Impact of isospin dependence of momentum dependent interactions on global and local thermalization

Karan Singh Vinayak and Asis K. Chaudhuri
Variable Energy Cyclotron Center, Kolkata - 700064, (West Bengal) INDIA[*]

Introduction

The transport phenomenon in heavy-ion reactions, especially at intermediate energies are very critical to understand the fundamental properties of nuclear matter such as nuclear equation of state (EOS). The nuclear stopping provide information about most of the dissipated energy during collision and shed light on the various kind of reaction mechanisms [1]. The phenomenon of nuclear stopping can also yield crucial facts regarding the nuclear equation of state, nucleon-nucleon cross-section and the thermalization/temperature reached in heavy-ion collisions [1, 2].

The momentum dependent interactions (MDI) affect the nuclear equation of state and plays a significant role in the dynamics of the reaction [3]. In addition to the reaction conditions and colliding partners (target & projectile), the reaction output also depend on the N/Z content of the system. This is because the interactions between the baryons are isospin dependent. To explore the isospin dependent part of the equation of state, we demonstrate the direct role of isospin dependence of nucleonic interactions (momentum dependent) on the global and local thermalization via. nuclear stopping.

The Formalism

Our calculations are carried out within the framework of isospin dependent quantum molecular dynamics (IQMD) model [4]. It contains the correlation effects and explicitly represents the many body states of the system. In IQMD model, the centroid of each nucleon propagates under the classical equations of motion:

$$\frac{d\vec{r_i}}{dt} = \frac{dH}{d\vec{p_i}} \; ; \; \frac{d\vec{p_i}}{dt} = -\frac{dH}{d\vec{r_i}} \cdot \quad (1)$$

The H referring to the Hamiltonian reads as:

$$H = \sum_i \frac{p_i^2}{2m_i} + V^{ij}_{Yukawa} + V^{ij}_{Coul} + V^{ij}_{skyrme} + V^{ij}_{symm} + V^{ij}_{mdi} . \quad (2)$$

For the present study, the symmetry energy as a function of density is taken as, $E_{symm}(\rho) = E_{symm}(\rho_o)(\rho/\rho_o)^{0.66}$ [5]. We optimized various EOS's (MDI & Iso-MDI) to study the global and local thermalization in heavy-ion collisions. The momentum-dependent interactions as a function of isospin term $V_{Iso-MDI}$ in IQMD model can be interpreted as:

$$V_{Iso-MDI} = (1.0 - 0.5\, T_3^i\, T_3^j).V_{mdi} \quad (3)$$

Here, T_3^i and T_3^j are the isospin component of interacting baryons. We termed this new version as IQMD(Th01) model [6].

Results and discussion

For the present analysis, we simulated the reaction of ${}^{142}_{54}Xe$ + ${}^{142}_{54}Xe$, at the incident energy of 100 MeV/nucleon. Both the mean field and nucleon-nucleon collisions govern the reaction dynamics at 100 MeV/nucleon. At higher incident energies, role of mean field will be negligible and the binary nucleon-nucleon collisions will dominate the dynamics of reaction. One can use the anisotropy ratio

[*]Electronic address: karansv@vecc.gov.in

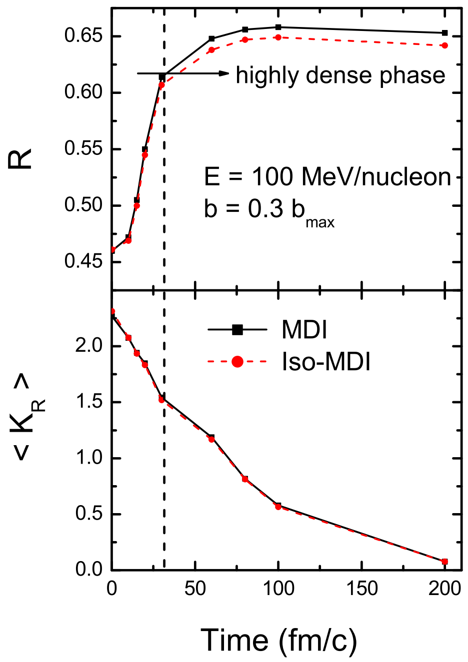

FIG. 1: The time evolution of anisotropy ratio (upper panel) and relative momentum (lower panel) for the system $^{142}_{54}Xe$ + $^{142}_{54}Xe$ at the incident energy of 100 MeV/nucleon.

(R) as a probe for the global thermalization [1, 2].

$$R = \frac{2}{\pi} \frac{[\ \sum_i p_\perp(i)\ ]}{[\ \sum_i p_{||}(i)\ ]}. \quad (4)$$

where the summation runs over all nucleons. The transverse and longitudinal momenta are $p_\perp = \sqrt{p_x^2(i) + p_y^2(i)}$ *and* $p_{||}(i) = p_z(i)$ respectively.

Also, the relative momentum $< K_R >$ can be signified as a probe for local equilibrium/local thermalization, which represents the relative momentum of two colliding Fermi spheres [7].

$$< K_R > = <|\ \vec{P_P}(\vec{r},t) - \vec{P_T}(\vec{r},t)\ |> \quad (5)$$

where,

$$\vec{P_i}(r,t) = \frac{\sum_{j=1}^{A} \vec{P_j(t)}\rho_j(\vec{r},t)}{\rho_j(\vec{r},t)}, i = 1,2 \quad (6)$$

Here $\vec{P_j}$ and ρ_j are the momentum and density of the j^{th} particle and i stands for either a projectile or target.

In Fig.1, we display the time evolution of anisotropy ratio (R) (upper panel) and relative momentum (K_R) (lower panel) at the incident energy of 100 MeV/nucleon. The relative momentum (local thermalization parameter) does not seem to get affected by the various EOS (MDI & Iso-MDI). However, the global nuclear stopping (anisotropy ratio R) is sensitive to the isospin momentum dependent EOS. Interestingly the effect of isospin is observed at the later stage, i.e. during the break up of the compressed matter.

The highly concentrated and heated nuclear matter during the initial violent phase does not show considerable variation for anisotropy ratio with the inclusion of isospin momentum dependent interactions. It can be concluded that the isospin dependence of the momentum dependent interactions affect the global thermalization of the system, but have no impact on the local thermalization.

References

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