Dynamics of loosely bound nuclei in production of intermediate mass fragments in heavy-ion collisions

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Introduction

In heavy-ion collisions, the study of nuclear multifragmentation is found to be one of the major tool to understand the behavior of hot and dense nuclear matter. The collisions are found to show a wide range of results depending upon the incident energy, impact parameter, mass asymmetry, isospin asymmetry, structural effects of the nuclei of the colliding nuclei etc. Previously, the studies about the IMF's have given pivotal role in experimental as well as in theoretical investigations towards the peak energy and fragment productions. For e.g., the rise and fall behavior of intermediate mass fragments for different reactions is analyzed by Sisan *et al.* [1]. On the same hand, similar theoretical studies are also reported same rise and fall behavior using the quantum molecular dynamics model [2]. Substantial number of attempts has been done in the past both experimentally and theoretically to explore the structural effects of the nuclei on the fragmentation pattern. The radii of the colliding nuclei play crucial role towards the structural effects at low energy phenomena for e.g. fusion barrier, cluster radio-activity, binding energies, neutron skin thickness, etc. However, the nuclear radii parametrization plays important role at intermediate energies also for e.g. Puri and collaborators reported strong role of nuclear structural effects on the collective flow and the transverse flow [3]. In many preceding studies, with the extended matter distribution of nucleus the fusion probabilities are studied using different proximity based potentials in which they revealed that the fusion probabilities are enhanced for the extended nuclei [4]. At intermediate energy, Liu *et al.* [5], considered the extended structure of nuclei on fragmentation and momentum dissipation. They manifested that the extended structured nuclei increases the fragment multiplicity at lower energies.

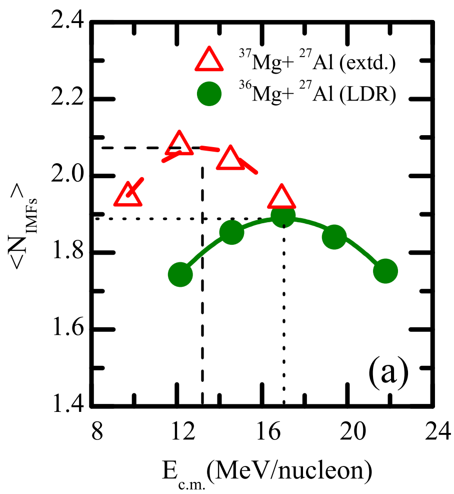

FIG. 1: The multiplicities of IMF's ($< N_{IMFs} >$) as a function of center-of-mass energy ($E_{c.m.}$) for the reactions involving $^{37}Mg+^{27}Al$ (Triangles) and $^{36}Mg+^{27}Al$ (Circles).

Results and Discussions

The current study is performed within the framework of Quantum Molecular Dynamics (QMD) model. The QMD model is a many body theory which simulates the heavy-ion reactions on an event-by-event basis, further details of which can be found in [6]. The simulations are performed for the comparative analysis of the central reactions of ^{37}Mg+^{27}Al and

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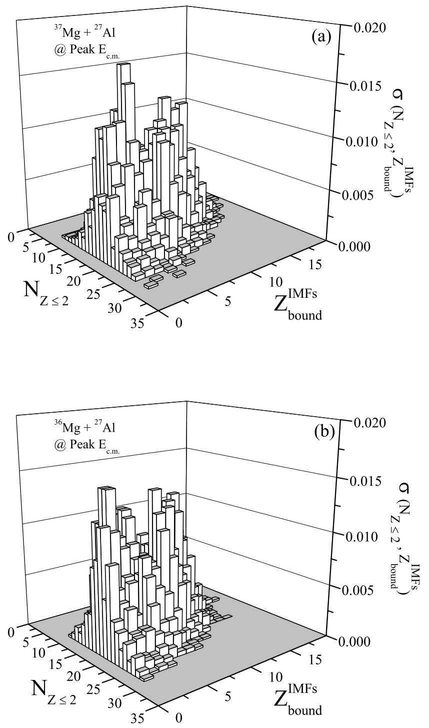

FIG. 2: The event-by-event correlations among the multiplicity of lighter fragments ($N_{Z\leq2}$) and charge bound in the intermediate mass fragments (Z^{IMFs}_{bound}) for the reactions of ^{37}Mg +^{27}Al (upper panel) and ^{36}Mg +^{27}Al (lower panel) at peak energy of IMF's production.

^{36}Mg+^{27}Al using soft equation of state. Here, we took ^{37}Mg and ^{36}Mg as projectiles with extended and LDR radius for the former and latter case. The extended radius of ^{37}Mg is taken as 6.041 fm, which is reported as halo nucleus as it deviates from A$^{1/3}$ form.

In order to check the crucial role of extended nucleus at intermediate energy regime towards the peak E$_{c.m}$ and peak N$_{IMF}$, we plot in fig.1, the peak N$_{IMF}$ as a function of center-of-mass energy for ^{37}Mg+^{27}Al and ^{36}Mg+^{27}Al. To estimate the peak $E_{c.m.}$ at which maximum emission of IMF's occurs, curves which represent the quadratic fit is also used for our calculations. Over here, a clear well established rise and fall behavior for both the reactions is observed as mentioned in Refs.[1, 2]. Although, it is also seen that for the extended ^{37}Mg nucleus the rise and fall of N$_{IMF's}$ production takes place at lower incident energy i.e. E$^{max}_{c.m}$ ∼ 13.21 in contrast to ^{36}Mg LDR radius i.e. E$^{max}_{c.m}$ ∼ 17.02. This can be elucidated as ^{37}Mg has larger radius compared to ^{36}Mg which causes it to be having a loosely bound structure. This larger radius generates it to have smaller Fermi momentum and lesser binding energy also. Owing to this loosely bound structure of the nuclei, lesser energy is needed to break the correlations among the nucleons.

To explore, what is happening within the events for the extended and LDR nuclei induced reactions, the event-by-event correlations is investigated at peak center-of-mass energy in fig. 2. At particular, the correlated events are obtained by picking up the events having certain specific value of N$_{Z\leq2}$ in co-occurrence with Z$^{IMFs}_{bound}$. Specifically, the fragment of one event with charge and number of fragments in the partition are taken into account. This particular exploration will help us to understand how the IMF's are distributed within the events for both the reactions at the peak E$_{c.m}$. Since the peak E$_{c.m}$ is quite different for both the reactions, but the correlations for the reactions is quite similar. So, we may say that the extended structure of the nucleus greatly change the energy of peak IMF's production. The dynamics of extended nucleus induced reactions is almost same to that of the LDR nucleus induced reactions at peak energy.

References

[1] D. Sisan *et al.,* Phys. Rev. C **63**, 027602 (2001).

[2] S. Kaur and R. K. Puri, Phys. Rev. C **87**, 014620 (2013); P. Bansal, S. Gautam and R. K. Puri, Eur. Phys. J. A **51**, 139 (2015).

[3] R. Bansal *et al.,* Phys. Rev. C **87**, 061602 (R) (2013); S. Gautam, Phys. Rev. C **88**, 057603 (2013).

[4] R. Kumari, Nucl. Phys. A **917**, 85 (2013).

[5] J. Y. Liu *et al.,* Phys. Lett. B **617**, 24 (2015).

[6] J. Aichelin, Phys. Rep. **202**, 233 (1991).