Validation of ^{7}Li(p,n) Neutron Spectrum by Spectral Unfolding

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Introduction

The measurement and analysis of neutron induced reactions ideally demands a $\delta-$function neutron spectrum. Due to practical limitations in the production of $\delta-$ function neutrons, the quasi-monoenergetic neutrons are being utilised for the measurement of point cross sections. Due to the huge requirement of nuclear data for Gen-IV nuclear reactors, fusion reactors and ADS, the accelerator based tunable neutron sources are having a renewed interest. Among these, the ^{7}Li(p,n) accelerator based neutron source is the most utilised tunable neutron source at lower energies. However, the quasi-monoenergetic behaviour of ^{7}Li(p,n) will be lost for the higher neutron energies, due to resonant excitation and break of ^{7}Be residue. Due to unavailability of convenient neutron sources, the ^{7}Li(p,n) neutrons are also utilised at higher energies in 15-20 MeV range, for the measurement of nuclear reactions having positive slope. The analysis of neutron spectrum for neutron cross section measurement was practiced by suppressing the low energy neutron contribution by tailing corrections. The tailing correction is performed by method of spectral indexing proposed by D.L.Smith [1]. But the tailing correction factor is too large and exceeds the main value by several factors for proton energies greater than 6 MeV. Thus this method cannot be utilised for higher energies. However integral reaction rate can be used for integral benchmarking purposes.Thus an exact knowledge on neutron spectrum is required.

The spectra available for ^{7}Li(p,n) reaction at the energy range are limited due to the experimental challenges and complexity in the theory, as at higher energies the major contribution of the neutron is the three-body breakup channel. The first measurement existing for ^{7}Li(p,n) is by McNaughton et al.[2].

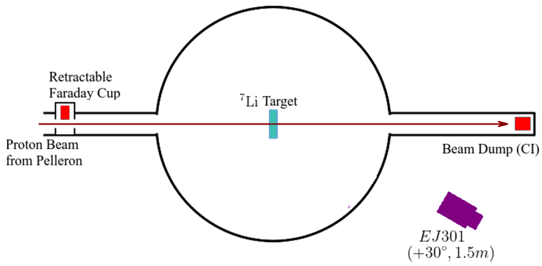

Figure 1: *Experimental Setup*

However the measurement is limited by the resolution of the spectrum, due to the weak timing from the cyclotron. Detailed analysis of three body breakup has been carried out by Midhun et al., by measuring the ^{7}Li(p,n)^{7}Be$\rightarrow^{3}He + \alpha$ breakup cross section experimentally. However, the final neutron spectrum reported by Midhun et al. is based on the theoretical estimations only. The current study is performed to validate the theoretically inferred spectrum produced by Midhun et al. Due to the unavailability of pulsed protons, the neutron spectrum has been produced through unfolding method.

Materials and Methods

The experiment is performed in BARC-TIFR Pelletron Linac facility by utilising 21 MeV, 5 pnA proton beam from the pelletron side along with the experiment described in Ref.[3]. 1.4mg/cm^{2} self supported Li target prepared by rolling is used. An EJ301 neutron scintillator is mounted at 30° from the beam axis, and at a distance of 1.5m from the target. The anode of the EJ301 is connected to

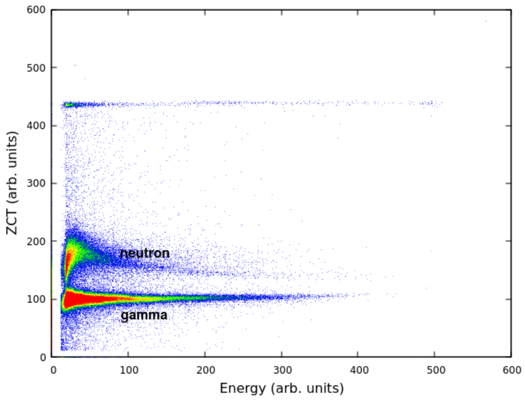

Figure 2: *Energy and ZCT correlation plot for EJ301 neutron detector*

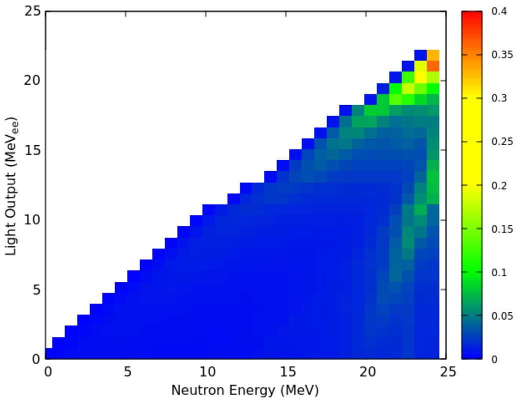

Figure 3: *Neutron Response Matrix of EJ301 neutron detector*

Mesytec MPD-4 module for n-γ discrimination. The beam dump is configured at 3m from the target and shielded with paraffin wax followed by lead bricks, for the isolation of neutron and gamma produced from beam dump. The beam current is monitored by a Faraday cup setup configuration at the beam dump. The experimental setup is shown in Fig 1.

A 2D spectrum between the Energy and Zero Cross over time (ZCT), a measurement of pulse shape discrimaniation(PSD), of the liquid scintillator is made and is shown in Fig 2. A 40 KeV$_{ee}$ CFD threshold has been chosen for the data acquisition. The Energy-ZCT spectrum has been properly gated for neutron group and projected for the neutron response spectrum.

The end point of neutron response spectrum is identified and a linear calibration for the energy has been applied. This spectrum is utilized for the unfolding process.The response spectrum achieved by

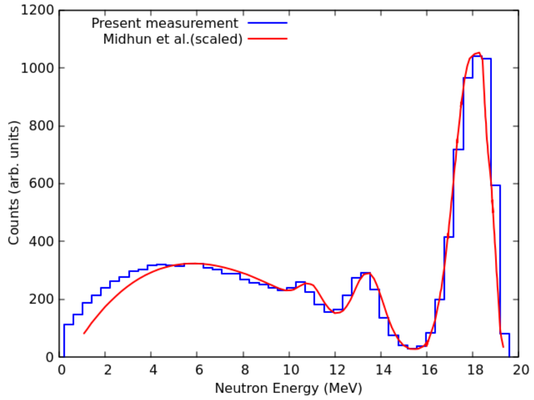

Figure 4: *The measured neutron spectrum compared with theoritical spectrum by Midhun et al.*

gating neutron group, response matrix of EJ301 are loaded onto Roounfold spectrum unfolding framework and unfolded spectrum of ^{7}Li(p,n) neutron source at 21 MeV proton energy is achieved and the final neutron spectrum achieved is compared with the spectrum reported by Midhun et al..The EJ301 response matrix, for unfolding, has been adapted from Sekimoto et al. [4], and conditioned upto 25 MeV neutron energy. The response matrix also accounts for the intrinsic efficiency of EJ301. This response matrix is shown in Fig 3.

Results and Discussion

The neutron spectrum from ^{7}Li(p,n) at 21 MeV, achieved through unfolding the neutron response spectrum is illustrated in Fig. 4, along with the theoritical spectrum reported by Midhun et al. In the present measurement, it is identified that n$_0$ and n$_1$ groups are merged together and formed as a single gaussian due to the higher thickness of the target. Further the neutron groups corresponding to resonant breakup of ^{7}Be from 7/2$^-$ and 5/2$^-$ states ,the direct groups are identified with acceptable resolution. The present measurement validates the n$_0$, n$_1$ and the three-body breakup contributions of ^{7}Li(p,n) neutron spectrum at 21 MeV.

References

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