Participant-spectator dynamics on peak mass production of IMFs

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Introduction

The reaction dynamics of mass asymmetric systems (where the mass asymmetry of reaction is defined as $\eta = \mid \frac{A_T - A_P}{A_T + A_P} \mid$; A_T (A_P) is the mass of target (projectile)) is quite different from symmetric systems was first noted by FOPI group [1]. It was found that in symmetric reactions ($\eta = 0$) the excitation energy is deposited in the form of compressional energy whereas in case of asymmetric reactions ($\eta \neq 0$) most of the excitation energy deposited in the composite system is in the form of thermal energy. In last few decades considerable progress has been made on the understanding of fragmentation of mass asymmetric reactions both experimentally and theoretically. In symmetric and asymmetric reactions, the rise and fall behavior of intermediate mass fragments (IMFs) is observed with incident energy as well as with impact parameter. The center of mass (lab) energy at which maximum multiplicity of IMFs is observed is termed as $< E^{max}_{c.m.} >$ ($< E^{max}_{lab} >$) and corresponding IMFs multiplicity as $< N^{max}_{IMFs} >$. Peaslee *et al.* studied the energy dependence of fragmentation of ^{84}Kr + ^{197} Au asymmetric collisions between 35 and 400 MeV/nucleon and observed the maximum IMFs production at 100 MeV/nucleon [2]. Sisan *et al.* performed a systematic study for symmetric and nearly symmetric reactions to see mass dependence of $< N^{max}_{IMFs} >$ and $< E^{max}_{c.m.} >$ [3]. Schüttauf *et al.* studied the collision of ^{129}Xe, ^{197}Au and ^{238}U projectiles with Be, C, A1, Cu, In, Au and U targets at incident energies between 400 and 1000 MeV/nucleon [4]. They studied that the energy of peak intermediate mass fragments (IMFs) production vary linearly with the projectile mass. In a detailed investigation Puri *et al.* found that the $< E^{max}_{c.m.} >$ is insensitive to different isotopes whereas for isobars a decreasing trend with a rise in the neutron content was found [5]. Recently, Puri *et al.* studied $< E^{max}_{c.m.} >$ for various asymmetric reactions using Isospin-dependent Quantum Molecular Dynamics (IQMD) model and results were found consistent with the available experimental data [6]. They also investigated the mass dependence of $< E^{max}_{c.m.} >$ for various mass asymmetries. Considering this we perform a study to disentangle the contribution of spectator and participant matter in the peak production of IMFs for various mass asymmetric reactions. The Isospin-dependent Quantum Molecular Dynamics (IQMD) model [7] along with clusertization algorithm based on spatial constraints [8] is used for the present study.

Results and Discussion

In the present study we have simulated the semi-central reactions of ^{80}Se+^{80}Se, ^{50}Ti+^{112}Pd and ^{27}Mg+^{138}Ba having different mass asymmetry factor (η) of 0.00, 0.38 and 0.67, respectively at incident energies between E$_{lab}$ = 45 - 300 MeV/nucleon. The total charge of colliding partners is fixed to 68, mass to $\sim$ 162 and N/Z ratio to $\sim$ 1.4.

In Fig. 1 and 2, the rise and fall trends in the multiplicity of IMFs (5$\leq$ A$_f$ $\leq A_{total}/6$) in spectator and participant zone are shown, respectively. We have defined participant and spectator matter in terms of rapidity as Y$_{c.m.}$/Y$_{beam}$ is divided into participant (-0.5 $\leqslant$Y$_{c.m.}$/Y$_{beam}$ $\leqslant$ 0.5) and spectator (-0.5 > Y$_{c.m.}$/Y$_{beam}$ > 0.5) regions. From the figures,

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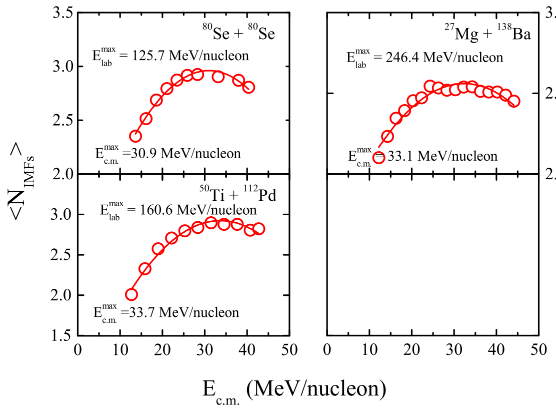

FIG. 1: The multiplicity of IMFs ($< N_{IMFs} >$) of spectator zone as a function of centre-of-mass incident energy (E$_{c.m.}$) for the different asymmetric reactions.

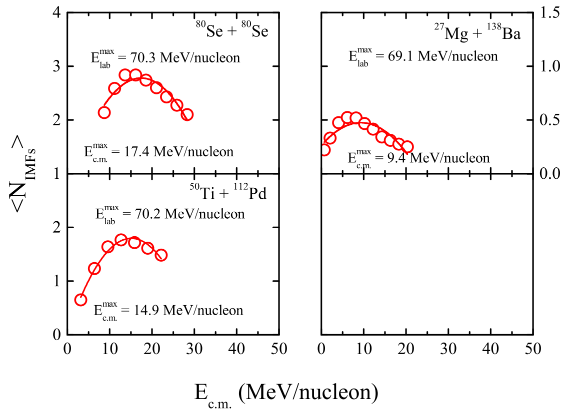

FIG. 2: The multiplicity of IMFs ($< N_{IMFs} >$) of participant zone as a function of centre-of-mass incident energy (E$_{c.m.}$) for the different asymmetric reactions.

one can observe that the peak IMFs multiplicity for spectator part is obtained at much higher incident (lab) energy compared to the IMFs produced from participant region. This is because spectator region has low excitation energy than participant region, thus a higher beam energy is required for mass breakage. We also notice that almost equal number of IMFs are produced from participant as well as spectator region (slightly higher for spectator as expected). However, during collision of asymmetric reactions, spectator region is dominated in governing the IMFs multiplicity. Also, it is observed that though multiplicity of IMF's originated from participant region is greatly reduced with mass asymmetry of colliding partners, however, the incident (lab) energy corresponding to peak IMFs multiplicity is similar for reactions. This may happen because of same excitation of overlapping region in mass symmetric as well as asymmetric reactions. On the other hand, spectator region excitation is greatly reduced for asymmetric reactions. Consequently, IMFs productions takes place at much higher beam energies. It is worth mentioning that $< E^{max}_{c.m.} >$ of a colliding system lies in between the peak energies obtained for spectator and participant part, separately.

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