Study of direct and sequential breakup of radioactive nuclei of ^{7}Be

D. Chattopadhyay[1,2],* S. Santra[1,3], A. Pal[1], A. Kundu[1,3], K. Ramachandran[1], R. Tripathi[3,4], T.N. Nag[4], and S. Kailas[1]

[1] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, India*
[2] *Nuclear Physics Division, Saha Institute of Nuclear Physics, Kolkata - 700064, India*
[3] *Homi Bhabha National Institute,Anushaktinagar,Mumbai - 400094, India and*
[4] *RadioChemistry Division, Bhabha Atomic Research Centre, Mumbai - 400085, India*

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Introduction

The study of nuclear physics using weakly bound stable and radioactive ion beam (RIB) is a topic of current interest. Most of the radioactive light nuclei are weakly bound and they exhibit cluster structure in their ground state [1]. Being weakly bound they are prone to breaking up into two or more cluster fragments. At energies around the Coulomb barrier, this may lead to a large suppression or enhancement in the probability of fusion with a heavy target nuclei. The projectile may breakup in two modes: direct or sequential. In the second mode, the projectile nucleus may get excited to any of its inelastic states in the continuum with finite lifetimes (resonant states) before breaking up into fragments. Search for these states of the weakly bound stable or unstable nuclei is a burning topic.

With the above motivation, we undertook a detailed study of breakup reactions (both direct and sequential) of radioactive nuclei of ^{7}Be which are produced by 1p pickup by weakly bound stable nuclei of ^{6}Li via the reaction ^{112}Sn(^{6}Li, ^{7}Be). The ^{7}Be lies on the proton rich side of the line of stability and it is weakly bound with a threshold energy of 1.59 MeV for breakup into ^{3}He and α. An unambiguous measurement of the non-capture breakup of ^{7}Be requires the detection of ^{3}He and α in coincidence. This paper reports the results of experimental investigation on the existence of ^{7}Be breakup into ^{3}He + α via its direct and resonance modes.

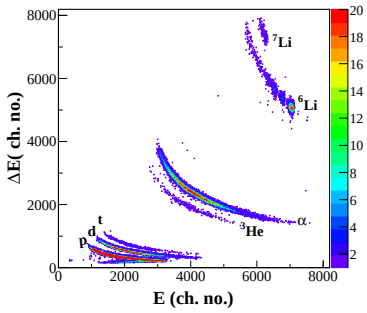

FIG. 1: A typical two-dimensional raw spectrum of one of the vertical strip 105° and E_{beam} = 30 MeV

Experimental details

Exclusive measurements have been carried out for ^{6}Li+^{112}Sn reaction at beam energy of 30 MeV, using the 14-UD Pelletron-LINAC facility in Mumbai. Self-supporting enriched (∼99.5%) ^{112}Sn foil of thickness ∼ 540 μg/cm^2 was used as a target. Five telescopes (S1-S5) of double-sided Si strip detectors were placed on one of the two rotatable arms inside a 1.5 m diameter scattering chamber to detect the projectile like fragments with a total angular range of about ∼ 93°. Two Si-surface barrier detectors (of thicknesses ∼ 1000 μm) kept at ±20° were used to monitor incident flux by measuring the Rutherford scattering. In addition there were five Telescopes (T1-T5) of single surface barrier detectors (with ΔE ∼ 50

*Electronic address: dipayanchattopadhyay90@gmail.com

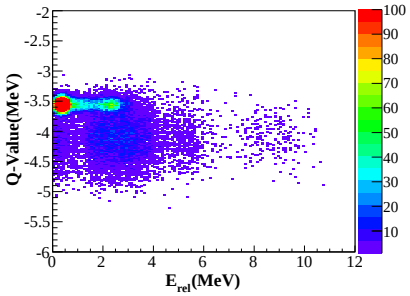

FIG. 2: Two-dimensional plot of Erel vs Q value showing the distribution of events with different projectile-like and target-like excitations for ^{3}He+α breakup reaction.

μm, E $\sim$ 1000-2000 μm) placed on the second arm of the scattering chamber to measure the elastic scattering cross-sections in additional angles particularly the forward ones. The typical 2D spectra of ΔE vs. E is shown in Fig.1, where the two bands corresponding to ^{3}He and α particles are clearly separated.

Results

Using the energies and laboratory detection positions of two breakup fragments of each coincident event, the values of 'θ,ϕ' of outgoing ^{7}Be (for ^{3}He + α breakup) , 'Q-Value' and 'Erel' (relative energy) were determined [2] and corresponding efficiency of the detector array has been obtained by a Monte-Carlo simulation. The 2D plot of 'Erel' vs. Q-Value is shown in Fig. 2. The 2D plot depicts the excitation of the target-like nuclei associated with the projectile-like nuclei. The relative energy(raw), the efficiency and the efficiency corrected relative energy distribution 'Erel' between two coincidence breakup fragments are obtained for ^{3}He + α breakup. The efficiency corrected relative energy of the breakup of ^{7}Be have been shown in Fig.3(a). It is interesting to see from the Fig. 3(a) that apart from the direct breakup at low energy there are two dominant peaks at 2.98 MeV and 5.14 MeV which correspond to first and second resonance states at $7/2^-$ (4.57 MeV) and $5/2^-$ (6.73 MeV). Though the direct breakup has been observed earlier in the literature, the observation of the resonant breakup states of ^{7}Be into ^{3}He+α is observed for the first time in the present work. The Q-value distributions of the corresponding reactions have been shown in Fig.3(b) from which it is concluded that the breakup is found to be mainly occurring via the g.s. of the target nuclei (Q-value=-3.55 MeV). In addition, breakup also occurs with the closely associated target excitations of ^{111}In. The determination of absolute cross sections for direct and sequential breakup of ^{7}Be along with the coupled channel calculation will help us understand both individual as well as total contributions of alpha cross sections towards the inclusive alpha particle production.

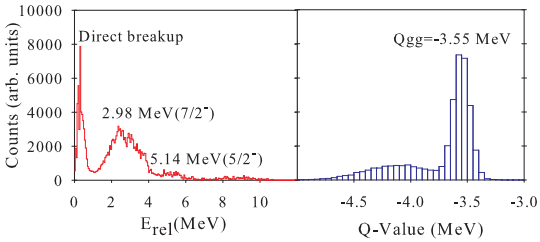

FIG. 3: (a) Efficiency corrected relative energy distribution and (b) The Q-Value distribution of the breakup events.

Summary

The breakup modes of radioactive nuclei of ^{7}Be have been identified through the relative energy distribution. Monte Carlo based simulation code has been developed to find the efficiency corrected relative energy distribution. The efficiency corrected relative energy distribution confirms the observation of breakup of ^{7}Be into α+^{3}He via its resonance states of $7/2^-$ and $5/2^-$ for the first time.

References

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[2] D. Chattopadhyay *et. al*, Phys. Rev. C **97**,051601(R) (2018).