Study of breakup and one neutron stripping followed by breakup reaction in ^{9}Be + ^{124}Sn system at E_{lab} = 29.1 MeV

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Introduction

^{9}Be nucleus is particularly useful for studying three-body correlations due to its Borromean structure, with a breakup threshold $E_{BU}^{\alpha\alpha n}$ = 1.57 MeV. More interestingly, ^{9}Be can also break via ^{8}Be(α+α)+n (E_{BU} = 1.66 MeV) and α+^{5}He(α+n) (E_{BU} = 2.45 MeV) sequential modes [1–4]. In reactions involving ^{9}Be, it is found that the 1n-stripping is one of the important reaction channels [5, 6]. Exclusive measurement is required to disentangle breakup of ^{9}Be and 1n-stripping followed by breakup of ^{8}Be. At present, limited exclusive data is available for this channel in the literature [5]. In continuation of our earlier study on breakup and 1n-stripping reactions in the ^{9}Be+^{124}Sn system at E_{lab} = 1.25 V_B [7, 8], we have now extended the investigation to E_{lab} = 29.1 MeV, which is just above the Coulomb barrier (V_B = 28.1 MeV).

Experimental Details

The experiment was performed at the BARC-TIFR Pelletron-LINAC Facility, Mumbai using the ^{9}Be beam at 35.8 and 29.7 MeV energies. A self-supporting foil of ^{124}Sn ($\sim$ 1.74 mg/cm^2) was used as target. Seven Si-strip detector telescopes in the $\Delta E - E$ arrangement, of active area 5 x 5 cm^2 were used. The ΔE detectors were single-sided strip detector with 16 strips and E detectors were double-sided with 16 strips in front and 16 strips in back sides. Typical thicknesses of ΔE and E detectors were $\backsim$ 20-50 µm and 1-1.5 mm, respectively. Two Si surface-barrier detectors (thickness $\sim$ 300 µm) were kept at ±20° for absolute normalization and beam monitoring. The data was recorded in an event by event mode using VME based data acquisition.

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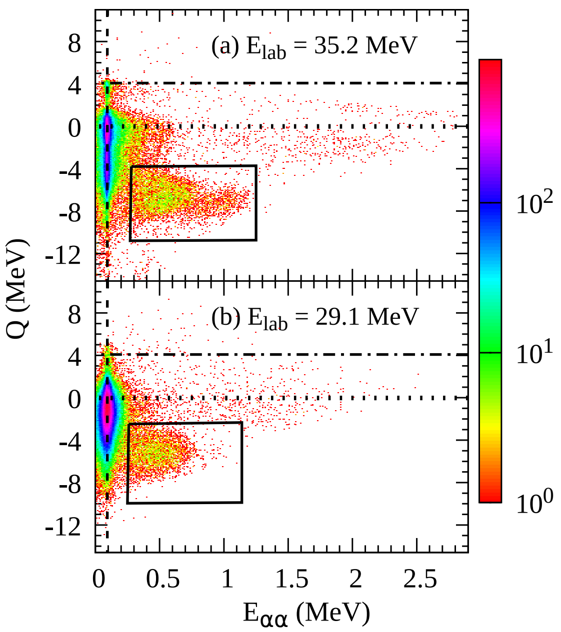

FIG. 1: Two-dimensional spectra of Q-value versus $E_{\alpha\alpha}$ for ^{9}Be + ^{124}Sn system: (a) E_{lab} = 35.2 MeV and θ_{lab} = 52°; (b) E_{lab} = 29.1 MeV and θ_{lab} = 122°.

Analysis and Results

Particles were identified using the energy loss information from the ΔE and E detectors. Two α fragments measured in coincidence were characterized by scattering angles (θ_{α_1}, ϕ_{α_1}; θ_{α_2}, ϕ_{α_2}) and kinetic energies (E_{α_1},E_{α_2}). The relative angle between the two α particles ($\theta_{\alpha\alpha}$) was calculated from scattering angles. The relative energy ($E_{\alpha\alpha}$), was obtained using the kinetic energies (E_{α_1},E_{α_2}) and the relative angle ($\theta_{\alpha\alpha}$). The kinetic energy and angle of scattering of ^{8}Be prior to breakup are also extracted using 3-body kinematics. The reaction Q-value was reconstructed utilising the missing energy technique.

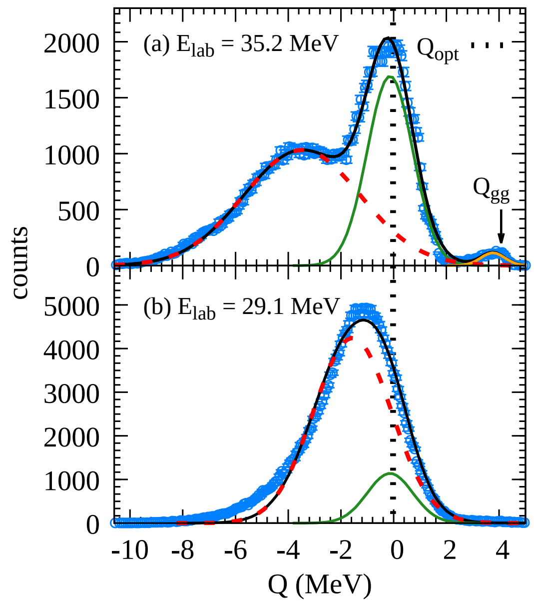

FIG. 2: Measured Q-value for events with two α-particles in coincidence: (a) E_{lab} = 35.2 MeV and (b) E_{lab} = 29.1 MeV.

Two-dimensional spectra of Q-value versus $E_{\alpha\alpha}$ were compared in Fig. 1 for E_{lab} = 35.2 MeV and 29.1 MeV.

In Fig. 1, it is observed that the majority of events are localized at $E_{\alpha\alpha}$ = 92 keV, signifying the breakup of ^{8}Be from its ground state. Additionally, two weakly populated horizontal bands are attributed to the breakup of ^{8}Be from the 2^+ state. A few events, appearing as a distinct cluster marked inside a box found to be peaking at $E_{\alpha\alpha} \sim 0.6$ MeV, correspond to the decay $^9\text{Be}^* \rightarrow {}^8\text{Be}_{2+}$+n [1, 9]. The kinematical line for 1n-stripping channel corresponding to ground state Q-value (Q_{gg}=4.1 MeV), and the optimum Q-value (Q_{opt}=0.0 MeV) from semi-classical theory of trajectory matching, are shown by dot-dashed and dotted lines, respectively.

The extracted Q-value plot at both the energies E_{lab} = 35.2 MeV and 29.1 MeV are compared in Fig. 2. A clear peak at Q_{gg} in Fig. 2(a) corresponding to the 1n-stripping leads to ^{125}Sn in the ground state. Further, the strong peak at Q=0.0 MeV represents a good agreement with the semi-classical theory for 1n-stripping channel. However, the peak at Q $\sim$ -4.0 MeV corresponds to the direct breakup of ^{9}Be. Relative contribution from all the three components, direct breakup, 1n-stripping peaks at Q_{gg} and Q_{opt} are extracted by fitting the spectra considering three Gaussian and shown by red (dashed), green and orange lines, respectively. As can be seen in the Fig. 2(b), absence of peak at Q_{gg} for E_{lab} = 29.1 MeV indicates a drastic reduction of 1n-stripping process. As well, the direct ^{9}Be breakup component is merged with 1n-stripping channel due to kinematical condition at E_{lab} = 29.1 MeV. The contribution of these two processes is obtained by fitting data with two Gaussian's simultaneously. The position and width of the 1n-stripping component are kept same as obtained for the data at E_{lab} = 35.2 MeV. A good fitting with data can be seen in Fig. 2(b), shows a dominance of direct breakup of ^{9}Be over the 1n-stripping followed by breakup of ^{8}Be. Detailed analysis along with theoretical calculations will be presented.

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