Monte Carlo simulation of neutron yield and energy distribution from ^{7}Li(p,n) reaction

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Introduction

The ^{7}Li(p,n) reaction is widely used as a tool to produce intense neutron source in the energy range starting from keV region to fast neutrons of a few MeV region. The low energy neutrons find their application in areas like radio-biology, boron neutron capture therapy (BNCT), nuclear-astrophysics etc. The fast neutrons are used in areas such as fission studies on actinide targets for applications in fast reactors, transmutation systems, radiography and tomography for non destructive analysis of samples etc. Moreover, this reaction has the advantage of controlling the neutron energy spectrum depending on the bombarding energy of protons.

In literature, there exists computational tools such as SimLiT [1], PINO [2], EPEN [3] which calculates neutron spectrum for a given proton energy and target geometry. In ref [3], it has been pointed out that the results from calculation of SimLiT and EPEN disagrees with the calculation of PINO at energies beyond the threshold of ^{7}Li(p,n)^{7}Be*, where ^{7}Be* is produced in first excited state. In all the aforementioned calculation only the contribution from ^{7}Be ground state and ^{7}Be* (first excited state) is considered. Given the importance of neutron spectrum from this reaction, we have also developed a code to calculate neutron spectrum and angular distribution as a function of incident proton energy (E_P) and sample geometry. Here, we present a brief report on the code developed.

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Simulation

A CERN ROOT based code, henceforth termed as LiPN (acronym for Li(p,n) reaction), has been developed to calculate the yield and angular distribution of neutrons from ^{7}Li(p,n) reaction. In threshold region i.e. from 1881 keV to 1925 keV the center of mass(COM) differential cross section data was derived from the analytical form as described in Refs. [4, 5]. For proton energy beyond 1950 keV the COM differential cross section data was derived from tabulated values by Liskien et al. [6] for both the ground state ^{7}Be channel and first excited state ^{7}Be* channel. The COM differential cross section in the region of 1925 keV $\leqslant E_P <$ 1950 keV, was determined using cubic spline interpolation of tabulated data from ref. [6].

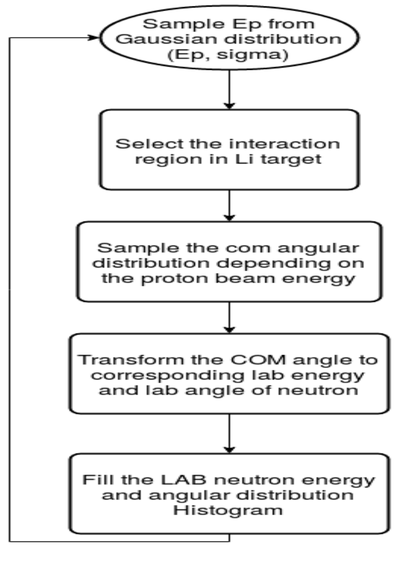

FIG. 1: A flowchart of the calculation algorithm.

For a given proton energy, the interaction region in the Li target was determined, and then the neutron angle in COM was determined based on sampling from COM differential cross section data. The angle information in COM along with sampled E_P was used to convert the neutron energy and angle in the Laboratory (LAB) frame. A basic flowchart for the algorithm used to calculate neutron spectrum is shown in Fig. 1.

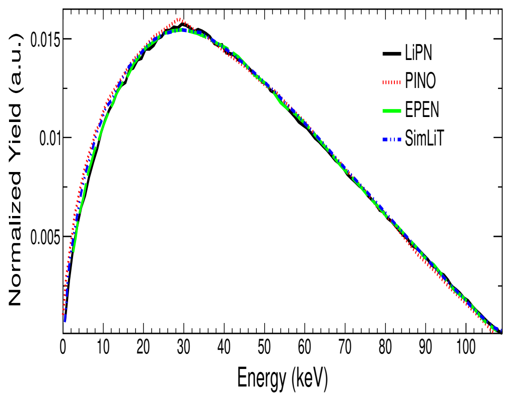

FIG. 2: Comparison of calculated neutron spectrum at E_P of 1912 keV.

Fig. 2 shows the comparison of calculated neutron spectrum in LAB frame, on a sample with maximum angular range of 63°, obtained from bombarding on 100μ thick ^{7}Li target with protons of energy E_P 1912 keV. It can be observed that all codes agrees quite reasonably in the threshold region of ^{7}Li(p,n) reaction. A similar comparison for proton energy E_P of 3500 keV is shown in fig. 3. Here the calculation is performed for a proton beam energy spread (sigma) of 20 keV and 38μ thick ^{7}Li target with neutron angular range of upto 26.8°. A clear departure of PINO calculation from EPEN and LiPN can be seen at this energy. Here it is mentioned that the calculation from SimLiT agrees quite reasonably with EPEN calculation as shown in ref. [3]. A similar disagreement was also reported in ref. [3] and it's origin was attributed to incompatible treatment of proton beam energy spread in PINO code. In fig. 3, we can observe a narrower satellite peak (low enery peak) in PINO calculation compared to other codes. Given the fact that the satellite peak is mainly due to ^{7}Li(p,n)^{7}Be* channel, a narrower peak could also be attributed to incorrect differential cross section data used during the sampling process for this channel.

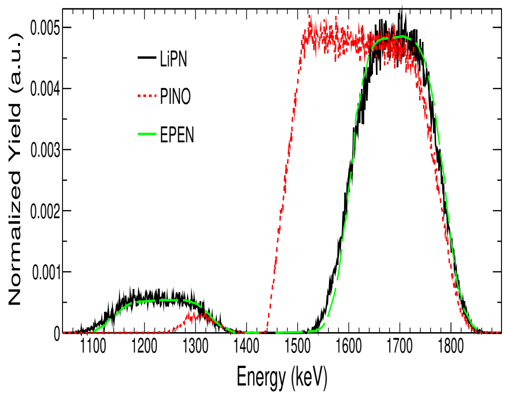

FIG. 3: Comparison of calculated neutron spectrum at E_P of 3500±20 keV.

The code will be extended further to simulate energy spectra and angular distribution of neutron from inverse kinematic i.e. p(^{7}Li, n) reaction.

References

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