Mass dependence of balance energy for different N/Z ratio

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Introduction

The investigation of the system size effects in various phenomena of heavy-ion collisions has attracted a lot of attention. The system size dependences have been reported in various phenomena like fusion-fission, particle production, multifragmentation, collective flow (of nucleons/fragments) as well as its disappearance, density, temperature and so on. The collective transverse in-plane flow has been investigated extensively during the past three decades and has been found to depend strongly on the combined mass of the system in addition to the incident energy as well as colliding geometry [1]. The energy dependence of collective transverse in-plane flow has led us to its disappearance. The energy at which flow disappears has been termed as the balance energy (E_{bal}) or the energy of vanishing flow (EVF). E_{bal} has been found to depend strongly on the combined mass of the system [1]. With the advent of radioactive ion beams the role of isospin degree of freedom on dynamics of heavy-ion collisions has been studied for the past decade. These studies are helpful to extract information about the asymmetric nuclear matter. In recent study Gautam et al. [2] has reported the different magnitude of isospin effects for different system masses. Here using IQMD model [3] we aim to study the mass dependence of E_{bal} for various N/Z ratios covering pure symmetric systems to highly neutron-rich ones.

Results and Discussion

We simulate the reactions of Ca+Ca, Ni+Ni, Zr+Zr, Sn+Sn, and Xe+Xe with N/Z varying from 1.0 to 2.0 in small steps of 0.2. The reactions are simulated at different incident energies around E_{bal} in small steps of 10 MeV/nucleon. Collective transverse in-plane flow is then calculated at each incident energy. Then straight line interpolation is used to calculate the E_{bal}. Where E_{bal} is the energy of vanishing flow. In Fig. 1, we display the percentage difference ($\Delta E_{bal}(\%)= \frac{E_{bal}^{symmoff} - E_{bal}}{E_{bal}}$) between calculations for E_{bal} without symmetry energy and with symmetry energy as a function of N/Z for Ca (pentagons) and Xe (hexagons) series. We see that the percentage difference increases with increases in N/Z for both Ca and Xe series, which shows that the effect of symmetry energy increases with increase in N/Z. The increase is more sharp for Ca series as compared to Xe, which indicates that with increase in N/Z the effect of symmetry energy increases more sharply for Ca as compared to Xe series. We also see that for N/Z = 1.0, the role of symmetry energy is same throughout the mass range as far as E_{bal}

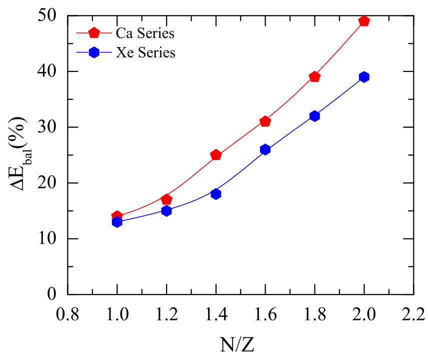

FIG. 1: N/Z dependence of $\Delta E_{bal}(\%)$ for Ca and Xe series. Various symbols are explained in text. Lines are only to guide the eye.

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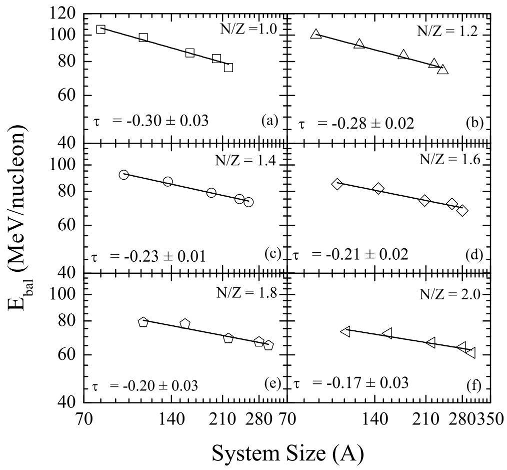

FIG. 2: System size dependence of E_{bal} for various N/Z ratios. Lines are of power law fit ($\propto A^{\tau}$).

is concerned.

In Fig. 2, we display the system size dependence of E_{bal} throughout the N/Z range from 1-2.We find that for each N/Z, E_{bal} follows a power law behavior ($\propto A^{\tau}$) with power law parameter τ = -0.30±0.03, -0.28±0.02, -0.23±0.01, -0.21±0.02, -0.20±0.03, and -0.17±0.03 for N/Z = 1.0 (open squares), 1.2 (triangles), 1.4 (circles), 1.6 (diamonds), 1.8 (open pentagons), and 2.0 (left triangles), respectively. We find that the value of τ decreases with increase in N/Z of the systems. This is due to that fact that for higher N/Z ratio the effect of symmetry energy is more in lighter masses (as discussed previously), thus decreasing the E_{bal} by larger magnitude on inclusion symmetry energy in lighter masses which results in less slope for higher N/Z ratio. Here we would like to stress that with increase in N/Z for a given mass (compare mass of about 120 in Fig. 2(a) and 2(b)), the E_{bal} decreases which is quite the opposite trend to the data [4]. Since we have taken the isotopes of a given element, where the data is for isobars and in Ref. [2] it has been shown clearly that Coulomb repulsion plays much more dominant role over symmetry energy in isospin effects (if one considers isobars) throughout the mass range and colliding geometry. Since Coulomb is repulsive so it lowers the E_{bal} in isobaric system with small N/Z. For isotopes Coulomb will be same, the effect of symmetry energy (repulsive for neutrons and attractive for protons) will be more in isotopic system with larger N/Z thus lowering E_{bal} for system having larger N/Z.

Acknowledgments

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