Direct and sequential breakup in ^{7}Li+^{112}Sn reaction

S. Santra[1,2],* D. Chattopadhyay[1,2], A. Pal[1,2], A. Kundu[1,2], K. Ramachandran[1], R. Tripathi[2,3], B.J. Roy[1,2], Y. Sawant[1], T.N. Nag[3], B. K. Nayak[1,2], A. Saxena [1,2], and S. Kailas[1,2]

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

(Dated: September 10, 2017)

Introduction

Study of projectile breakup in the field of target nucleus is a burning topic, particularly due to recent advent in the availability of weakly bound exotic beams. Measurements for direct and sequential breakup cross sections in reactions involving weakly bound stable projectiles like ^{6,7}Li and ^{9}Be on a few heavy and light targets are available. Investigation of sequential breakup in the above reactions through new resonance states and/or transfer channels is a matter of great interest for detailed understanding of breakup reaction mechanism. With these motivations, a reaction involving ^{7}Li on a medium mass target ^{112}Sn has been measured to study different breakup channels. Though the breakup of ^{7}Li into $\alpha + t$ via its first resonance state ($7/2^{-}$, 4.63 MeV) is measured in a few systems, there is no measurement available so far for its second resonance state i.e., 5/2- (6.67 MeV). The importance of this state is however remarkable as various studies on elastic scattering show a very significant effect of coupling of this resonance state of ^{7}Li [1, 2].

This paper reports the results of experimental investigation on the existence of ^{7}Li breakup into $\alpha + t$ via its second resonance state and the cross sections for both first and second resonance states as well as direct breakup. In addition, the breakup induced by $2n$-transfer channel i.e., ^{7}Li$\rightarrow^{5}$Li$\rightarrow \alpha + p$ breakup via ground state of ^{5}Li is also presented.

*Electronic address: ssantra@barc.gov.in

The experiment

Exclusive measurements have been carried out for ^{7}Li+^{112}Sn reaction at beam energy 30 MeV, using the 14-UD Pelletron-LINAC facility in Mumbai. Self-supporting enriched ($\sim$99.5%) ^{112}Sn foil of thickness ~ 540 μg/cm^2 was used as a target. Five telescopes (S_1-S_5) 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 $\sim 93^{\circ}$. Two Si-surface barrier detectors (of thicknesses ~ 1000 μm) kept at $\pm 20^{\circ}$ were used to monitor incident flux by measuring the Rutherford scattering. In addition there were five Telescopes (T_1-T_5) of single surface barrier detectors (with ΔE $\sim 50\mu$m, E $\sim 1000 - 2000\mu$m) placed on the second arm of the scattering chamber to measure the elastic scattering cross-sections in additional angles particularly the forward ones.

Results

Using the energies and laboratory detection positions of two breakup fragments of each coincident event, the values of 'θ, ϕ' of outgoing ^{7}Li (for $\alpha + t$ breakup) or ^{5}Li (for $\alpha + p$ breakup), 'Q-Value' and 'E_{rel}' [3] were reconstructed and corresponding efficiency of the detector array has been obtained by a Monte-Carlo simulation. The efficiency corrected relative energy distribution 'E_{rel}' between two coincidence breakup fragments thus obtained for $\alpha+t$ and $\alpha+p$ breakup have been shown in Fig.1(a) and (b) respectively. The Q-value distributions of the corresponding reactions have been shown in Fig.1(c) and (d) respectively. In the relative energy dis-

TABLE I: Experimental and theoretical peak positions corresponding to the excitation energy above breakup threshold ($E_x - E_{th}$) and widths for different breakup states

State	Peak position (MeV)		Peak width MeV)	
	Theory	Expt	Theory	Expt
^{7}Li (7/2$^-$)	2.23	2.16	0.2	0.09
^{7}Li(5/2$^-$)	4.28	4.20	1.2	0.88
^{5}Li(g.s.)	2.15	1.97	1.5	1.5

tribution of $\alpha + t$ breakup it is interesting to see that apart from the direct breakup at low energy there are two dominant peaks at 2.23 MeV and 4.28 MeV which correspond to first and second resonance states at 7/2$^-$ (4.63 MeV) and 5/2$^-$ (6.67 MeV). The comparison of the peak positions and widths of resonance states with theoretical values in Table I actually confirms the observation of ^{7}Li breakup into $\alpha + t$ via its 5/2$^-$ resonance state for the first time along with 7/2$^-$ resonance and direct breakup.

Differential cross-sections for ^{7}Li$\rightarrow$ $\alpha + t$ breakup via its two resonance states 7/2$^-$, 5/2$^-$ and its direct breakup are shown in Fig.2(a), (b) and (c) respectively. The cross-sections for $2n$ transfer followed by immediate breakup i.e., ^{7}Li$\rightarrow^5$Li$\rightarrow$ $\alpha + p$ breakup via the ground state (3/2$^-$) of ^{5}Li is shown in Fig.2(d). The cross sections have been obtained by integrating the yields under the respective peaks in efficiency corrected relative energy distributions and normalizing with the yield and solid angle of monitor detector as well as Rutherford cross section at monitor angle.

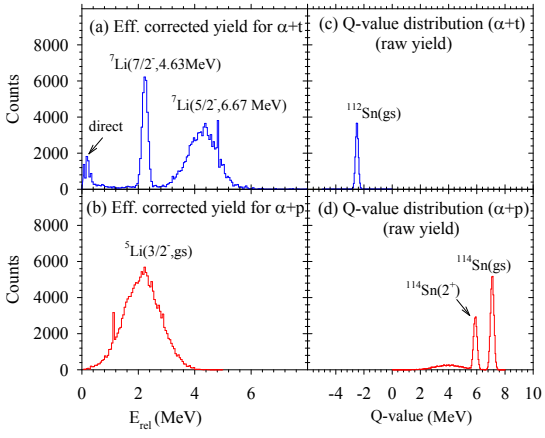

FIG. 1: Efficiency corrected relative energy distributions for (a) $\alpha + t$ and (b) $\alpha + p$ breakup respectively; and (c,d) corresponding Q-value distributions obtained from raw yield.

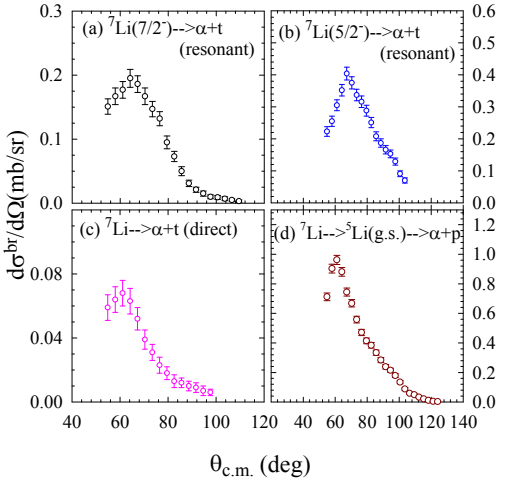

FIG. 2: Differential cross sections for (a,b) sequential (resonant) breakup of ^{7}Li$\rightarrow$ $\alpha + t$, (c) direct breakup of ^{7}Li$\rightarrow$ $\alpha + t$ and (d) sequential (transfer) breakup of ^{7}Li$\rightarrow^5$Li$\rightarrow$ $\alpha + p$ at $E_{\rm beam}$=30 MeV

In summary, we have observed the breakup of ^{7}Li into $\alpha + t$ through its second resonance state (5/2$^-$) for the first time. Further, the results on direct and resonant breakup of ^{7}Li into $\alpha + t$ and $2n$ transfer induced breakup into $\alpha+p$ presented here provides a good foundation towards the understanding of the total reaction mechanisms of the projectile breakup as well as the production of large inclusive α.

References

[1] K. Rusek *et al.*, PRC 67,014608(2003).
[2] W. Ott *et al.*, NPA 489, 329(1988).
[3] D. Chattopadhyay *et al.*,PRC 94,061602(R)(2016).