$^{24}Mg(^{12}C, 2^{12}C^{*}_{2+})^{12}C^{*}_{2+}$ reaction at 113.7 MeV and the $^{24}Mg^{*}$ resonance overlap.

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Discovery of $^{12}C+^{12}C \rightarrow {}^{24}Mg$ high lying resonances in elastic and inelastic scatterings of two ^{12}C's by D. Bromley's group from Yale University started the rapid growth in Heavy Ion reaction studies. Here excitation functions were obtained by changing the incident ^{12}C energy in short energy steps. These excitation functions revealed pronounced resonances of the compound system formed by the two colliding ^{12}C's. Resonances of ^{24}Mg up-to 56 MeV excitations and high angular momenta $\sim 24\hbar$ were unimaginable. While the ^{24}Mg resonances were observed to decay into various channels but mainly into $^{12}C_{(g.s.)}+^{12}C_{(g.s.)}$, $^{12}C_{(2+)}+^{12}C_{(g.s.)}$ and $^{12}C_{(2+)}+^{12}C_{(2+)}$ channels. Besides these the channels involving ^{8}Be and ^{16}O particles were also observed[1–3]. To explain these unexpected findings theoreticians made models using soft as well as hard nuclear matter[4]. The other heavy ion reactions involving ^{16}O, ^{28}S, ^{40}Ca and their combination did not provide as spectacular results as the ^{12}C's. The $^{24}Mg(^{12}C,^{24}Mg^{*} \rightarrow {}^{12}C^{*}+^{12}C^{*})$ reaction around 100 MeV energies had only one $^{24}Mg^{*}$ resonance in the three body final state.

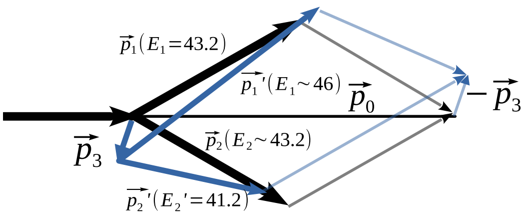

FIG. 1: Schematic kinematic diagram of the $^{24}Mg(^{12}C, 2^{12}C^{*}_{2+})^{12}C^{*}_{2+}$ reaction at 113.7 MeV.

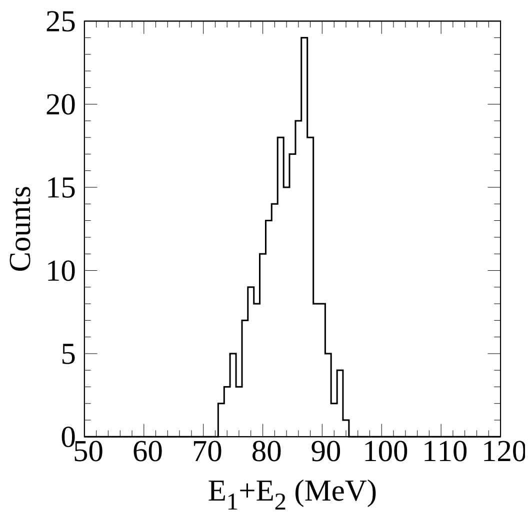

FIG. 2: Summed energy spectrum for $^{24}Mg(^{12}C, 2^{12}C^{*}_{2+})^{12}C^{*}_{2+}$ at 113.7 MeV.

In order to investigate the influence of the 2-body $^{24}Mg^{*}$ resonances, we went a step ahead in these efforts to experimentally generate two $^{24}Mg^{*}$ resonances in the three body final state of the $^{24}Mg(^{12}C, 2^{12}C^{*}_{(2+)})^{12}C^{*}_{(2+)}$ reaction. The schematic kinematic diagram is seen in Fig.1

The experiment on this reaction was performed at the BARC-TIFR Pelletron LINAC Facility at an incident beam energy of 113.7

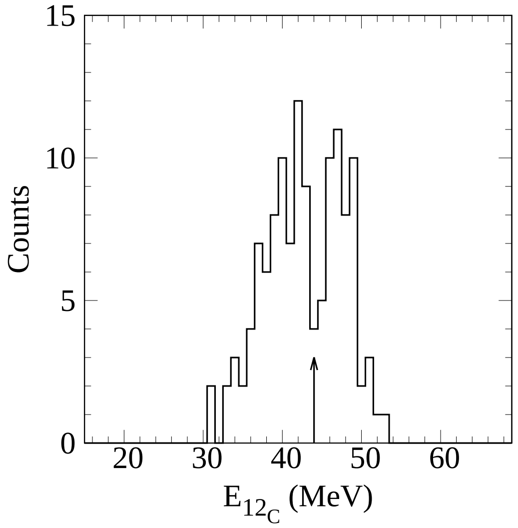

FIG. 3: Energy sharing distributions of the $^{12}C_{(g.s.)}$ formed from the decay of three ^{12}C's 2^+ resonances to ^{12}C in the reaction $^{24}Mg(^{12}C, 2^{12}C^*_{2+})^{12}C^*_{2+}$ at the incident energy of 113.7 MeV.

MeV. The beam current of 2-3pnA bombarded a self supporting natural ^{24}Mg target of thickness $\simeq 400\mu gm/cm^2$. Target thickness was measured using the α-energy loss method. Four E-ΔE telescopes T1, T2, T3 and T4 comprised of thickness of the $\sim$ 300 μm E and $\sim$ 15-25 μm of the ΔE Si- surface barrier detectors were used in the symmetric co-planer geometry. These were calibrated using Th-α source as well as elastic scattering of ^{12}C on Au target at different angles. Two monitor detectors were kept at forward angles of 10^0 to monitor the beam current. One pair of telescopes T2 and T3 detectors were placed at an angle of 35.7^o on either side of the beam direction. The other detector pair T1 and T4 was placed at an angle of 45.7^o on either side of the beam direction in the horizontal reaction plane. The symmetric 37.5^o angle was chosen such that kinematically (see Fig.1) the recoiling undetected $^{12}C^*_{(2+)}$ is at zero energy, when the two decayed $^{12}C^*_{(2+)}$ nuclei (to $^{12}C_{(g.s.)}$) are detected in coincidence. A sharp coincidence spectrum was observed in the TAC.

The separation of different elements like B, C, N and O was very good in the E-ΔE 2-D spectrum. However a peak in the summed energy spectrum of two detected ^{12}C's around E_1+E_2 $\sim$ 87 MeV is seen in Fig.2. A slice of this summed energy spectrum around 87 $\pm$ 1 MeV gives rise to an energy sharing spectrum in Fig.3. It shows a dip at the zero recoil momentum position (q_{Recoil}=0) for $E_{^{12}C}$ at $\sim$ 44 MeV. We expected a peak at E_1=E_2 $\sim$ 44 MeV. The splitting is noteworthy. While almost no counts were seen for the zero recoil momentum, where the two $^{24}Mg^*$ resonances should overlap. A broad Gaussian type of characteristic peak is excepted instead of a split double peak in seen in Fig.3. This is a big surprise and indicates that there is some perturbation between the two resonances of $^{24}Mg^*$ overlapping in the final state.

In conclusion, this experiment of two overlapping $^{24}Mg^*$ resonances in the reaction $^{24}Mg(^{12}C, 2^{12}C^*_{2+})^{12}C^*_{2+}$ indicates the result to be much different compared to a single resonance peak observed in the final state of conventional reactions[1–3]. This seems to arise because the Hamiltonian has three body resonance besides a two body resonance.

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