Influence of isospin momentum dependent interaction on the energy of vanishing flow

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Introduction

The heavy-ion collisions at intermediate energies provide a rich physical insight into the reaction dynamics. Collective transverse flow is preferential emission of the particles within, and to a particular side of reaction plane. At low incident energy, the dominance of the mean field leads to attractive collective transverse flow which turns positive at higher incident energy due to the dominance of nucleon-nucleon collisions while going from low to the higher incident energy, collective flow vanishes at a particular incident energy labeled as energy of vanishing flow or balance energy (E_{bal}). E_{bal} has been found to be sensitive towards the nuclear matter equation of state (EOS). The role of momentum dependent interactions (MDI) on the dynamical process in the heavy ion collisions has been in usage for many years. Recently, Liu et al. [1] considered an isospin degree of freedom in MDI to obtain isospin momentum dependent interactions (Iso-MDI). They attempted to study the role of Iso-MDI on the isospin fractionation ratio and its dynamical mechanism at intermediate energies. In present analysis we have tried to study the effect of Iso-MDI on the energy of vanishing flow or balance energy. The study is carried out within the framework of IQMD [2] model.

Results and Discussion

For the present analysis, we simulate several thousands of events for each reaction at incident energies around E_{bal} in steps of 10 MeV/nucleon for each isotopic system of Ca+Ca and Xe+Xe. In particular, we simulate the reactions of ^{40}Ca+^{40}Ca, ^{44}Ca+^{44}Ca, ^{52}Ca+^{52}Ca, ^{56}Ca+^{56}Ca, ^{60}Ca+^{60}Ca at scaled impact parameter of (b/b_{max}=0.4) and ^{120}Xe+^{120}Xe, ^{124}Xe+^{124}Xe, ^{130}Xe+^{130}Xe, ^{136}Xe+^{136}Xe, ^{140}Xe+^{140}Xe for colliding geometry (b=0-3 fm). We use soft and hard EOS with MDI, without MDI and with Iso-MDI, labeled, respectively as Soft, SMD and Iso-SMD. Similarly, for hard EOS, Hard, HMD, Iso-HMD. For the transverse flow, we use the quantity, "directed transverse momentum" defined as:

$$\left\langle p_x^{dir} \right\rangle = \frac{1}{A}\sum_{i=1}^{A} \mathrm{sgn}\{Y(i)\} p_x(i),$$

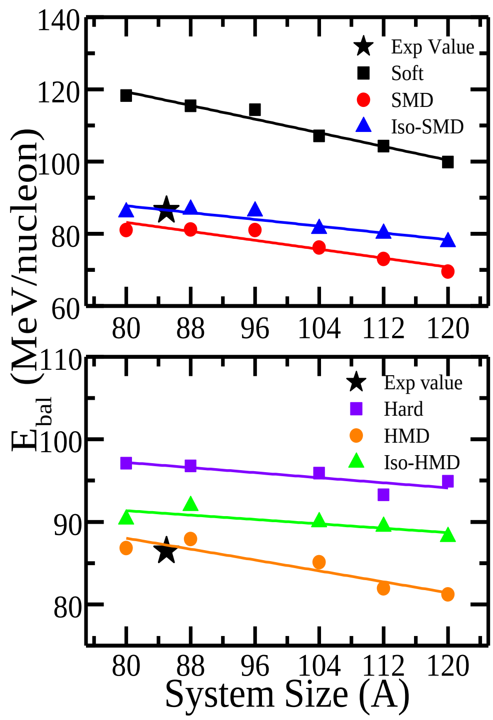

Fig. 1 E_{bal} as a function of combined mass of system (A) for isotopic series of Ca. Upper panel is for soft EOS and lower panel is for hard EOS. Various symbols are explained in the text.

Where $Y(i)$ is the rapidity and $p_x(i)$ is the momentum of ith particle. The rapidity is defined as [3],

$$Y(i) = \frac{1}{2}\ln\frac{E(i)+p_z(i)}{E(i)-p_z(i)},$$

where $E(i)$ and $p_z(i)$ are the energy and longitudinal momentum of ith particle, respectively. In Fig.1 we display the E_{bal} as a function of combined mass for isotopic series of Ca for soft and hard equations of state (EOS). Black squares, red circles and blue triangles represents the Soft, SMD and Iso-SMD EOS respectively and violet squares, orange circles and green triangles represents the Hard, HMD, and Iso-HMD EOS respectively.

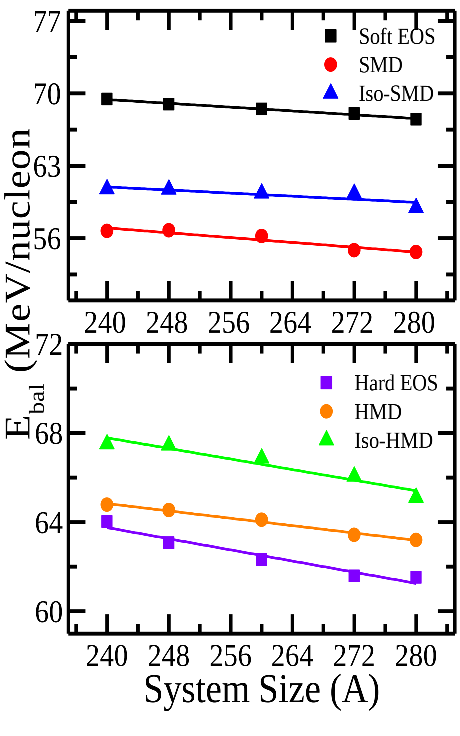

Fig. 2 E_{bal} as a function of combined mass of system (A) for isotopic series of Xe. Upper panel is for soft EOS and lower panel is for hard EOS. Various symbols are explained in the text.

As the total mass of the system increases the E_{bal} decreases because of the dominance of the Coulomb interactions in heavier colliding nuclei. It has been found that MDI and Iso-MDI affects drastically the directed transverse flow as well as its disappearance but mass dependence of E_{bal} remains unchanged. With the inclusion of MDI and Iso-MDI there is earlier transition from negative to positive value of directed flow because of the repulsive nature of momentum dependent interactions and hence will lower the balance energy. Balance energy has higher values in case of Iso-MDI compared to MDI because of the inclusion of isospin degree of freedom in MDI the neutron-proton correlations become stronger than neutron-neutron or proton-proton correlations. Our results are in good agreement with experimental data [4] in case of Iso-MDI. In Fig. 2, we display the E_{bal} as a function of combined mass of the system for isotopic series of Xe for different soft and hard EOS. Various symbols are displayed different EOS, similar to that in Fig. 1. Similar results are obtained in case of Xe isotopic series as for calcium isotopic series. In conclusion, the calculated results show that the isospin dependence of MDI brings an important isospin effect into the balance energy in the intermediate energy heavy ion collisions. Therefore, the role of Iso-MDI is important for investigating accurately the equation of state of isospin asymmetric nuclear matter.

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