Separating the Direct Knockouts from the Resonant Breakups Using Event Mixing Technique

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Many heavy ion experiments[1] use heavy cluster direct-knockout reactions such as $A(a, 2a)b$ to extract the ground state cluster spectroscopic factor for the $a+b$ component of the target nucleus A. The diagram of Fig.1(a) represents a one step direct a-knockout from the target nucleus A. The knockout reactions contrast, a large number of heavy ion reaction studies where the reaction proceeds through A^*, a sequential process (see Fig.1(b)), the so called inelastic or resonance-breakup [2–4]. he resonance-breakup into cluster fragments indicates the presence of those clusters in A*.

In the $A(a, 2a)b$ reaction the kinematics is fully ascertained through the energy-momentum conservation. The incident energy is chosen such that out of the three final state particles the $a + a$ pair is not having any nuclear molecular resonance $B^* \equiv (a + a)$. On the other hand the other two pairs of $a + b$ entities of the 3-body final state have lower relative energies and may be forming nuclear molecular resonances of nucleus A in its excited state. For example a large number of nuclear molecular resonances are seen to exist in Ref.[5] for the $^{24}Mg^*$ compound system. Now in the case selected here the incident energies and angles of the two detected a particles of the 3−body final state are chosen such

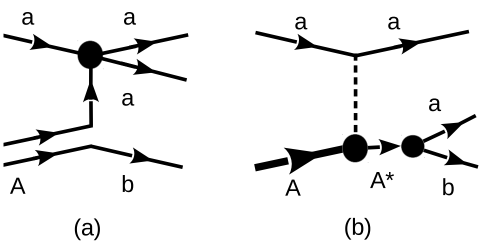

FIG. 1: Schematic diagrams of the direct reaction A(a,2a)b. Fig. a) one step direct $a_{(g.s.)}$-knockout and Fig. b) resonance-breakup, through A* subsequently decaying into fragments a and b.

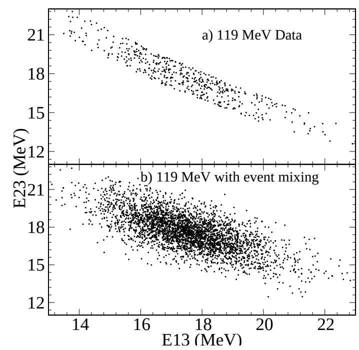

FIG. 2: Comparison of Dalitz plots for E_0=119 MeV a) Experimental data and b) Simulations done by the event mixing technique [6].

that corresponding to the zero recoil momentum, q_b=0 the two detected particles form no resonances with the recoiling residual nucleus b. Now the events for this kinematics will correspond to the direct a-cluster knockout reaction. Comparison of the data with the FR-DWIA predictions will indicate the amount of $a + b$ nuclear clustering in the ground state of nucleus A.

Now for finding the ^{16}O-^{8}Be component of $^{24}Mg_{(g.s.)}$ the experiment on $^{24}Mg(^{16}O, 2^{16}O)^{8}Be$ reaction was performed earlier with symmetric coplanar knockout kinematics [1]. With E_0=119 MeV, the θ_1=θ_2=40.9^o, corresponds to k_3=0 for E_1=E_2=52.5 MeV. The relative energies, E_{13} and E_{23} for both $^{16}O_{(1)}$-^{8}Be and $^{16}O_{(2)}$-^{8}Be systems respectively correspond to the energy just before the ∼ 33 MeV ^{24}Mg resonance energy. Hence this corresponds to the pure direct ^{16}O-knockout from $^{24}Mg_{(g.s.)}$.

In order to find contribution from the resonances present in the 3-body final state data the normal procedure one draws Dalitz plot. With the Dalitz formalism the data is plotted as a function of the two relative energiesof

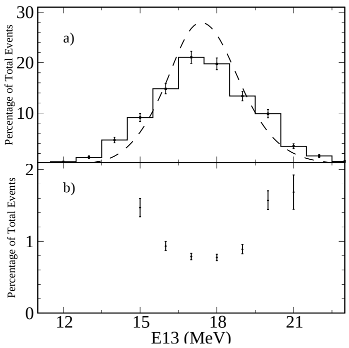

FIG. 3: a) Comparison of the experimental data (Solid line) with the normalized simulations by the event mixing technique (Dashed line) for the total number of events in percentages for the relative energy E13. b) Ratios of experimental data to the event mixing calculations plotted for the relative energy E13.

the *a*-*b* systems of the 3-body final state. The Dalitz plot (E_{13} vs. E_{23}) for all the relevant events for *a*-*b* partners is shown in Fig.2 for the E_0=119 MeV data. This figure (with 3100 events) may or may not display for the clustered events corresponding to the presence of ^{16}O-^{8}Be resonances discernible to the naked eye.

From these data new events are generated by an event mixing method[6]. Here the new events are generated by picking up three different energies, for the corresponding three outgoing particles, by a random selection from the actual events. We generated about 10^7 random events from our data for E_0=119 MeV. These mixed events have the characteristics of not having any resonance like structures. This is because a certain relative energy is required for a resonance formation. The random choice of energies effectively melts the resonances of the actual data and converts them to non resonance data of the mixed events. Therefore in the mixed events data there is an increase in the non resonant component equal to the amount of the resonant component. A comparison of the actual data with the mixed event data can be made if the mixed data are normalized to the number of the actual data. This comparison is made in Fig.3a. Here it is noticed that the mixed events data form sharper distributions than the actual data. Correspondingly the peak number of counts are increased for the normalized mixed events data. A detailed assessment has been made by taking the ratio of the actual data and the normalized mixed event data in Fig.3b. With no resonance this ratio should result in a straight line parallel to the E_{ij}-axis with a ratio value of ∼1.0. Yet in Fig.3b, a line curving upwards is seen with a minimum at the corresponding peak position of the normalized mixed event data. These results indicate that there were resonances present in the actual data on the sides where the ratio is more than ∼1.0. With the melting of the resonances on the sloping sides of the distribution the mixed counts around the peak are increased by that much. The crossing of the ratio curve around ∼1.0 value indicates the position of the resonances. The ratio data curve shows the separation between the resonances to be $\gtrsim$3.5 MeV. The lower values for the actual data peak in comparison to the mixed events data peak value is seen to be ∼20%, indicating it to be the resonance contribution to the sides of the peaked distributions of the actual data.

The event mixing method described here can separate the resonance breakup contributions from the direct knockout components.
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