Effect of initialization on the fragment production

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Introduction

The structural effects that enter the calculations through the radii of colliding nuclei play crucial role on the low energy phenomena such as fission, fusion, cluster radioactivity, formation of super heavy nuclei etc. [1]. In recent studies, Puri and co-workers showed that initialization of nuclear radius in dynamical model can affect the reaction dynamics throughout the periodic table [2]. They found that directed-in-plane flow and its disappearance is affected significantly by a small variation in the initial setup of the nuclei. The effect was more pronounced in lighter systems compared to heavier ones. In an another study, the role isospin dependence of nuclear radii on reaction dynamics is checked through transverse flow as well as multifragmentation [3]. Unfortunately, no study exist in the literature where the role of nuclear radius is checked on $\langle N_{IMF}\rangle^{max}$ and $E^{max}_{c.m.}$. In the present study, our aim is to see the role of reduced as well as enhanced liquid drop model (LDM) based nuclear radius on the fragments of different sizes and to see the behavior of $\langle N_{IMF}\rangle^{max}$ and $E^{max}_{c.m}$ in presence of reduced and enhanced LDM radius.

The Model

The present study is carried out within the framework of the isospin-dependent quantum molecular dynamics (IQMD) model [4]. In IQMD model, propagation of each nucleon is governed by the classical equations of motion:

$$\frac{d\vec{r}_i}{dt} = \frac{d\langle H\rangle}{d\vec{p}_i}, \qquad \frac{d\vec{p}_i}{dt} = -\frac{d\langle H\rangle}{d\vec{r}_i}, \qquad (1)$$

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where H stands for the Hamiltonian which is given by:

$$H = \sum_i^A \frac{p_i^2}{2m} + \sum_i^A (V_i^{Sky} + V_i^{Yuk} + V_i^{Coul} + V_i^{sym}). \qquad (2)$$

The V_i^{Sky}, V_i^{Coul}, V_i^{Yuk} and V_i^{sym} are, respectively, the Skyrme, Yukawa, Coulomb, and symmetry potentials.

Results and Discussion

We simulated the reactions of ^{40}Ar+^{45}Sc (E = 35 - 115 MeV/nucleon), ^{58}Ni+^{58}Ni (E = 35 - 105 MeV/nucleon), ^{86}Kr+^{93}Nb (E = 35 - 95 MeV/nucleon), and ^{84}Kr+^{197}Au (E = 35 - 400 MeV/nucleon) for central geometries (b = 0.0 fm). We, here, used a soft equation of state along with standard isospin- and energy-dependent cross section. To see the effect of nuclear radius on fragmentation pattern, we have reduced and enhanced the standard radius used in IQMD model (i.e., liquid drop model) by 10%. In first case, we reduce the radius by 10% i.e., 0.9 × R_{IQMD} (labelled as R^{Red}). In second case, one has extended radius by 10% i.e., 1.1 × R_{IQMD} (labelled as R^{Ext}).

In fig. 1, we display the time evolution of the largest fragment survived A^{max}, free nucleons, light charged particles (LCPs) 2≤A≤4, and intermediate mass fragments (IMFs) 5≤A≤44, for the reaction of ^{86}Kr+^{93}Nb at 50 MeV/nucleon. The solid (dashed) lines represent the calculations for reduced (enhanced) radius, respectively. At the start of the reaction, A^{max} is close to composite mass of projectile and target. With the time (around ∼ 25 - 30 fm/c), the excited compound nucleus starts decaying by the emission of nucleons and fragments. As a result, free nucleons, LCPs, and IMFs display a constant rise in their multiplicity. From the fig. we see that, the A^{max} is bigger in the case of

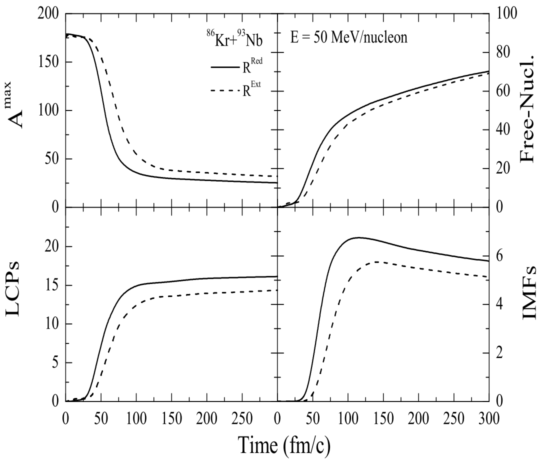

FIG. 1: The time evolution of the largest fragment A^{max}, free nucleons, LCPs, and IMFs for the reaction of ^{86}Kr+^{93}Nb at 50 MeV/nucleon.

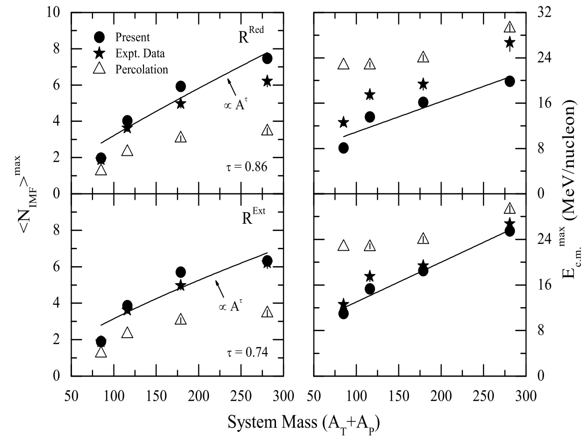

FIG. 2: $\langle N_{\rm IMF}\rangle^{max}$ (left panel) and $E_{c.m.}^{max}$ (right panel) as a function of composite system mass.

enhanced radius compared to reduced one. This may be due to the reason that in case of reduced radius, Fermi momentum will be higher that will make the compound system unstable and hence will lead to smaller largest fragment compared to enhanced radius where Fermi momentum will be comparatively less. The unstable compound nucleus, in the case of reduced radius, will decay via emitting free-nucleons, LCPs and IMFs. Thus, the number of free-nucleons, LCPs and IMFs are higher in the case of reduced radius.

From fig. 1, we see that the multiplicity of various fragments is sensitive towards the nuclear radius. It would be interesting to see the effect of nuclear radius on the maximal production of IMFs and corresponding incident beam energy in center-of-mass system. In fig. 2, we display the peak multiplicity of IMFs $\langle N_{\rm IMF}\rangle^{max}$ (left panel) and the corresponding incident energy ($E_{c.m.}^{max}$) (right panel) as a function of the combined mass of the system for reduced (upper panel) and enhanced (lower panel) nuclear radius. For the detailed calculations of $\langle N_{\rm IMF}\rangle^{max}$ and $E_{c.m.}^{max}$, we refer the reader to Ref. [5]. The solid stars represent the experimental data whereas solid circles correspond to our theoretical calculations. Open triangles represent percolation model calculations [6]. The lines in the left (right) panels represent power law (linear) fit to theoretical calculations. We find that $E_{c.m.}^{max}$ and $\langle N_{\rm IMF}\rangle^{max}$ increase with increase in the composite mass of the system. $E_{c.m.}^{max}$ shows a linear dependence ($\propto$ A) whereas $\langle N_{\rm IMF}\rangle^{max}$ follows a power law behavior ($\propto A^{\tau}$) with τ = 0.86 (0.74) for reduced (enhanced) radius. From the figure, we see that calculations using extended radius shows better agreement with experimental data.

Acknowledgments

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