Breakup contribution in the neutron yield of ^{7}Li(p,n) reaction

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There is a renewed interest in the monoenergetic neutron generating reactions such as (p, n) reaction with ^{7}Li and ^{9}Be targets [1]. ^{7}Li(p, n)^{7}Be is a charge exchange reaction which has been studied over several decades. Neutron groups corresponding to the ground (n_0) and first excited state (n_1) of ^{7}Be are well studied. Measured cross sections corresponding to n_0 and n_1 groups are available for incident proton energy (E_p) starting from the threshold (E_t=1.88 MeV) of this reaction to several tens of MeV [2].

^{7}Be produced in this reaction is a weakly bound nucleus having a breakup threshold of E_B = 1.59 MeV. For excitation energy above E_B it breaks into two fragments ^{4}He and ^{3}He. Therefore breakup process is also expected to contribute in the total neutron yield from ^{7}Li(p, n) reaction for $E_p \geq E_t + E_B$. Neutron groups n_2 and n_3 resulted in this reaction corresponding to $7/2^-$ (4.57 MeV) and $5/2^-$(6.73 MeV) resonance states of ^{7}Be and are occured through the charge exchange reaction followed by the breakup process [3]. Study of this breakup process proceeds through resonance states gives important information about the cluster structure of ^{7}Be. Apart from the breakup through resonance state there is also a possibility of breakup through continuum states which would have resulted in continum unlike the discrete neutron energy spectra in the former. No measured cross section data are available for the n_2, n_3 groups and that resulted from continuum states of ^{7}Be.

An experiment was performed using proton beams of energy 7 -12 MeV from K-130 Cyclotron to measure the breakup contribution in the total neutron yield. A natural Li target of thickness 6.72 mg/cm^2 was used. Seven liquid scintillator based neutron detectors were used to measure the neutron energy spectra using the time of flight (TOF) technique covering lab angles from 25° to 150°. Start time of the TOF was taken from the RF signal of the Cyclotron whereas the stop was taken from the individual neutron detectors. Pulse shape discrimination using zero cross over technique was used to discriminate neutrons from the γ-ray induced events.

Neutron energy spectra were determined from the measured TOF distributions which are shown in Fig. 1 for three E_p and three lab angles. Fig. 1 shows a decrease in double differential cross sections in centre of mass frame ($d^2\sigma/dEd\Omega_{C.M.}$) with the increase in E_p in the 7 to 12 MeV region which are in agreement with the earlier report [2]. The peak at the rightmost edge of the neutron spectra is due to the contributions of both n_0 and n_1 groups [^{7}Li(p,n$_0$+n$_1$)^{7}Be(g.s.+0.43 MeV)] which could not be resolved as the energy resolution of the TOF setup is much higher than the separation between two corresponding ^{7}Be states. The second energy peak obtained for E_p=9 and 12MeV are corresponds to the $7/2^-$ state of ^{7}Be.

Neutron energy spectra were fitted with a function consists of multiple Gaussians and an exponential function. Gaussians are taken to consider the ground, 1st (429 keV), 2nd (4.57

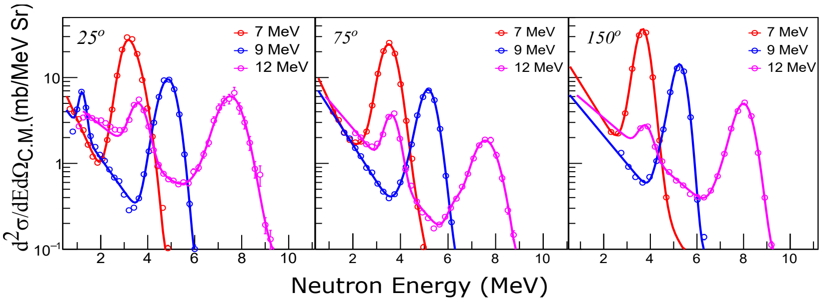

FIG. 1: Neutron energy spectra from ^{7}Li(p, n)^{7}Be reactions measured at different beam energies and lab angles are shown in symbols. Solid lines are the fits using a function consists of multiple Gaussians and an exponential functions.

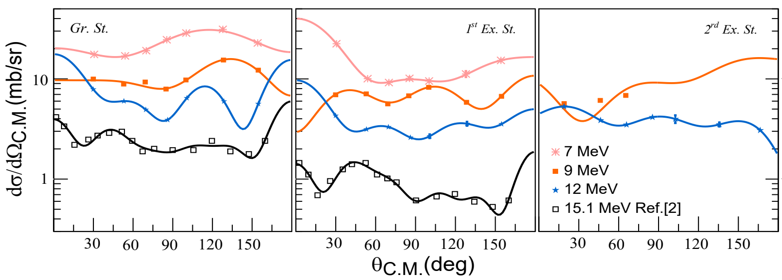

FIG. 2: Angular distributions of neutrons corresponding to ground and first two excited states of ^{7}Be are shown in symbols. Solid lines are the fits using Legendre polynomials.

MeV) excited states of the ^{7}Be and the exponential function to considered the breakup through continuum states. Number of Gaussian used is strongly depend on the proton beam energy. For example at E_p = 12 MeV three Gaussians were used whereas for E_p=7 MeV only two Gaussians were required to fit the data. The area under each Gaussian and the exponential parts were determined which were then plotted as a function of centre of mass angle $\theta_{C.M.}$. The angular distributions $d\sigma/d\Omega_{C.M.}$ of neutrons thus obtained for ground and first two excited states of ^{7}Be are shown in Fig. 2. Data at E_p = 15.1 MeV taken from Ref. [2] for n_0 and n_1 groups are also shown for comparison. Fig. 2 shows $d\sigma/d\Omega_{C.M.}$ of the individual neutron groups decreases with the increase in beam energy. $d\sigma/d\Omega_{C.M}$ of n_0, n_1 and n_2 neutron groups were fitted using a series of Legendre polynomials as shown in Eqn. 1.

$$\left(\frac{d\sigma}{d\Omega}\right)_{C.M.} = \sum_{n=0}^{N} A_n P_n(cos\theta) \qquad (1)$$

where A_n is the coefficient of the Legendre polynomial of order n. Fits are shown with solid lines in Fig. 2. The angle integrated cross section σ for a given neutron group was then determined using the relation $\sigma = 4\pi A_0$, where A_0 is the zeroth order polynomial. In summary, angular distributions has been presented for three neutron groups in ^{7}Li(p,n)^{7}Be reaction for proton energy range 7 -12 MeV.

References

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