Role of isospin degree of freedom on N/Z dependence of participant-spectator matter

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Introduction

With the availability of high-intensity radioactive beams at many facilities as well as a number of next generation beam facilities being constructed or being planned, the studies on the role of isospin degree of freedom have recently attracted a lot of attention in both nuclear physics and astrophysics. The ultimate goal of such studies is to extract information on the isospin dependence of in-medium nuclear effective interactions as well as equation of state (EOS) of isospin asymmetric nuclear matter. The later quantity especially the symmetry energy term is important not only to nuclear physics community as it sheds light on the structure of radioactive nuclei, reaction dynamics induced by rare isotopes but also to astrophysics community as it acts as a probe for understanding the evolution of massive stars and supernova explosion. Role of isospin degree of freedom has been investigated in collective flow and its disappearance at balance energy [1, 2]. At balance energy, attractive interactions due to mean field are balanced by repulsive interactions due to nucleon-nucleon collisions and this counterbalancing is reflected in quantities like participant-spectator matter [3]. In the present work, we study the role of isospin degree of freedom on the N/Z dependence of participant-spectator matter. The study is carried out within the framework on isospin-dependent quantum molecular dynamics model [4] which is the extension of quantum molecular dynamics model. The IQMD model treats different charge states of nucleons, deltas, and pions explicitly, as inherited from the Vlasov-Uehling-Uhlenbeck (VUU) model.

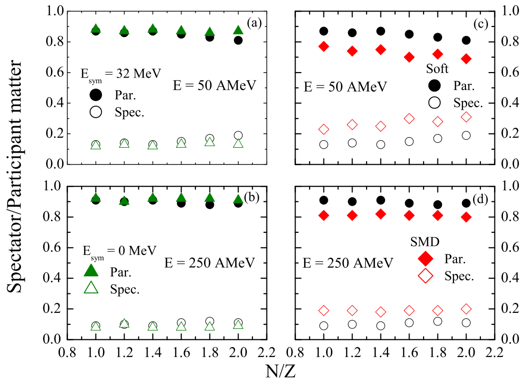

FIG. 1: The N/Z dependence of participant and spectator matter for the reactions of Ca+Ca at 50 (upper panels) and 250 (lower) MeV/nucleon for different N/Z ratios with E_{sym} = 0 MeV (left panels) and MDI (right). Various symbols are explained in the text.

Results and discussion

We simulate the reactions of Ca+Ca series series having N/Z ratio varying from 1.0 to 2.0 in steps of 0.2. In particular we simulate the reactions of ^{40}Ca+^{40}Ca, ^{44}Ca+^{44}Ca, ^{48}Ca+^{48}Ca, ^{52}Ca+^{52}Ca, ^{56}Ca+^{56}Ca, and ^{60}Ca+^{60}Ca at b/b_{max} = 0.2-0.4. The incident energies are taken to be 50 and 250 MeV/nucleon. The reactions are followed till the transverse flow saturates. Since the E_{bal} is smaller in heavier colliding nuclei compared to the lighter ones, so the saturation of transverse flow occurs much earlier in lighter colliding systems as compared to the heavier ones. Though transverse flow saturates much earlier, there are certain variables which keep on

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changing, so we follow all the reactions uniformly upto 800 fm/c.

In fig. 1, we display the N/Z dependence of participant-spectator matter for Ca+Ca reactions (circles). Solid (open) symbols are for participant (spectator) matter. Upper (lower) panels represent the results for 50 (250) MeV/nucleon. From figure, we find that at participant-spectator matter changes slightly with N/Z ratio at lower incident energy of 50 MeV/nucleon. On the other hand, the participant-spectator matter is almost independent of the N/Z ratio at 250 MeV/nucleon. When we increase the N/Z ratio at fixed Z, the mass of the system increases. Due to increase in mass, the participant matter should increase with N/Z (at fixed incident energy). Also, as we moving to higher N/Z ratios, the role of symmetry energy also increases. And due to repulsive nature of symmetry energy, lesser number of collisions will take place at central dense zone and hence amount of participant matter should decrease with increase in N/Z ratio. Hence, the net effect is due to the interplay of mass effects and symmetry energy effects. To see the relative importance of these two effects, as a next step, we make the strength of symmetry energy zero and calculate the participant-spectator matter for Ca+Ca reactions. The results are displayed in Fig. 1(a) (50 MeV/nucleon) and 1(b) (250 MeV/nucleon) (triangles). From figure, we see that on reducing the strength of symmetry energy to zero, the participant (spectator) matter increases (decreases) slightly for higher N/Z ratios whereas the effect on lower N/Z ratios is almost negligible. This indicates that the decrease in participant matter for higher N/Z ratios is due to the role of symmetry energy. The momentum-dependent interactions play significant role in the dynamics of heavy-ion collisions. To see the role of MDI on participant-spectator matter we calculate the participant-spectator matter for SMD EOS for the reactions of Ca+Ca. The results are displayed by diamonds in Fig. 1(c) and 1(d) at 50 and 250 MeV/nucleon, respectively. From figure, we see that participant [closed diamonds] (spectator, open diamonds) matter decreases (increases) with SMD. This is due to the fact that since MDI is repulsive in nature, so the matter is thrown away from the central dense zone and hence lesser number of collisions will take place which leads to decrease (increase) in participant (spectator) matter.

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