Study of $\alpha-$cluster transfer reactions with ^{7}Be in the context of helium-burning process

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Introduction

The α-cluster transfer reactions have earlier been used as a potential tool to study the reactions in the helium burning phase of stars [1]. The direct capture reactions with extremely small cross sections at low energies are difficult to measure in the laboratory. Hence, an indirect technique to study $\alpha-$capture reactions is useful. This involves investigation of α-cluster transfer reactions to populate the relevant states in the residual nuclei. The technique has been extensively used on stable nuclei to investigate the astrophysical $\alpha-$capture reactions. The loosely bound Lithium isotopes ^{6}Li and ^{7}Li [2, 3] are widely studied in this regard due to their α-cluster structure. Amro *et al.* [4] carried out similar study on the radioactive mirror counterpart ^{7}Be. However, the uncertainty in the optical model parameters (OMP) due to the limited angular distribution presented a serious problem in the study of transfer reactions. The study shows that α-cluster transfer reaction is more probable than breakup of ^{7}Be. This low breakup yield makes the ^{7}Be nucleus an excellent candidate for the study of high-excitation α-cluster states in the residual nuclei. We studied the α-cluster transfer reactions of ^{7}Be to populate the states of ^{16}O that dominantly contribute to the alpha capture reaction $^{12}C(\alpha,\gamma)^{16}O$ in helium-burning process in nuclear astrophysics.

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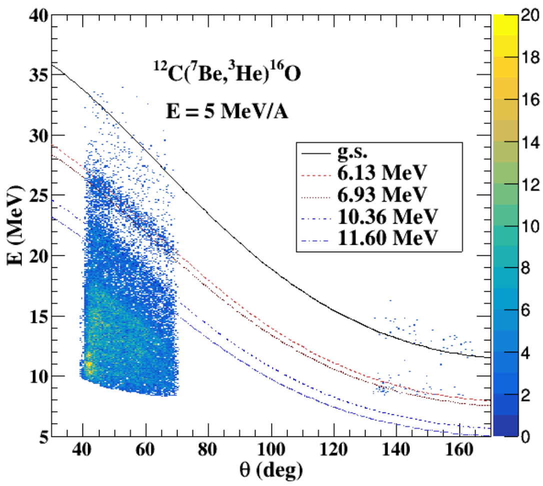

FIG. 1: Energy (E) vs angle (θ) spectrum of ^{3}He from ^{12}C(^{7}Be,^{3}He)^{16}O* at E(^{7}Be) = 5 MeV/A.

Experimental Results

We carried out an experiment with a 5 MeV/A ^{7}Be beam incident on the CD_2 and CH_2 targets at the HIE-ISOLDE facility of CERN. The detector setup consists of an array of $\Delta E - E$ telescopes in the angular range of $40° - 80°$, $127° - 165°$ and an annular E detector covering $8° - 25°$. A detailed description can be found in [5–7].

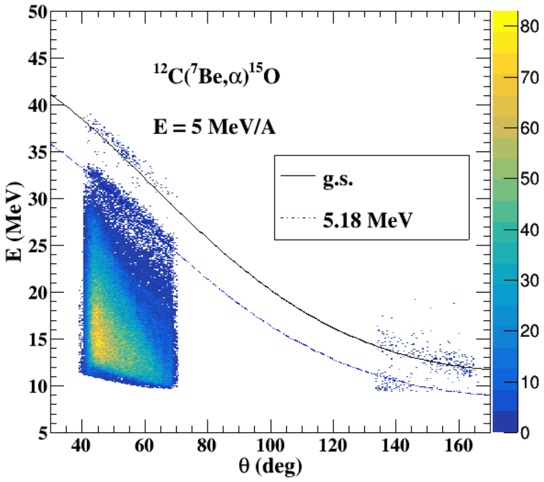

FIG. 2: Energy (E) vs angle (θ) spectrum of ^{4}He from ^{12}C(^{7}Be,^{4}He)^{15}O* at E(^{7}Be) = 5 MeV/A.

We detected the ^{3}He nuclei corresponding to the reaction ^{12}C(^{7}Be,^{3}He)^{16}O*. The plot of energy vs angles of ^{3}He give clear indication of the transfer channels to different excited states of ^{16}O (Fig. 1). The separation of other closely spaced higher excited states of ^{16}O is in progress. In addition to α transfer, we observed significant ^{3}He transfer channels, ^{12}C(^{7}Be,^{4}He)^{15}O* to the ground state and 5.18 MeV excited state of ^{15}O (Fig. 2). The detailed study of ^{3}He and α transfer from these reactions, in comparison with the breakup of ^{7}Be into α and ^{3}He is in progress.

Discussion

We report the transfer reaction studies from ^{7}Be + ^{12}C at 5 MeV/A. Both the ^{3}He and α-particle transfer reaction channels have been observed in the angular range $40° - 165°$. The α-particle transfer populates states of ^{16}O upto $\sim$20 MeV. Work on resolving the higher excited states is being carried out. The ^{3}He transfer populates the ground and 5.18 MeV excited state of ^{15}O. The dominant excited states, namely 6.13 (2^+) and 6.93 (1^-) MeV, contributing to the $\alpha-$ capture reaction on ^{12}C in the helium-burning cycle has been identified. At present, we are working on the angular distributions of the reactions.

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