First breakup measurement with ^{11}B projectile

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Studies involving exclusive measurements on breakup of weakly bound ^{10,11}B projectiles [1, 2] are hardly explored, in comparison to the other weakly bound stable projectiles like ^{6,7}Li and ^{9}Be. In an experimental work, the breakup of ^{11}B through some of its resonance states has been studied using the difficult-to-get radioactive ion beam ^{10}Be in the reaction ^{10}Be(d,n) [3]. However, a more trivial solution i.e. the use of stable intense ^{11}B beam to measure its direct breakup has alluded so far. Therefore, in the present work, experimental studies on breakup reaction with ^{11}B projectile have been attempted for the first time in order to shed more light on the breakup mechanism of ^{11}B and its significance on reaction dynamics and cluster structures.

An exclusive measurement on the breakup of ^{11}B projectile was carried out at a bombarding energy of 65 MeV using a self supporting ^{197}Au target (thickness $\sim$ 500 μg/cm^2) at BARC-TIFR Pelletron-Linac accelerator facility, Mumbai, India. Five telescopes made of double sided silicon strip detectors covering an angular range of $50° - 122°$ were used. Additionally, five smaller size telescopes made of silicon surface barrier detectors covering an angular range of $30° - 70°$, at 10 degrees apart, have also been placed on the opposite arm to measure inclusive yields of all the light charged particles. We identify various charge particles produced in the reaction using the Δ E vs. E$_{total}$ plot. As shown in Fig.1 different particle bands such as ^{9,10}Be, ^{6,7,8,9}Li, ^{4,6}He and ^{1,2,3}H produced in the reaction have been clearly identified. All the detectors were calibrated using the known energies of α particles from ^{229}Th source. For the present work, data from two strip telescopes with angular ranges 67-105 ° have been analyzed as per the following the steps.

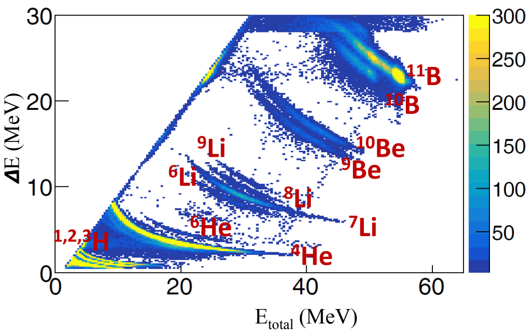

FIG. 1: Typical 2D spectrum clearly distinguishing different particle bands.

In the present analysis we focus on the breakup channel $^{11}\text{B} \rightarrow \alpha + {}^{7}\text{Li}$. First, the momentum vectors of the detected particles (^{7}Li and ^{4}He) are reconstructed with the help of the measured energy and position (θ, ϕ) of the particle. Using the above momentum vectors, the relative energy (E$_{relative}$) between the two breakup fragments and the Q-value of the reaction are calculated using the following equations.

$$E_{relative} = \frac{(p_{Li} - p_{\alpha})^2}{2\mu} \quad (1)$$

$$Q = E_{Li} + E_{\alpha} + E_{recoil} + E_{loss} - E_{beam} \quad (2)$$

where μ is the reduced mass of the two breakup fragments; E$_{recoil}$ is the recoil en-

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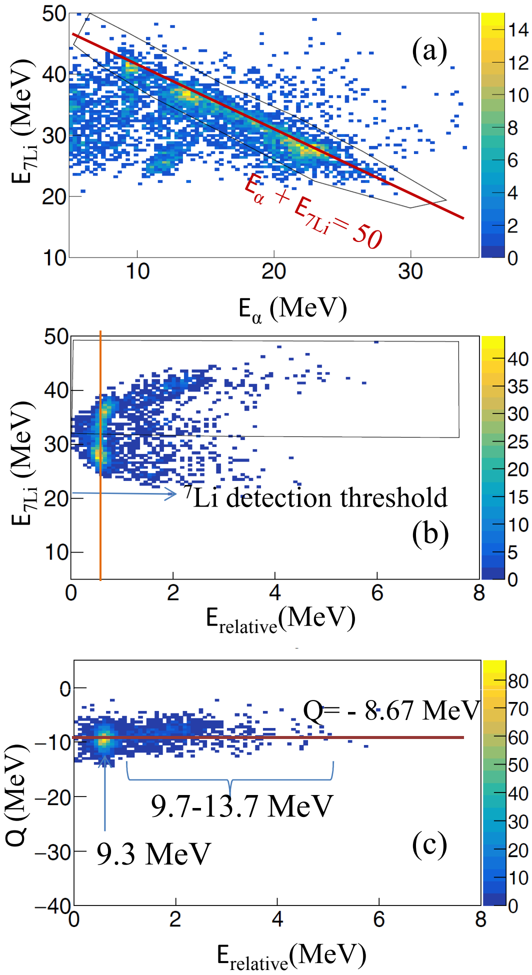

FIG. 2: Correlation plots of (a) E_{7Li} vs. E_α, (b) $E_{relative}$ vs. E_{7Li} and (c) $E_{relative}$ vs. Q

ergy of the target, derived using the momentum conservation equation and E_{loss} is the energy loss of the fragments within the target. (3) Events are filtered with appropriate kinematical filters and (4) finally several resonant breakup states are identified from the relative energy distribution plot.

Following the above prescription, first, energy correlation of ^{7}Li and ^{4}He, the two breakup fragments (detected in coincidence) from the projectile have been shown in Fig.2(a), where the events shown within the black contour, follow the relation $E_{Li}+E_\alpha$ = 50 MeV (red solid line) and correspond to the desired breakup events originated from different resonant and non-resonant breakup states of ^{11}B. The events lying only within the shown contour have been used for further analysis. Now the correlation between the relative energy and the measured energy of ^{7}Li have been shown in Fig.2(b), manifesting the expected parabolic dependency. It may be observed that, we get several peaks (distinct at 0.6 MeV and inseparable in the range of 1.0 - 5.0 MeV) in the relative energy spectrum (not shown separately), manifesting the role of several resonant breakup states. Further, we observe that along the drawn solid line two patches corresponding to $E_{relative}$ = 0.6 MeV state and only upper parabolic branch corresponding to higher relative energies appear in the above plot. It is due to the fact that the patches corresponding to higher resonant states in the lower parabolic arm is missing due to the energy detection threshold of ^{7}Li (shown by horizontal arrow in Fig.2(b)) in our telescopes. Now to obtain the relative contribution of each resonant state another gate (shown by black box) in Fig.2(b) have been further applied on raw (not shown here) relative-energy vs. Q value plot and shown in Fig.2(c). The filtered Q value spectrum peaking around -8.67 MeV (breakup threshold of $^{11}B \rightarrow \alpha + {}^7Li$) signifies the occurrence of breakup from the ground state of the target. Using the above efficiency uncorrected plot, relative contributions of 9.3 MeV state ($E_{relative}$=0.6MeV) and inseparable states in the range of 9.7-13.7 MeV($E_{relative}$= 1.0-5.0 MeV) are found to be $\sim$ 70% and 30% respectively.

In summary, we have studied breakup of ^{11}B projectile for the first time and observed several resonant breakup states just above the break-up threshold.

References

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