Nuclear stopping as a probe to study charge asymmetry of system at 600 MeV/nucleon

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Introduction

Heavy-ion collisions at intermediate and high energies provide us with unique opportunity to study the properties of hot and dense nuclear matter. The nuclear matter at high densities and temperature aids in extracting information about nuclear equation of state (EOS). Nuclear multifragmentation is observed to be important reaction mechanism at intermediate energy heavy-ion collisions. The isospin dependence of nuclear fragmentation has been extensively studied experimentally as well as theoretically using observables such as isospin diffusion [1], isospin fractionation [2], liquid-gas phase content [3], etc.. Nuclear stopping is used to study effect of charge asymmetry on the equilibrium processes of colliding systems. Nuclear stopping can be studied using various observables such as R_p, R_E, *vartl* and Q_{zz}. In the present study nuclear stopping of all fragments and intermediate mass fragments ($6 \leq A_f \leq 43$) is studied for isobaric and isotopic pairs using Isospin dependent Quantum Molecular Dynamics (IQMD) [4] model. Here R_p, R_E, *vartl* of all fragments and intermediate mass fragments (IMFs) are calculated. All these quantities involve transverse and longitudinal momenta in one or the other form.

R_p is defined as [5]

$$R_p = \frac{2\sum_i^{A_f} p_\perp}{\pi \sum_i^{A_f} p_\parallel} , \tag{1}$$

where $p_\perp(p_\parallel)$ are the transverse (longitudinal) momenta and $\sum$ is over all nucleons or fragments, where $p_\perp = \sqrt{p_x^2 + p_y^2}$.

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R_E is defined as [5]

$$R_E = \frac{\sum_i^{A_f} E_\perp}{\sum_i^{A_f} E_\parallel} , \tag{2}$$

where $E_\perp(E_\parallel)$ is the c.m transverse (parallel) energy and $\sum$ is over all nucleons or fragments.

vartl is the ratio of variances of the transverse to that of longitudinal rapidity distribution and is defined in Ref. [6, 7].

$$vartl = \frac{< y_x^2 >}{< y_z^2 >}, \tag{3}$$

where $<y_x^2>$ and $<y_z^2>$ are the variances of rapidity distribution of particles in the x and z directions.

Results and discussions

We simulated the reactions of ^{107}Sn + ^{nat}Sn, ^{124}Sn + ^{nat}Sn and ^{124}La + ^{nat}Sn for the central collisions (b = 0-2 fm) using soft equtaion of soft. These reactions are simulated at incident energy of 600 MeV/nucleon. In Fig. stopping power of all fragments and IMFs for all the three reaction pairs is displayed. The yield of IMFs at central collisions is shown in the inset. It is observed that when stopping of all fragments is evaluated, it gives same value for isobaric pair i.e, ^{124}Sn + ^{nat}Sn and ^{124}La + ^{nat}Sn and smaller value for ^{107}Sn + ^{nat}Sn due to reduced total colliding mass. However, when stopping of IMFs is studied it is observed that ^{124}Sn + ^{nat}Sn reaction showed higher stopping incomparison to ^{124}La + ^{nat}Sn. It is also noticed that nuclear stopping becomes greater than one due to a larger opening of phase space at such high energy [8]. The yield of IMFs which is shown in the inset is same for all three reacting pair.

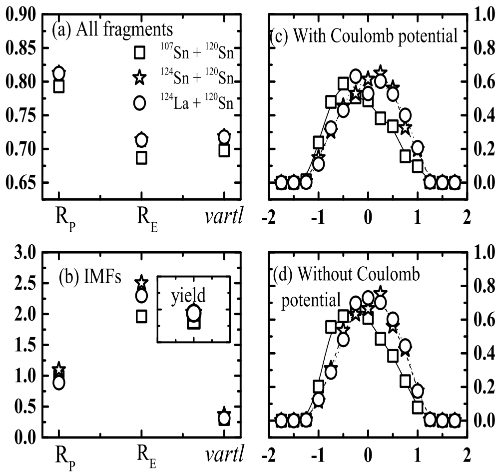

FIG. 1: R_p, R_E, *vartl* of (a) all fragments, (b) intermediate mass fragments (IMFs) ($6 \leq A_f \leq 43$) and rapidity distribution (dN/dy) of intermediate mass fragments (IMFs) (c) with Coulomb (d) without Coulomb in central collisions (b = 0-2 fm) is displayed. Yield of IMFs is shown in the inset for central collisions (b = 0-2 fm).

To further investigate this different behaviour of stopping of IMFs we have probed various parameters such as nuclear symmetry energy, nucleon-nucleon scattering cross-section and Coulomb interaction which could effect the isospin dynamics of reacting partners. The contribution of nuclear symmetry energy is too weak to consider at such high energy and role of nucleon-nucleon collisions is also not very significant which is counter-checked by studying rapidity distribution of isobaric pair. So, only parameter left is Coulomb interactions. Effect of Coulomb interactions on reaction dynamics is shown in the top and bottom right pannel of figure. It is observed ^{124}La + ^{nat}Sn has widened rapidity distribution when compared to its isobaric counterpart. This difference in rapidity distribution is examined by neglecting Coulomb potential from calculations. It is noticed that now rapidity distribution gets narrow down. This is due to the replusive nature of the interactions which pushes the nucleons away from the mid-rapidity resulting in widened rapidity distribution. This effect is weak in ^{124}Sn + ^{nat}Sn due to weaker role of Coulomb potential. Thus, we can conclude that nuclear stopping is a good probe to study charge asymmetry of system at 600 MeV/nucleon.

References

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