolated from under etched tracks and carbon recoils by appropriate gating. The gated events were projected on the diameter axis and the proton energy corresponding to each event was identified by the track diameter-energy calibration. The calibration has been taken from the previous work by our group [1]. Each track event were converted to incident neutron energy with accounting for the recoil angle through two body kinematics. The events were binned into a histogram as a function of neutron energy.

The efficiency of the CR-39 is accounted for by considering the ^{1}H(n, el) cross sections corresponding to each energy bin, and the number of proton targets in the effective active thickness of the CR39. The histogram is then corrected with efficiency to obtain the final spectrum.^{1}H(n, el) cross sections were taken from ENDF/B-VIII.0 evaluated nuclear data

In order to validate the measured neutron spectrum, a theoretical calculation of the neutron spectrum has been prepared, by performing Talys-1.96 calculations. The model parametrization, including level densities and γ strengths of the talys code has been optimized to the experimental (γ,n) cross sections for ^{nat}W and ^{nat}Pb taken from EXFOR. The neutron spectrum for each energy point in the bremsstrahlung energy range is calculated based on the optimized parametrisation [2]. The neutron spectrum at each energy point is altered with the bremsstrahlung weights and the composite spectrum is derived. The derived composite spectrum is compared with the measured spectrum.

Results and Discussion

The typical track diameter-brightness plot obtained, is illustrated in figure 1. this shows a clear clustering corresponding to proton recoils, and the scattered events corresponding to the recoil of other particles. The clustering in the correlation plot holds the $\frac{MZ^2}{E}$ dependence and consistency of stopping power-range relations.

The neutron spectrum over the energy 0.7-10 MeV are recorded . The efficiency corrected neutron spectrum generated from the proton recoil events, through two body kinematics is presented in figure 2,along with Talys-1.96 (γ,n) calculate spectrum. This shows a good agreement between the experimental and theoretical spectra. The present method is successful in the measurement of neutron spectrum with reasonable sensitivity, achieved by removing the 'dark tracks'. This method can be utilized for the measurement of neutrons in the mixed high intensity radiation field.

References

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