Influence of isospin momentum dependent interactions on transverse flow

*Amandeep Kaur[1], Deepshikha[1] and Suneel Kumar[1]
[1] School of Physics and Materials Science,
Thapar University, Patiala 147004, Punjab, INDIA
* email: amanganday@gmail.com

Introduction

Collective transverse flow is preferential emission of the nucleons within, and to a particular side of reaction plane. It is quantified by the first harmonic $\langle v_1 \rangle$ in the Fourier expansion of the azimuthal distribution of produced nucleons with respect to the reaction plane [1]. The collective transverse flow was found to be very sensitive towards the equation of state and nucleon-nucleon (nn) cross section. The effect of momentum dependent interaction (MDI) on the observable in the heavy ion collisions have been studied for many years. Nowadays, the isospin effect of MDI has attracted a lot of attention. Recently, Liu et al. [2] considered an isospin degree of freedom in MDI to obtain isospin momentum dependent interactions (Iso-MDI). They tried to study the role of Iso-MDI on the isospin fractionation ratio and its dynamical mechanism at intermediate energies. In present analysis we have tried to study the effect of Iso-MDI on transverse flow.

Methodology

The study is carried out within the framework of isospin dependent quantum molecular dynamics (IQMD) model [3]. This model treats the different states of nucleons, deltas and pions explicitly. In this model the nucleons are represented by the Gaussian-shaped density distributions.

$$f_i(r,p,t) = \frac{1}{\pi^2 \hbar^2} e^{-(r-r_i(t))^2 \frac{1}{2L}} e^{-(p-p_i(t))^2 \frac{2L}{\hbar^2}}$$

Here Gaussian width L is regarded as a description of the interaction range of a nucleon. In IQMD model, the cenetroid of each nucleon propagates under the classical equations of motion.

$$\frac{dr_i}{dt} = \frac{\partial\langle H \rangle}{\partial p_i}; \frac{dp_i}{dt} = -\frac{\partial\langle H \rangle}{\partial r_i} \text{ with}$$

$$\langle H \rangle = \langle T \rangle + \langle V \rangle$$

The baryon-baryon potential V^{ij}, in the above relation, reads as:

$$V^{ij}(r'-r) = V^{ij}_{Skyrme} + V^{ij}_{Yukawa} + V^{ij}_{Coul} + V^{ij}_{mdi} + V^{ij}_{sym}$$

The momentum dependence of NN interactions V^{MDI}, which may optionally be used in IQMD, is fitted to experimental data on the real part of nucleon optical potential [4] which yield:

$$V_{mdi} = \delta . \ln^2 \left(\in .(\Delta p)^2 + 1 \right) \left(\frac{\rho}{\rho_0} \right)$$

To explore the role of isospin in heavy-ion collisions, we introduced the isospin dependence of momentum dependent interactions and analyzed its impact on transverse flow. We here speculated the momentum dependent interactions as a function of isospin term $V_{Iso\text{-}MDI}$ in IQMD model as:

$$V^{Iso-MDI} = \left(1.0 - 0.5 T_{3i} T_{3j}\right) V^{MDI}$$

Where T_{3i}, T_{3j} are the isospin components of interacting baryons.

Results and Discussion

For the present analysis, we have simulated several thousands of events for reaction ${}^{124}_{54}Xe + {}^{124}_{54}Xe$ at incident energy E=400 MeV/nucleon for impact parameter range $\hat{b}$ =0.6-0.8. We use hard equation of state (EOS) with MDI, without MDI and with Iso-MDI, labeled, respectively as Hard, HMD and Iso-HMD. Transverse flow has great dependence on rapidity and transverse momentum.

$$\langle v_1 \rangle = \left\langle \frac{p_x}{p_t} \right\rangle = \langle \cos(\phi) \rangle$$

Where $\langle v_1 \rangle$ is called as directed flow parameter. It is the measure of the collective motion of the particles in the reaction plane and p_t is a transverse momentum defined as $p_t = \sqrt{p_x^2 + p_y^2}$, and p_x and p_y are projections of particle transverse momentum in perpendicular to reaction plane, respectively. The rapidity is defined as $Y^{red} = Y_{c.m.} / Y_{beam}$, and $Y_{c.m.}$ is given by:

$$Y_{c.m.} = \frac{1}{2} \ln \frac{E(i) + p_z(i)}{E(i) - p_z(i)}$$

Where, E(i) and $p_z(i)$ are the energy and longitudinal momentum of the i^{th} particle, respectively.

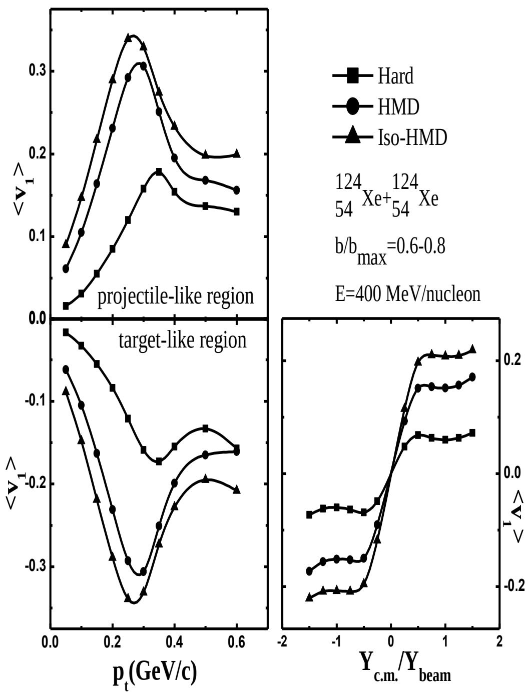

Fig. 1 Transverse flow $\langle v_1 \rangle$ as a function of transverse momentum (p_t) (left panels) and rapidity ($Y_{c.m.}/Y_{beam}$) (right panel) for different hard EOS at E=400 MeV/nucleon for impact parameter range $\hat{b}$ =0.6-0.8.

In Fig.1 we display the directed transverse flow $\langle v_1 \rangle$ as a function of transverse momentum (p_t) (left panels) and rapidity ($Y_{c.m.}/Y_{beam}$) (right panel) for different EOS. Black squares, circles and triangles represent the Hard, HMD and Iso-HMD EOS respectively. A significant variation in directed transverse flow has been observed with the inclusion of MDI and Iso-MDI. With the inclusion of MDI and Iso-MDI results in larger positive value of $\langle v_1 \rangle$ for projectile like region and larger negative value for target like region. This happens because of the repulsive nature of MDI. In Iso-MDI this repulsion will also depend on the isospin component of interacting baryons. The Iso-MDI results in the larger peak value of $\langle v_1 \rangle$, compared to MDI. In conclusion, the calculated result shows that the isospin dependence of MDI brings an important isospin effect into the transverse flow in the intermediate energy heavy ion collisions. Therefore, the role of Iso-MDI is important for investigating accurately the equation of state of isospin asymmetric nuclear matter.

Acknowledgement: This work has been supported by a grant from the Department of Atomic Energy, Govt. of India, vide Grant no. 2012/37P/16/BRNS.

References

[1] S. A. Voloshin and Y. Zhang, Z. Phys. C **70**, 665 (1996)

[2] J. Y. Liu, W. J. Guo, Z. Y. Xing, and X. G. Lee, Chin. Phys. Lett. **22**, 65 (2005).

[3] C. Hartnack et al., Eur. Phys. J. A **1**, 151 (1998); C. Hartnack et al., Phys. Rep. **510**, 119 (2012).

[4] J. Aichelin, A. rosenhaur, G. Peilert, H. Stocker, and W. Greier, Phys. Rev. Lett. **58**, 1926 (1987).