Effect of isospin degree of freedom on the counterbalancing of collective transverse in-plane flow

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Introduction

Isospin degrees of freedom play an important role in heavy-ion collisions (HIC) through both nn collisions and equation of state (EOS). To access the EOS and its isospin dependence it is important to describe observables which are sensitive to isospin degree of freedom. Collective transverse in-plane flow as well as its disappearance has been found to be one such observable [1] where it is well known that there exists a particular incident energy called as balance energy (E_{bal}) at which in-plane transverse flow disappears [2]. The disappearance of flow occurs due to the counterbalancing of attractive and repulsive interactions. In literature [3, 4]the isospin dependence of collective flow as well as its disappearance has been explained to be a result of complex interplay between various reaction mechanisms, such as nn collisions, symmetry energy, surface properties of colliding nuclei and Coulomb repulsion. Here we aim to understand the effect of above mentioned mechanisms on the counterbalancing of collective flow. The present study is carried out within the framework of IQMD [5] model.

Results and Discussion

We calculate E_{bal} for isobaric pairs with N/Z = 1 and 1.4 throughout the mass range. In Figs. 1(a), (b), and (c), we display E_{bal} as a function of impact parameter b for masses 116, 192, and 240, respectively, for both the full and reduced Coulomb. For the full Coulomb (green circles), for all the masses at all colliding geometries, the system with higher N/Z

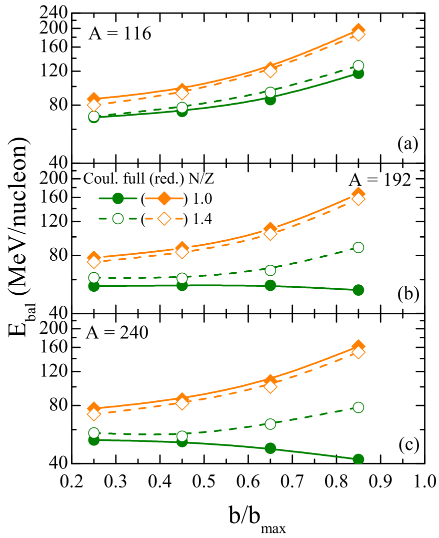

FIG. 1: E_{bal} as a function of impact parameter for different system masses. Symbols are explained in the text. Lines are only to guide the eye.

(open symbols) has larger E_{bal} in agreement with previous studies [1, 3, 4]. Moreover, the difference between E_{bal} for a given mass pair, increases with the increase in colliding geometry. This is more clearly visible in heavier masses. Also for N/Z = 1.4, E_{bal} increases with the increase in impact parameter. However for N/Z = 1 (solid symbols), the increase in E_{bal} with the impact parameter is true only for a lighter mass system such as A = 116. For heavier masses, E_{bal} in fact, begins to decrease with the increase in impact parameter in contrast to the previous studies [1, 3]. However, when we reduce the Coulomb [by a factor of 100 (diamonds)], we

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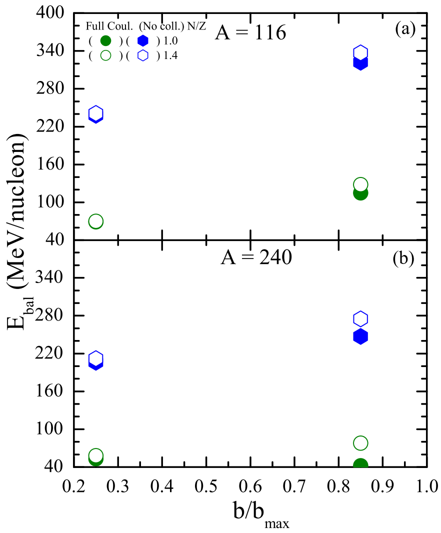

FIG. 2: E_{bal} for central and peripheral collisions with no nn collisions. Symbols are explained in the text.

find that: (i) Neutron-rich systems have a decreased E_{bal} as com pared to neutron-deficient systems. This is true at all the colliding geometries throughout the mass range. This also shows the dominance of Coulomb repulsion over symmetry energy in isospin effects. (ii) The difference between E_{bal} for systems with different N/Z remains almost constant as a function of colliding geometry, which indicates that the effect of the symmetry energy is uniform throughout the range of b. This also shows that the large differences in E_{bal} values for a given isobaric pair are due to the Coulomb repulsions. (iii) In heavier systems, at peripheral colliding geometry, the increase in E_{bal} is more in systems with $N/Z = 1$ compared to $N/Z = 1.4$, which shows the hugely dominant role of Coulomb repulsion at high colliding geometry and a large amount of energy is needed to counterbalance the effect of mean field.

To understand the counterbalancing of Coulomb repulsion and mean field in lighter and heavier systems, we switch off the collision term and calculate the E_{bal} for A = 116 and 240 at two extreme bins. The results are displayed in Fig. 2. The hexagons represent the calculations without collisions. The other symbols have the same meaning as in Fig. 1. We find that at a given impact parameter E_{bal} increases by a large magnitude for both systems, which shows the importance of collisions. The increase is of the same order for both the masses at both impact parameter bins, indicating the same role of cross section for both lighter and heavier masses. Moreover, the same order of increase of E_{bal} at the central and peripheral colliding geometry (when we switch off the collisions) indicates the importance of collisions at high colliding geometry as well. The effect that E_{bal} decreases with the increase in impact parameter (due to the dominance of Coulomb) for heavy mass systems with $N/Z = 1$ (Fig. 1, lower panel) does not appear here for lighter as well as heavier masses. This also indicates toward the increasing importance of isospin dependence of cross section with increase in impact parameter. Therefore in Fig. 1, the reduced Coulomb allows one to examine the balance of nn collisions and mean field while in Fig. 2 the removal of nn collisions allows one to examine the balance of Coulomb and mean field.

Acknowledgments

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