# $^{12}C$-$^{12}C$ Description of $^{24}Mg$ and Perturbing Resonances.

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Formation of nuclear molecular resonances has been observed in the high excitation region (e.g. in $^{24}Mg$) of light medium mass nuclei in collision[1] (see Fig.1). The ground state of nuclei, such as $^{24}Mg$ have not been scrutinized experimentally for the existence such medium mass cluster structures. Low lying states of $^{24}Mg$ are well described in terms of $^{12}C$+$^{12}C$ as well as $^{16}O$+$^{8}Be$ clusters[2, 3]. The ground state cluster structure is expected to show up best in cluster knockout reactions which are sensitive to the nuclear surface exclusively

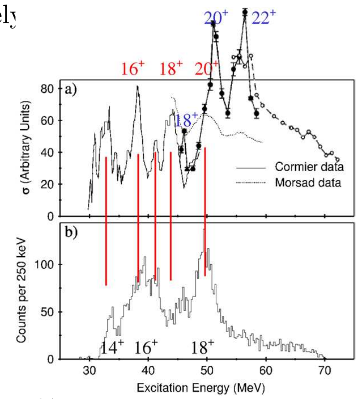


FIG. 1: $^{24}Mg$ resonances at high excitations.

An experiment on $^{24}Mg(^{12}C, 2^{12}C)^{12}C$ reaction was performed using $\sim$ 3-4 $pnA$ current of 104 MeV $^{12}C$ beam on 400 $\mu g/cm^2$ $Mg$ target. The kinematics was chosen such that there is no $^{12}C$-$^{12}C$ resonance contribution at the symmetric angle pair with minimum recoil momentum, $q_R^m$=0 (at $\theta_1$=$\theta_2$=40.5$^o$). Data is also taken when the 38.5 MeV 16$^+$ resonances (see Fig.1), appearing in both the relative motions of the one and the other of the two scattered $^{12}C$'s (with respect to the lone recoiling spectator $^{12}C$), coincide at $\theta_1$=$\theta_2$=36.7$^o$, where the minimum recoil momentum $q_R^m$ is $\sim$ $80MeV/c$

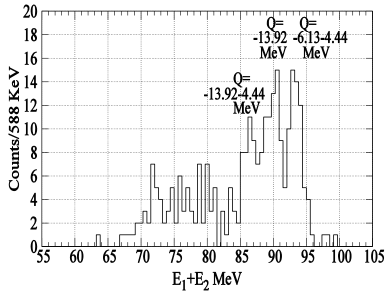


FIG. 2: $E_1$ + $E_2$ spectrum for $\theta_1$=$\theta_2$=40.5$^o$.

The summed energy, ($E_1$+$E_2$) spectrum of the two detected $^{12}C$'s at $\theta_1$=$\theta_2$=40.5$^o$ is shown in Fig.2. A peak at $Q \sim$ -13.92 MeV is clear indication of the two detected $^{12}C$'s belonging to the breakup of the $^{24}Mg_{g.s.}$ target into the two $^{12}C$'s. This angle pair encompasses the kinematics corresponding to the zero recoil momentum condition, i.e. $q_R^m$=0. Significantly large counts corresponding to $Q$= -13.92 MeV indicate that there are significant contributions from direct reactions ensuing from $^{12}C$+$^{24}Mg$ channel to the three $^{12}C$'s in the final channel. From the $\theta_1$=$\theta_2$=40.5$^o$ summed energy spectrum, the $Q$= -13.92 MeV peak results in an energy sharing spectrum shown in Fig.3. This spectrum is having very intriguing characteristics. This cross section vs energy $E_1$ distribution has two broad peaks one at 40 MeV and the other at 46 MeV. These

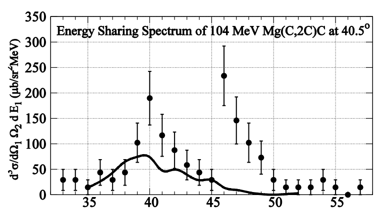


FIG. 3: Energy sharing spectrum for $Q = -13.92$ MeV peak of Fig.2, at $\theta_1$=$\theta_2$=40.5$^o$.

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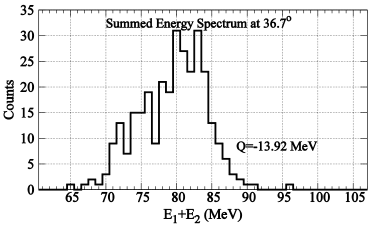


FIG. 4: $E_1 + E_2$ spectrum for $\theta_1$=$\theta_2$=36.7$^o$

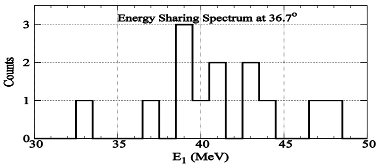


FIG. 5: Energy sharing spectrum for $Q = -13.92$ MeV contributions of Fig.4, at $\theta_1$=$\theta_2$=36.7$^o$.

two peaks on either side of the $E_1$=$E_2$ = 45 MeV dip (the zero recoil momentum position) are estimated to arise as a result of excitation and decay of the $16^+$ - $^{24}Mg$ resonance at 38.5 MeV excitation energy. One of the observed $^{12}C_{g.s.}$'s is scattered inelastically at 40.5$^o$ in one of the detectors with energy $E_1$ = 40 or 46 MeV. The recoiling $^{24}Mg$ in 38.5 MeV $16^+$ excited state, decays into two $^{12}C_{g.s.}$'s one of them is detected at close to $90 - E_1$ MeV energy in the other detector at 40.5$^o$ while the remaining one becoming the spectator $^{12}C$. Surprising observation is that at $E_1 \sim 45$ MeV there should be a peak for $^{12}C$ knockout from $^{24}Mg_{g.s.}$ bound in $\ell = 0$ state instead there are hardly two counts, corresponding to a cross section value of (29±21) $\mu b/sr^2 MeV$.

Comparing our FR-DWIA calculations with this $E_1$ = 45 MeV experimental value for the knockout contribution. An all through attractive (A) $^{12}C$-$^{12}C$ interaction potential (used for generating the $t$-matrix) provides a cross section value of 17.8 $\mu b/sr^2 MeV$, a value within the error bars of the experimental value but indicating that $^{24}Mg$ is fully clustered into $^{12}C$+$^{12}C$. However taking the clue from our previous$^{16}O(^{12}C, 2^{12}C)^4He$ results [4] it is apparent that $^{12}C$-$^{12}C$ interaction potential is having a repulsive core of more than $\sim$ 3.3 $fm$. Therefore using a repulsive core $^{12}C$-$^{12}C$ potential we obtained an enhancement of ∼50, almost two orders of magnitude corresponding to a cross section value of 874 $\mu b/sr^2$ MeV, leading to a vary small value of spectroscopic factor of $\sim$ 0.033. Thus a consistent understanding of ($^{12}C$, $2^{12}C$) reactions on both $^{16}O$ and $^{24}Mg$ indicates that $^{24}Mg_{g.s.}$ is having only a very small parentage of $^{12}C$-$^{12}C$ structure.

We now look at the summed energy spectrum for $\theta_1$=$\theta_2$=36.7$^o$, in Fig.4. It is to be stressed here that corresponding to this angle pair the kinematics allows the 38.5 MeV $16^+$ resonances to coincide at $E_1$=45 MeV. This means that both the detected $^{12}C$'s at $\sim$ 45 MeV kinetic energy each make the 38.5 MeV resonance with the undetected recoiling $^{12}C$. Corresponding to the $Q \sim$ -13.92 MeV peak in the summed energy spectrum the energy sharing distribution is shown in Fig.5. Curiously it is observed that corresponding to $E_1$=$E_2$ $\sim$ 45 MeV let alone a peak there is not a single count at this location. The reason for this missing peak at the position where the two resonances are supposed to occur simultaneously is ascribed to be the perturbation caused by one resonance on another. This killing of the overlapping two body resonances in a three body final state of three $^{12}C$'s can be understood in terms of similar behavior in classical mechanics of the 'Kirkwood Resonances'. This phenomena is observed, for example, in the perturbation caused by Saturn's moon on the Saturn's rings such that the orbits in the rings affected by this perturbation are missing. Similarly there are missing asteroid belts between the Jupiter and Sun, due to some frequency matching of the asteroid with that of the Jupiter around the Sun. The perturbation results in killing that asteroid belt. It is probably the first time this classical perturbation phenomenon has been observed at the nuclear scale.

## References

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