Study of nuclear dynamics of neutron-rich colliding pair at energy of vanishing flow

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Introduction

The collective transverse in-plane flow has been used extensively over the past three decades to study the properties of hot and dense nuclear matter., i.e., the nuclear matter equation of state (EOS) and in-medium nucleon-nucleon cross section. It has been reported to be highly sensitive to the entrance channel parameters like incident energy, colliding geometry and system size. The energy dependence of flow led to its disappearance at a particular incident energy called energy of vanishing flow (EVF) or balance energy (E_{bal}). A large number of theoretical studies have been carried out in the past studying the sensitivity of E_{bal} to the system size and colliding geometry. Role of isospin degree of freedom in collective transverse in-plane flow and its disappearance has also been a matter of great interest for the past decade [1]. The availability of radioactive ion beams (RIBs) around the world helps in carrying out the studies on the matter lying far away from the stability line. A number of studies have been carried out in the recent past to see the role of isospin degree of freedom in collective flow and its disappearance [1, 2]. In Ref. [3] author and others studied the isospin effects in E_{bal} at all the colliding geometries. A very few studies have been carried out to study other related phenomena at E_{bal} of the neutron-rich systems. An important quantity which reflects the dynamics in a heavy-ion collision is the density and temperature reached in a reaction. In the present paper, we study the density and temperature reached in heavy-ion reactions of neutron-rich matter at E_{bal} using isospin-dependent quantum molecular dynamics (IQMD) model [4].

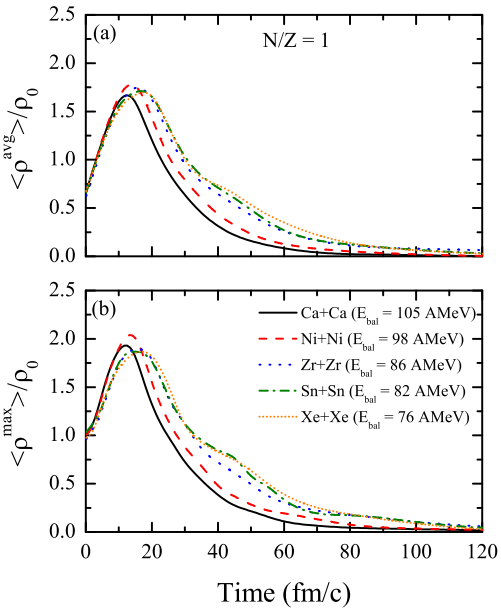

FIG. 1: (Color online) The time evolution of average density (upper panel) and maximum density (lower panel) for systems having N/Z = 1.0. Lines are explained in the text.

Results and discussion

We simulate the reactions of Ca+Ca, Ni+Ni, Zr+Zr, Sn+Sn, and Xe+Xe series having N/Z = 1.0, 1.6 and 2.0. In particular, we simulate the reactions of ^{40}Ca+^{40}Ca (105), ^{52}Ca+^{52}Ca (85), ^{60}Ca+^{60}Ca (73); ^{58}Ni+^{58}Ni (98), ^{72}Ni+^{72}Ni (82), ^{84}Ni+^{84}Ni (72); ^{81}Zr+^{81}Zr (86), ^{104}Zr+^{104}Zr (74), ^{120}Zr+^{120}Zr (67); ^{100}Sn+^{100}Sn (82), ^{129}Sn+^{129}Sn (72), ^{150}Sn+^{150}Sn (64) and ^{110}Xe+^{110}Xe (76), ^{140}Xe+^{140}Xe (68) and ^{162}Xe+^{162}Xe (61) at an impact parameter of b/b_{max} = 0.2-0.4 and at the incident energies

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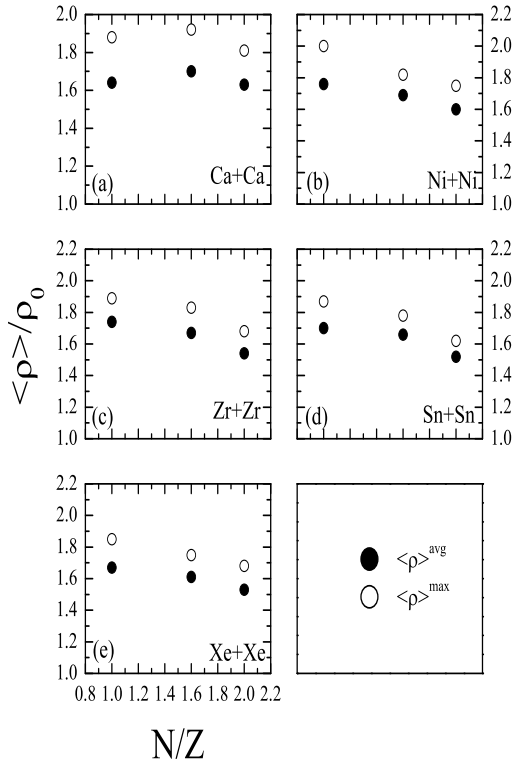

FIG. 2: The N/Z dependence of maximal value of average (solid circles) and maximum density (open circles) for different N/Z ratios.

equal to balance energy. The values in the brackets represent the balance energies for the systems. In fig. 1(a), we display the time evolution of average density (ρ^{avg}/ρ_0) whereas fig. 1(b) displays the time evolution of maximum density (ρ^{max}/ρ_0) for the systems having N/Z = 1.0, i.e, we display the reactions of ^{40}Ca+^{40}Ca, ^{58}Ni+^{58}Ni, ^{81}Zr+^{81}Zr, ^{100}Sn+^{100}Sn, and ^{110}Xe+^{110}Xe at energy equal to balance energy. From figure, we find that maximal value of ρ^{avg}/ρ_0 is higher for lighter systems as compared to the heavier ones. Moreover, the density profile is more extended in heavier systems indicating that the reaction finishes later in heavier systems. This is because of the fact that the heavier reaction occurs at low incident energy. Also the ρ^{avg}/ρ_0 and ρ^{max}/ρ_0 are nearly same for heavier systems but differ for lighter systems. Further, the maximum and average densities are comparable for medium and heavy mass systems indicating that the dense matter is formed widely and uniformly in the central zone of the reaction. On the other hand, the substantial difference in two densities for the lighter colliding nuclei indicates the non-homogeneous nature of dense matter.

In fig. 2 we display the N/Z dependence of maximal value of ρ^{avg} and ρ^{max}. Solid (open) symbols display the results for ρ^{avg} (ρ^{max}). From figure we see that both ρ^{avg} and ρ^{avg} decreases slightly with N/Z of the system for all the system masses. A slight exception to this is there for the lighter mass of Ca+Ca [5].

Acknowledgments

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References

[1] R. Pak *et al.*, Phys. Rev. Lett. **78**, 1022 (1997); *ibid.* **78**, 1026 (1997).
[2] S. Gautam *et al.*, J. Phys G: Nucl. Part. Phys. **37**, 085102 (2010).
[3] S. Gautam and A. D. Sood, Phys. Rev. C **82**, 014604 (2010); S. Gautam *et al.*, Phys. Rev. C **83**, 014603 (2011).
[4] C. Hartnack *et al.*, Eur. Phys. J. A **1**, 151 (1998); R. K. Puri *et al.*, Nucl. Phys. A **575**, 733 (1994); E. Lehmann *et al.*, Phys. Rev. C **51**, 2113 (1995); R. K. Puri *et al.*, J. Comp. Phys. **162**, 245 (2000), A. D. Sood *et al.*, Phys. Rev. C **70**, 034611 (2004)
[5] S. Gautam, Phys. Rev. C **83**, 064604 (2011).