

## Analysis of carbon fragments emissions in the decay of light mass composite nuclei

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### Introduction

In recent works, we have investigated extensively the decay of number of light mass compound systems (CS) formed in heavy ion reactions. The collective clusterization approach of dynamical cluster decay model (DCM) [1–5] has been extended successfully to study these very light mass CS i.e.  $^{20,21,22}\text{Ne}^*$  [1],  $^{26,27,28,29}\text{Al}^*$  [2],  $^{31}\text{P}^*$  and  $^{32}\text{S}^*$  [3],  $^{28,30,31}\text{Si}^*$  [1, 4]. Considering nuclei with quadrupole deformed and compact configurations, a comparative decay analysis of these systems had been undertaken for the emission of different intermediate mass fragments (IMFs) or clusters. The clustering effects in decay of  $^{20}\text{Ne}^*$  has been exclusively explored within the quantum mechanical fragmentation theory (QMFT) followed by DCM to address decay of the same at higher excitation energies. The results are very well supported by the relativistic mean field theory and the Ikeda diagrams [1]. Further, the study reveals the presence of competing reaction mechanisms of compound nucleus (fusion-fission, FF) and of non-compound nucleus origin (deep inelastic orbiting, DIO) in the decay of these CS  $^{20,21,22}\text{Ne}^*$ ,  $^{28}\text{Si}^*$  and  $^{32}\text{S}^*$ , at different excitation energies. The DIO contribution in the IMF cross section  $\sigma_{IMF}$  is extracted for these composite systems,  $\sigma_{IMF}$  is given as the sum of FF cross section  $\sigma_{FF}$  and DIO cross section  $\sigma_{DIO}$ . The study of CS  $^{26,27,28,29}\text{Al}^*$  and  $^{31}\text{P}^*$  shows the presence of FF component in the  $\sigma_{IMF}$ , the contribution of non-compound nucleus effects has not been observed for these systems. The DCM calculated  $\sigma_{FF}$  are in good agreement with the available experimental data for these light mass CS. Here, in the decay of CS, the

decaying fragments are first preformed with certain probability  $P_0$ , and then tunnel the potential barrier with penetration probability  $P$ . The preformation probability  $P_0$  carries the information about the competition of various decaying fragments, which in turn depends upon their minimized fragmentation potential. This means that  $P_0$  carries the significant information about nuclear structure which is missing in the statistical models. Furthermore,  $P$  affects the decay cross section of IMFs emissions. Note that  $P_0$  and  $P$  are the main contributors for the calculation of decay cross section.

It is interesting to mention here that in the above mentioned studies, IMF  $Z=6$  is quite prominent as compared to its neighboring fragments which is also observed in the experimental data. In this work we have explored the systematics of the DCM calculated  $\sigma_{IMF}$  for  $Z=6$  i.e. decay cross section of carbon fragments  $\sigma_C$  at different compound nucleus excitation energies ( $E_{CN}^*$ ), for the CS  $^{20,21,22}\text{Ne}^*$  and  $^{26,27,28,29}\text{Al}^*$ .

### Methodology

The DCM [1–5] is worked out in terms of collective co-ordinates of mass (and charge) asymmetries, for  $\ell$ -partial waves, gives the compound nucleus (CN) decay cross-section as

$$\sigma = \frac{\pi}{k^2} \sum_{\ell=0}^{\ell_{max}} (2\ell+1) P_0 P; \quad k = \sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \quad (1)$$

where,  $\mu = [A_1 A_2 / (A_1 + A_2)] m$  is the reduced mass, with  $m$  as the nucleon mass and  $\ell_{max}$  is the maximum angular momentum.  $P$  is penetrability of interaction barrier (of the preformed clusters with preformation probability  $P_0$ ), calculated as the WKB tunneling probability, around the Interaction barrier.

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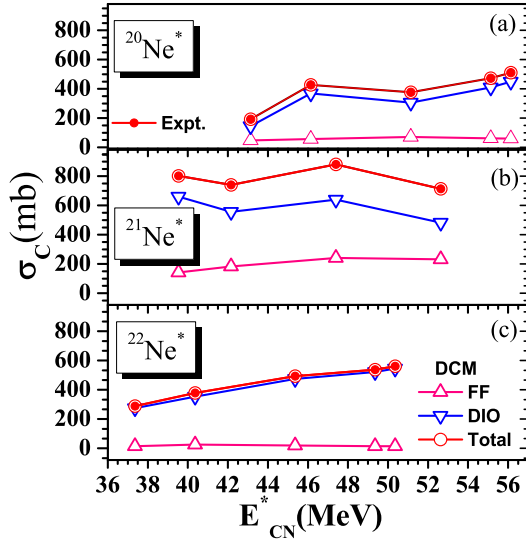


FIG. 1: The variation of  $\sigma_C$  as a function of  $E_{CN}^*$  for the decay of CS a)  $^{20}\text{Ne}^*$ , b)  $^{21}\text{Ne}^*$ , c)  $^{22}\text{Ne}^*$ .

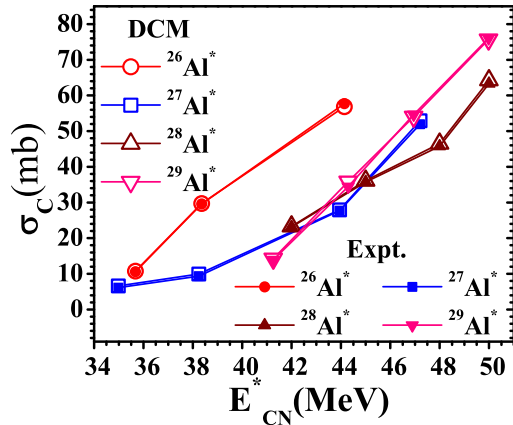


FIG. 2: Same as Fig. 1, but for CS  $^{26,27,28,29}\text{Al}^*$ .

### Calculations and Discussions

Fig. 1 shows the variation of  $\sigma_C$  with  $E_{CN}^*$  of CS a)  $^{20}\text{Ne}^*$ , b)  $^{21}\text{Ne}^*$ , c)  $^{22}\text{Ne}^*$ . In Fig. (a) we see that in the decay of composite system  $^{20}\text{Ne}^*$ ,  $\sigma_C$  has a very small contribution from FF process whereas DIO process contributes the most. However, there is competition between both the processes for the decay of  $^{21}\text{Ne}^*$  (Fig. 1 (b)), as  $\sigma_C$  in this case having noticeable contribution from FF process though it is smaller than that of DIO process. Fig. 1(c) presents the totally dominating scenario by the DIO process, as  $\sigma_C$  has almost

all the contribution from this process. It is important to point out here that experimental verification of these results will be highly interesting as the contribution from both the processes has been evaluated within DCM [1]. Fig. 2 gives results for  $\sigma_C$  in the decay of  $^{26,27,28,29}\text{Al}^*$  CS, due to FF process only as the contribution of non-compound nucleus effects has not been observed for these systems, mentioned in the introduction also. It is relevant to mention here that earlier investigations have revealed that the  $Z=6$  (carbon) fragments are strongly favored of all the IMFs in case of all the isotopes of  $\text{Al}^*$ , i.e having largest values of  $P_0$  [2]. In Fig. 2 we find that  $\sigma_C$  increases with rise in  $E_{CN}^*$  for all  $\text{Al}^*$  isotopes. Moreover, at fixed  $E_{CN}^* \sim 44$  MeV, we find that  $\sigma_C$  is maximum for  $^{26}\text{Al}^*$  and least for  $^{27}\text{Al}^*$  composite system. These results are in good agreement with the experimental data. The present investigation is highly motivating to further study the  $\sigma_C$  in the decay of few more CS in this mass region, before reaching the final conclusion.

### References

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