Effect of initialization on the entropy production

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Introduction

The knowledge about the hot and dense nuclear matter is essential to probe the nuclear matter equation of state as well as to understand various astrophysical phenomena such as supernova explosion and formation of neutron star etc. Unfortunately, the hot and dense nuclear matter produced in a reaction remains for a very short interval of time ($< 10^{-22}$s). Thus, one needs observables that can preserve the memory of the hot and dense phase of the nuclear matter. The entropy production is proposed to keep the memory of the early phase of the matter [1–4]. Entropy produced in a reaction can be estimated via number of different prescriptions proposed in the literature. Siemens and Kapusta [1] argued that the ratio of the deuterons to protons, (R_{dp}) can be used to measure the entropy. Later on, Bertsch and Cugnon [2] proposed that other light clusters should also be taken into account to have better estimation of the entropy. Therefore, they replaced R_{dp} ratio by the ratio of the deuteronlike to the protonlike clusters. At low incident energies, the contribution of heavier fragments (A>4) may also affect the entropy production [3].

The entropy production is found to remain nearly unaffected by the system mass as well as by the alteration of the incident beam energy [4]. Recently, Puri and co-workers checked the role of various entrance channels, model ingredients and neutron content of reacting partners on the entropy production in heavy-ion collisions [5, 6]. Interestingly, entropy production remained unaffected in almost every case. However, the choice of the Gaussian width of the nucleons affected the entropy production significantly. Around the Fermi energy region, the multiplicity of various fragments is found to be sensitive towards the initial set up of nuclear radius. Therefore, it will be interesting to see how nuclear radius via initialization will affect the entropy production as entropy production depends directly on the production of light clusters.

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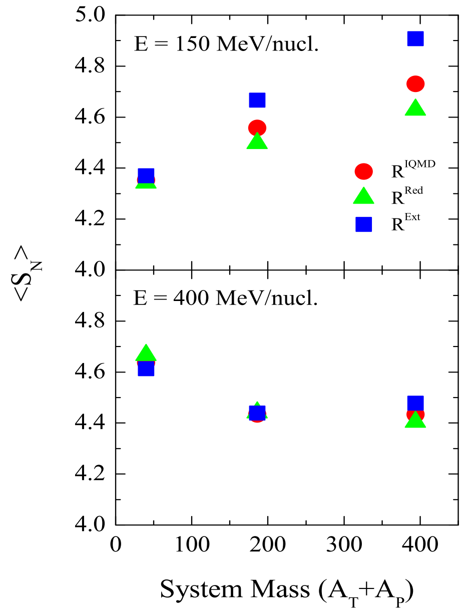

FIG. 1: The system size dependance of the entropy per nucleon at incident energies of 150 (upper panel) and 400 (lower panel) MeV/nucleon.

The present study is carried out within the framework of the isospin-dependent quantum molecular dynamics (IQMD) model [7].

Results and discussion

For the present analysis, we simulated the reactions of ^{20}Ne+^{20}Ne, ^{93}Nb+^{93}Nb and ^{197}Au+^{197}Au at incident energies of 150 MeV/nucleon and 400 MeV/nucleon over whole range of impact parameter ($\hat{b}$ = 0.0

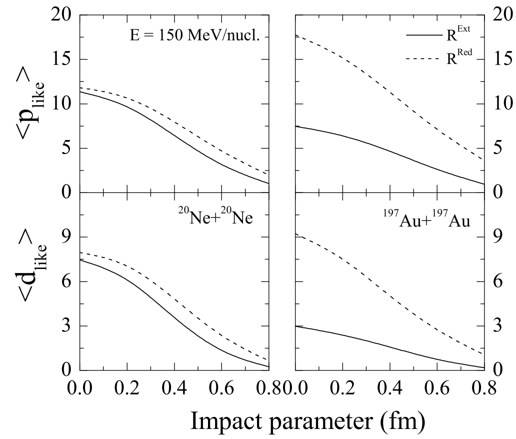

FIG. 2: The yields of $\langle p_{like} \rangle$ and $\langle d_{like} \rangle$ clusters as a function of impact parameter for the reactions of ^{20}Ne+^{20}Ne and ^{197}Au+^{197}Au at incident energies of 150 MeV/nucleon.

- 0.8). Here, a soft equation of state was used along with standard isospin- and energy-dependent cross-section and clusters were identified using minimum spanning tree method. To see the effect of nuclear radius on light cluster formation and entropy production, we reduced (labelled as R^{Red}) and extended (labelled as R^{Ext}) the standard radius used in IQMD model (i.e., liquid drop model) by 10%. The simulations were carried out with reduced Fermi momentum (by 30%). Obviously, the Fermi momentum will be decided accordingly in each case. All reactions are followed till 300 fm/c. The yield ratios are extracted after the compression phase is over and nucleonic density gets saturated ($\sim$ 40 fm/c) as described in Refs. [5, 6].

In Fig. 1, we display the system mass dependance of the entropy at incident energies of 150 (upper panel) and 400 (lower panel) MeV/nucleon. The solid circles, triangles and squares represent the results for normal, reduced and enhanced nuclear radii. From the fig., we see that the entropy is insensitive towards the change in the nuclear radius but shows slight sensitivity towards nuclear radius at 150 MeV/nucleon for heavy system. This sensitivity, however, washes away at 400 MeV/nucleon. To look into this trend, we will check the relative contribution of the p_{like} and d_{like} clusters towards entropy.

In Fig. 2, we display the impact parameter dependance of the p_{like} and d_{like} clusters produced for the reactions of ^{20}Ne+^{20}Ne (left panel) and ^{197}Au+^{197}Au (right panel) at 150 MeV/nucleon. From Fig, we see that the yields of p_{like} and d_{like} clusters are enhanced for the case of reduced radius compared to extended one. The percentage difference between the yield of d_{like} clusters for reduced and enhanced radius is higher compared to yield of p_{like} clusters when ^{197}Au+^{197}Au reaction is considered. However, at 400 MeV/nucleon, the percentage difference among the yields of the p_{like} and d_{like} clusters for the reduced and enhanced radius is nearly equal in both systems (not shown here). This may be due to the reason that at lower incident energies, system will have less excitation energy to break the matter into lighter fragments. Thus at 150 MeV/nucleon, the yield of d_{like} clusters is more for reduced radius and hence $\widetilde{R}_{dp}$ ratio will be more that will lead to net decrease in the entropy production for reduced radius.

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