Study of continuum states of ejectiles in ^{7}Li+^{93}Nb reaction around the Coulomb barrier

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In order to unravel the role of weak binding on reaction dynamics we have recently performed a set of exclusive measurements with ^{7}Li on medium mass nucleus ^{93}Nb to get cross-sections for breakup, transfer followed by breakup and fragment capture mechanisms [1, 2]. Elastic scattering angular distributions and fusion cross-sections (both complete and incomplete) have also been measured to constrain parameters of the coupled channels calculations. In this work we present extensive theoretical analysis to explain differential cross-sections of direct breakup, and unbound states populated after one neutron stripping and one proton pickup reactions, for the first time. The transfer of a nucleon to the continuum is a complex process, which requires the simultaneous understanding of both the breakup and transfer reactions. Detailed coupled channels Born approximation (CCBA) calculations along with the continuum discretized coupled channels calculations (CDCC) to simultaneously explain the large number of observables are presented.

Two sets of calculations were carried out to describe the data. Those for the elastic scattering and breakup processes were performed within the CDCC formalism using a cluster folding model for the structure of ^{7}Li. Calculations for the transfer breakup employed the CCBA framework, i.e., CDCC in the entrance and exit channel and DWBA for the transfer step, utilizing the potentials that explained the elastic scattering data. Both the CCBA and CDCC calculations described here were performed using the code FRESCO [3].

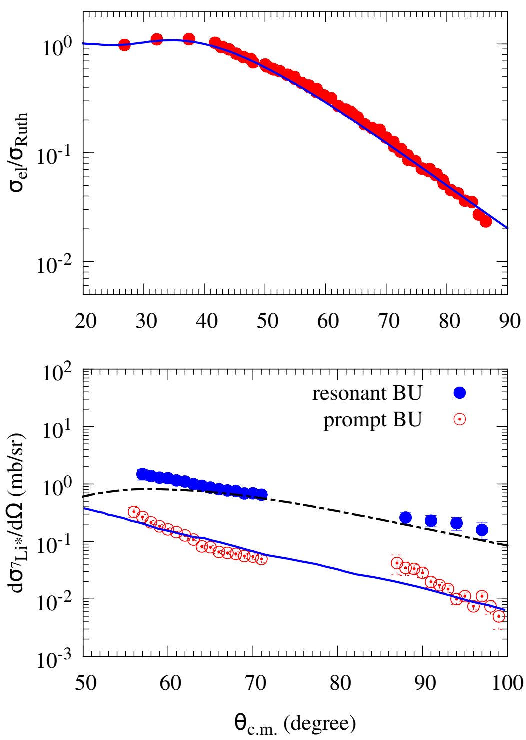

FIG. 1: (a) Measured elastic scattering and (b) prompt and resonance breakup cross-section of ^{7}Li for ^{7}Li+^{93}Nb system at beam energy E_{beam}=28 MeV along with CDCC calculations.

In the CDCC formalism ^{7}Li nucleus was considered as having α+t cluster structure. The binding potentials between α+t were taken from Ref [5]. The α+t continuum was discretized into a series of momentum bins of width $\Delta k = 0.2$ fm^{-1} (up to $k = 0.8$ fm^{-1}) for

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L = 0, 1, 2 and 3, where $\hbar k$ denotes the momentum of the α+t relative motion. All couplings, including continuum−continuum couplings, up to multipolarity $\lambda = 2$ were incorporated. The optical potential for the entrance channel were generated by folding the α-target (V_α) and triton-target (V_t) potentials. The Wood-Saxon potential parameter for V_α and V_t were taken from global optical model potential [7, 8]. The real and imaginary strengths of the cluster-folded potentials were adjusted to describe the elastic scattering data. The results of the calculations for the elastic scattering along with measured data is shown in Fig.1(a). The measured resonant breakup cross-section of ^{7}Li from $\frac{7}{2}^-$ state and the prompt breakup cross-section corresponding to breakup from continuum states of ^{7}Li are shown in Fig.1(b) by solid and open circles, respectively. In the measurement resonant breakup of ^{7}Li from 4.63 MeV ($\frac{7}{2}^-$) state was observed as the measured relative energy between α+t was 2.16 MeV. The calculated angular distributions for the resonant state is shown in Fig.1(b) by dot-dashed line. The prompt breakup cross-section corresponding to the relative energy between α+t from 0.0-1.1 MeV. The calculated prompt breakup cross-section corresponding to the ^{7}Li* in continuum states having excitation energy 2.46-3.56 MeV is shown in Fig.1(b) by the solid line.

In case of ^{93}Nb(^{7}Li,^{8}Be*) reaction, a peak at 92 keV was observed in the measured relative energy spectra of $\alpha - \alpha$, corresponding to the breakup of ^{8}Be from its ground state [1]. The excitation energy of ^{92}Zr* was also extracted. The $\alpha - \alpha$ coincident cross-sections from the ground state breakup of ^{8}Be and the excitation energy of ^{92}Zr* up to 4.0 MeV is shown in Fig.2 by solid circles. In the CCBA calculations of ^{93}Nb(^{7}Li,^{8}Be*) reaction, 0.0 MeV (0^+), 2.45 MeV (5^-) and 2.74 MeV (4^-) states of ^{92}Zr was included in the calculation. The calculation was limited to these three states only because, the spectroscopic factor for the other states are not available. The calculation is shown in Fig.2 by the solid line, in good agreement with the data.

In case of ^{93}Nb(^{7}Li,^{6}Li*) reaction, the peak at 710 keV in the measured relative energy spectra of $\alpha - d$, corresponding to the breakup

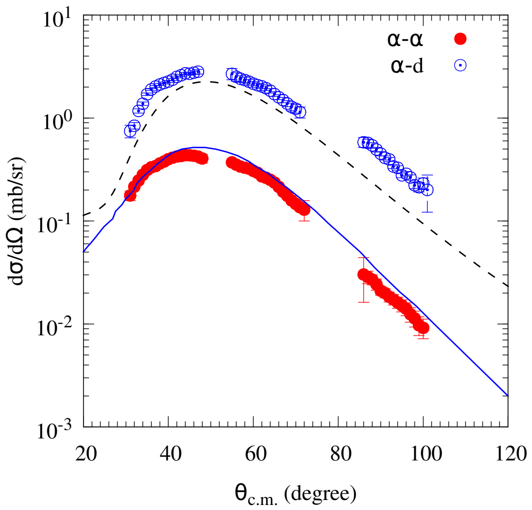

FIG. 2: Measured exclusive cross-sections of transfer-BU reactions for ^{93}Nb(^{7}Li,^{8}Be*) and ^{93}Nb(^{7}Li,^{6}Li*) along with CCBA calculations plotted as solid and dashed curve respectively.

of ^{6}Li from its first resonant state 3^+ (2.18 MeV) [1]. The cross-section of the 3^+ resonant state is shown in Fig.2 by open circles. The CCBA calculations, including excited states of ^{94}Nb up to 1.0 MeV is shown in Fig.2 by the dash line. The calculations under estimates the data because, the measured data corresponding to the excitation energy of ^{94}Nb up to 3.0 MeV.

In summary, measured direct and transfer breakup cross-sections for ^{7}Li+^{93}Nb reaction at E_{beam}=28 MeV are explained in continuum discretized coupled channels and coupled channels Born approximation framework.

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