Investigating the neutron groups in ^{9}Be(α,n)^{12}C reaction

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The ^{9}Be(α,n)^{12}C reaction is an important source of mono energetic neutrons as it provides widely spaced distinct neutron groups corresponding to the different energy levels of ^{12}C. The number of neutron groups populated depends on the incident α energy, E_α. ^{9}Be(α,n)^{12}C reaction can be used to probe the cluster structures of light mass nuclei like ^{9}Be and ^{12}C [1]. This reaction has been studied earlier mostly by preparing a homogeous mixture of an α emitting source with ^{9}Be powder where several neutron groups were observed [2]. This may be treated as results of a thick target experiment. Likewise measurments done with ultra thin targets (thickness 50μg/cm^2) showed neutron groups corresponding to the ground and excited states of ^{12}C only [3]. Moreover there is no reported data on neutron emission from three body breakup of ^{9}Be.

The present work was aimed to investigate the neutron groups generated in this reaction and to determine the breakup cross section using a target of intermediate thickness ($\sim$1.8 mg/cm^2), generally used in neutron spectroscopy. The experiment was carried out using α beam of energies 5.5 and 6.5 MeV from K130 Cyclotron operated in the 3^{rd} harmonic mode, at VECC. Seven liquid organic scintillator filled cylindrical detectors of dimension 5″× 5″ and one 2″ (dia) × 8″ (length) were used to detect the ejected neutrons spanning the angular range of 35° to 150° with respect to the incident beam direction and at a distance of 1.5m from the centre of reaction chamber (except for 60° and 35° which were at 1m and 2m respectively). Time Of Flight (TOF) technique was adopted to measure the neutron energies using Cyclotron RF signal as the start and individual neutron detector signals as stop. Neutron and γ-ray induced events were discriminated using TOF and pulse shape analysis using Zero Cross Over (ZCO) technique. The measured 2D spectrum of ZCO vs TOF and 1D spectrum of TOF are shown in Fig. 1.

The neutron TOF spectrum was converted to energy spectrum using the prompt γ-peak as time reference and applying standard Jacobian transformation. The neutron energy spectra thus obtained are shown in Fig. 2. The spectra were then fitted with a combination of five gaussian and one exponential functions. Five distinct peaks with $E_{\max}$ around 10 MeV were observed in the spectra. Out of these, the green lined peak at the highest energy (n_0 group) and the orange lined peak (n_1 group) have an energy gap of $\approx$ 4.5 MeV which corresponds to the ground and 1^{st} excited states of ^{12}C (4.4 MeV) respectively. The lowest energy peak (n_2 group) in aqua blue line has an energy gap of $\approx$ 7.9 MeV from the n_0 group and corresponds to the Hoyle state of ^{12}C (7.66 MeV) along with some contributions from ^{9}Be* breakup. Next are the black lined (n_1' group) and the magenta lined (n_0' group) distributions at 3.0 and 7.5 MeV whose origin needs to be understood. A possibility could be from the inelastic excitation of ^{9}Be followed by it's breakup ^{9}Be(α, α')^{9}Be* $\rightarrow$ ^{8}Be + n. However, kinematic calculation indicates that ^{9}Be* breakup neutrons cannot

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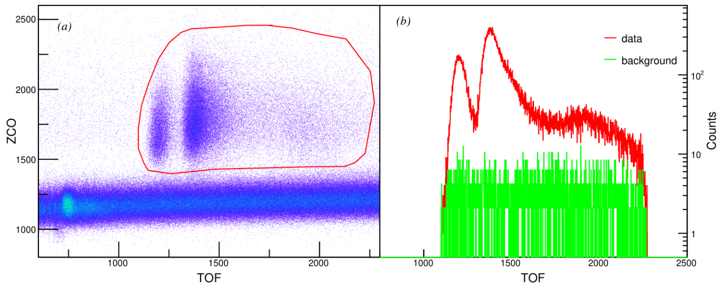

FIG. 1: (a) TOF vs ZCO spectra in ^{9}Be(α, n)^{12}C reaction. (b) TOF spectra at E_α = 5.5 MeV.

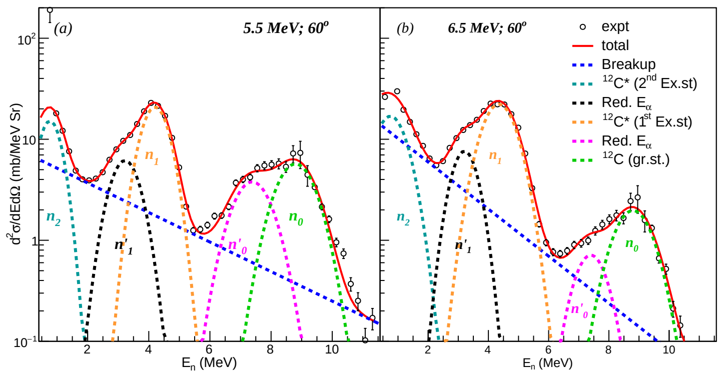

FIG. 2: Measured neutron energy spectra in ^{9}Be(α, n)^{12}C reaction for E_α = 5.5 and 6.5 MeV.

reach energy beyond 1.5 MeV in the studied E_α region. Interestingly, the difference between these two neutron groups (n'_1 and n'_0) is 4.4 MeV which again corresponds to the ground and 1st excited states of ^{12}C. n'_0 and n'_1 groups are originating from the same reaction occuring at a reduced beam energy as compared to n_0 and n_1. It is generally considered that reaction takes place from the middle layer of the target having a finite thickness to account for the average beam energy loss. At the half value layer, E_α reduces to 4.8 and 5.9 MeV for incident beam energies of 5.5 and 6.5 MeV respectively due to energy loss at half of the target thickness. Kinematic calculations indicate the origin of n_0 and n_1 groups corrsponding to these reduced energies. Analyses of n'_0 and n'_1 groups indicate that reaction occured at $E_\alpha = 4.08$ and 5.26 MeV. This correlates to the residual energies after loss of initial beam energy in the entire target thickness. The peaks (n'_0 and n'_1) in the spectrum arise due to matching resonances in ^{13}C and thus their origin from ^{9}Be(α,n)^{12}C reaction can be confirmed.

References

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