Intermediate mass fragment production due to momentum dependent interactions in mass asymmetric collisions

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Introduction

The study of highly excited and densed nuclear matter is one of the challenging topics of nuclear physics which acts as an important tool to extract information about nuclear equation of state and for understanding of astrophysical happenings such as supernova explosions and physics of neutron stars. The instability of highly excited matter under the conditions of high temperature and density, leads to the total disassembly of the nucleus into free particles, light, medium and intermediate mass fragments (IMFs) which is termed as multifragmentation. It is established that the size of projectile and target combination, quantified in terms of mass asymmerty (η), affects the reaction dynamics[1]. The asymmetry of reaction is defined as $\eta = (A_T - A_P)/(A_T + A_P)$; A_T, A_P are masses of target and projectile respectively. The symmetric reaction (η= 0) involves more compression while the asymmetric reaction ($\eta \neq$ 0) involve more thermalisation.

It is well known that the outcome of a reaction depends not only on incident beam energy, impact parameter and mass asymmetry (η) but also on the relative momentum of the nucleons. The momentum dependent interactions (MDI) play a very important role in understanding the multifragmentation [2]. When the reaction takes place the formation of spectator and participant zone takes place. In the participant zone, the projectile nucleons feel strong repulsion, due to their large relative momenta, from the target nucleons which leads to MDI. Therefore, it is very important to study the formation of the fragments by employing the momentum dependent equation of state. We aim to study the IMF production due to momentum dependent interactions in asymmetric colliding nuclei. For this, the heavy ion collisions of asymmetric colliding pair of nuclei are simulated using the isospin dependent quantum molecular dynamics model and the fragments are constructed with the minimum spanning tree method.

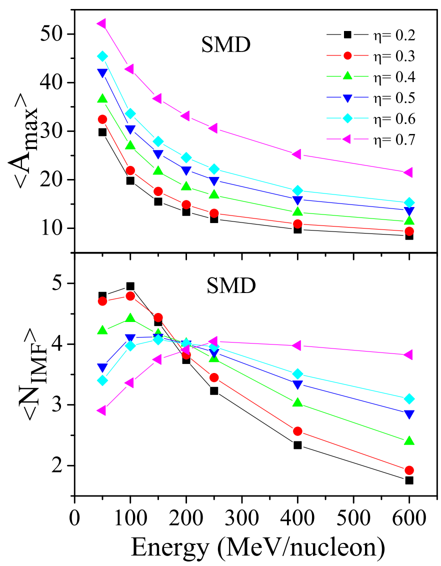

FIG. 1: The variation of A_{max} and IMFs with energy using SMD for different values of η.

Isospin dependent Quantum Molecular Dynamics (IQMD) Model

Isospin dependent quantum molecular dynamics model is an improved version of QMD

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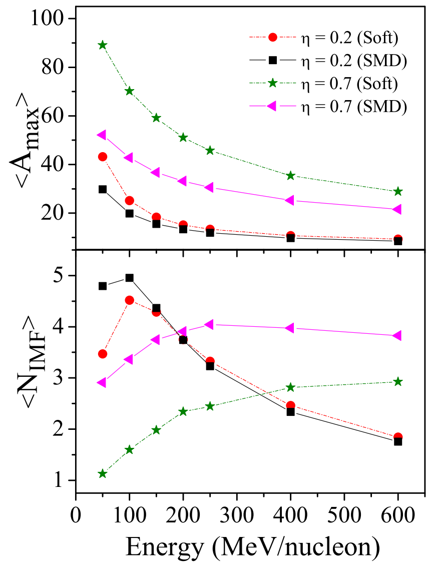

FIG. 2: Comparison of soft [4] and momentum dependent equation of state on A_{max} and IMFs multiplicity.

[3], where nucleons interact via two and three body interactions. The nucleons propagate according to classical Hamiltons equation of motion.

$$\frac{d\overrightarrow{r}_i}{dt} = \frac{d<H>}{d\overrightarrow{p}_i};\frac{d\overrightarrow{p}_i}{dt} = \frac{-d<H>}{d\overrightarrow{r}_i} \qquad (1)$$

with $<H> = <T> + <V>$ is the Hamiltonian.

The interaction potential V^{ij} is given as V^{ij}=V^{ij}_{Sky}+ V^{ij}_{Yuk}+ V^{ij}_{Coul}+ V^{ij}_{MDI}+ V^{ij}_{symm} where V_{Sky}, V_{Yuk}, V_{Coul}, V_{MDI}, V_{symm} represents the Skyrme, Yukawa, Coulomb, momentum dependent and symmetry potentials respectively.

Results and Discussions

To fulfill our aim, we carried out simulations of asymmetric colliding nuclei $_{26}Fe^{56}$+$_{44}Ru^{96}$ (η=0.2), $_{24}Cr^{50}$+$_{44}Ru^{102}$ (η=0.3), $_{20}Ca^{40}$+$_{50}Sn^{112}$ (η=0.4), $_{16}S^{32}$+$_{50}Sn^{120}$ (η=0.5), $_{14}Si^{28}$+$_{54}Xe^{124}$ (η=0.6), $_{8}O^{16}$+$_{54}Xe^{136}$ (η=0.7) for total mass= 152 at semi central impact parameter ($\hat{b}$= 0.3) and energy varying from 50 to 600 MeV/nucleon.

Fig.1 shows the simulation results for variation of A_{max} (heaviest fragment) and IMFs (5≤A≤A_{tot}/6) using soft momentum dependent (SMD) equation of state for different values of mass asymmetry (η). At low energy (50 MeV/nucleon) the excitation energy deposited in spectator part is not large enough, so most of matter is in form of largest/heavy fragment and less number of IMFs for large η. With increase in energy, MDI break the heavy fragments into IMFs. With further increase in energy the IMFs multiplicity decreases due to breaking of IMFs into light fragments.

Fig.2 shows the comparison of impact of soft [4] and momentum dependent equation of state on multiplicity of A_{max} and IMFs at fixed $\hat{b}$= 0.3. From Fig.2 it is clear that MDI has visible impact on A_{max} and IMFs production. The relative multiplicity of IMFs increases by 27.6% , 61% in case of η = 0.2, 0.7 respectively by inclusion of MDI while relative multiplicity of A_{max} decreases by 31%, 41% in case of η = 0.2, 0.7 respectively at E= 50 MeV/nucleon. Thus we observe that the impact of MDI increases with increase in mass asymmetry. Hence the momentum dependent interactions play an important role in fragment production.

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