STRUCTURAL EFFECTS ON THE PEAK PRODUCTION OF FRAGMENTS*

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We study the role of systematic reduction and enhancement in nuclear radius on the multiplicities of various fragments using the Isospin-dependent Quantum Molecular Dynamics (IQMD) model. We find that multiplicities of various fragments are sensitive towards change in nuclear radius. We also find that peak center-of-mass energy ($E_{\rm cm}^{\rm max}$) and peak multiplicity of intermediate mass fragments ($\langle N_{\rm IMF}\rangle^{\rm max}$) are sensitive towards the nuclear radius.

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1. Introduction

In literature, several experimental as well as theoretical attempts have been made to explore the effect of incident beam energy, collision geometry and mass of the reacting partners on the fragmentation pattern [1–4]. In recent studies, Puri and co-workers found rise and fall of the multiplicity of intermediate mass fragments (IMFs) in accordance with experimental observations [5, 6]. $\langle N_{\rm IMF}\rangle^{\rm max}$ and $\mathrm{E}_{\rm cm}^{\rm max}$ (energy at which maximal production of IMFs occurs) were found to scale with the system mass and results were in good agreement with the experimental data. $\langle N_{\rm IMF}\rangle^{\rm max}$ and $E_{\rm cm}^{\rm max}$ are also affected by the isospin asymmetry of the reacting partners [6].

In addition to various entrance channels and model ingredients, the initialization of the nuclei in a transport model also affects the reaction dynamics [7–10]. The structural effects play crucial role on the low energy phenomena such as fission, fusion, cluster radioactivity, formation of super heavy nuclei *etc.* through radii of colliding nuclei [11, 12]. 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 [9].

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Unfortunately, no study exists in the literature where the role of nuclear radius is checked on $\langle N_{\rm IMF}\rangle^{\rm max}$ and $E^{\rm max}_{\rm cm}$. 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 $\langle N_{\rm IMF}\rangle^{\rm max}$ and $\mathrm{E}^{\rm max}_{\rm cm}$ in presence of reduced and enhanced LDM radius. The present study is made within the framework of the IQMD model [7]. The phase space generated within the IQMD model is analyzed using the minimum spanning tree (MST) method with clusterization range of 2.8 fm.

2. Results and discussion

We simulated the reactions of ^{40}Ar+^{45}Sc, ^{58}Ni+^{58}Ni, ^{86}Kr+^{93}Nb, and ^{84}Kr+^{197}Au for central geometries. Here, the choice of colliding pairs, incident energies and impact parameter is guided by the experimental studies [4]. We used a soft equation of state along with isospin- and energy-dependent cross section. To see the effect of nuclear radius on fragmentation pattern, we have reduced (labeled as $R^{\rm Red}$) and extended (labeled as $R^{\rm Ext}$) the standard radius used in IQMD model by 10%.

In Fig. 1, we display the time evolution of the largest fragment $A^{\rm max}$, free nucleons, light charged particles (LCPs) $2 \leq A \leq 4$, and IMFs $5 \leq A \leq 44$, for the reaction of ^{86}Kr+^{93}Nb at 50 MeV/nucleon. The solid (dashed) lines represent the calculations for reduced (enhanced) radius, respectively. Shaded region represents the difference in calculations using reduced and enhanced radius. At the start of the reaction, $A^{\rm max}$ is close to composite

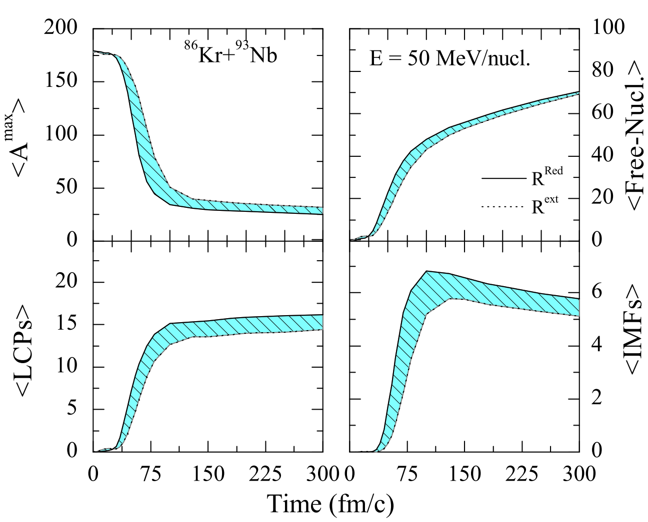

Fig. 1. The time evolution of the largest fragment $A^{\rm max}$, free nucleons, LCPs, and IMFs for the reaction of ^{86}Kr+^{93}Nb at 50 MeV/nucleon.

mass of projectile and target. The excited compound nucleus starts decaying with time by emitting free-nucleons and fragments. As a result, free nucleons, LCPs, and IMFs show rise in their multiplicity. From the figure, we see that the $A^{\max}$ is bigger in the case of enhanced radius compared to reduced one. This may be due to the reason that in the case of reduced radius, Fermi momentum will be higher that will make the compound system unstable and hence lead to smaller $A^{\max}$ compared to enhanced radius. 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 is higher in the case of reduced radius.

From the above figure, 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 the center-of-mass system. In Fig. 2, we display $\langle N_{\mathrm{IMF}}\rangle^{\max}$ (left panels) and $E_{\mathrm{cm}}^{\max}$ (right panels) as a function of the combined mass of the system for reduced (upper panels) and enhanced (lower panels) nuclear radius. $\langle N_{\mathrm{IMF}}\rangle^{\max}$ and corresponding $E_{\mathrm{cm}}^{\max}$ are obtained by making a quadratic fit to the model calculations for $\langle N_{\mathrm{IMF}}\rangle$ as a function of E_{cm}. The solid stars (solid circles) represent the experimental data (theoretical calculations). We also compared our results with percolation model calculations (open triangles) [4]. The lines in the left (right) panels repre-

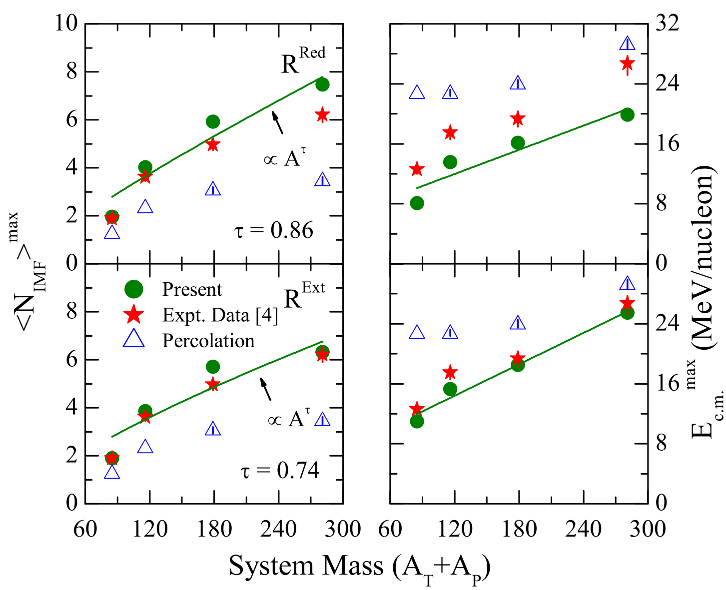

Fig. 2. $\langle N_{\mathrm{IMF}}\rangle^{\max}$ (left panel) and $E_{\mathrm{cm}}^{\max}$ (right panel) as a function of composite mass of the system ($A_{\mathrm{T}} + A_{\mathrm{P}}$). Solid stars represent experimental data [4].

sent power law (linear) fit to theoretical calculations. We find that $E_{\rm cm}^{\rm max}$ and $\langle N_{\rm IMF}\rangle^{\rm max}$ increase with the increase in the composite mass of the system. $E_{\rm cm}^{\rm max}$ shows a linear dependence ($\propto A$), whereas $\langle N_{\rm IMF}\rangle^{\rm max}$ follows a power law behavior ($\propto A^{\tau}$). From the figure, we see that calculations using enhanced radius show better agreement with experimental data. Note that, here, the value of enhanced radius is close to isospin dependent nuclear radius given in Ref. [12].

3. Summary

We explored the role of initialization via nuclear radius on the fragmentation pattern. We found that multiplicities of various fragments, $\langle N_{\rm IMF}\rangle^{\rm max}$ and $E_{\rm c.m.}^{\rm max}$ are sensitive towards the initial setup of nuclear radius. With an increase in the nuclear radius, $\langle N_{\rm IMF}\rangle^{\rm max}$ get decreased whereas $E_{\rm c.m.}^{\rm max}$ increased. Calculations using extended radius showed better agreement with experimental data.

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