Isospin effect on elliptical flow for mass asymmetric nuclear collisions

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Introduction

Collective flow is the measure of the transverse motion imparted to the particles and fragments during the collision of two nuclei. Among the different kind of collective flow, elliptical flow enjoys the special status due to its sensitivity towards reaction dynamics. The azimuthal asymmetric emission pattern in which particles found to be preferentially emitted perpendicular to the reaction plane describes the elliptical flow. Elliptical flow has been studied extensively at BEVALAC, SIS and AGS energies [1].

In literature efforts have been made to understand the isospin effects on the elliptical flow. Isospin degree of freedom enter into the calculations via. Coulomb potential, symmetry potential and isospin dependent nucleon-nucleon cross-section. Recently, Zhang *et al.* [2] studied the elliptical flow in heavy-ion collisions for $Z \leq 2$ particles at an incident energy ranging from several tens to hundred of MeV/nucleon. They showed that soft nuclear equation of state and energy dependent in-medium nucleon-nucleon cross-section are required to describe the excitation function of the elliptical flow at intermediate energies.

On the other hand, S. Kumar *et al.* [3] studied the elliptical flow for the whole mass range of symmetric reactions and they showed that transition energy for the whole mass range follow a power law behavior. K. S. Vinayak *et al.* [4] reported that the elliptical flow is highly sensitive towards the different forms of density dependent symmetry energy. Also in Ref. [5], an attempt has been made to study the effect of charge asymmetry and isospin dependent nucleon-nucleon cross-section on elliptical flow and they concluded that different aspects of elliptical flow strongly depend on the isospin dependence of the nucleon-nucleon cross-section and isotopic contents of the colliding nuclei.

All these studies were silent about the isospin effects in mass asymmetric nuclear collisions. As noted by FOPI group [6], the reaction dynamics in asymmetric collisions is quite different as compared to symmetric collisions. This difference is due the different deposition of the excitation energy in symmetric and asymmetric collisions. The symmetric collisions generate high compression whereas asymmetric collisions lead to thermalization. Therefore, asymmetric collisions are helpful to investigate reaction dynamics. The mass asymmetric parameter is defined as, $\eta = (A_T - A_P)/(A_T + A_P)$, where A_P and A_T are the masses of projectile and target respectively. The present work is carried out to study the effect of Coulomb potential on the transverse momentum dependence of elliptical flow by taking mass asymmetric collisions. The study is performed within the frame work of IQMD [7] model.

Results and Discussion

For the present analysis several thousand of events have been simulated for the reaction time upto 200fm/c. The reactions of ${}^{197}_{79}Au + {}^{197}_{79}Au$, ${}^{175}_{71}Lu + {}^{197}_{79}Au$, ${}^{131}_{54}Xe + {}^{197}_{79}Au$ and ${}^{40}_{20}Ca + {}^{197}_{79}Au$ having mass asymmetry η=0, η=0.1, η=0.2 and η=0.7 respectively, have been studied at an incident energy of 50 MeV/nucleon and at scaled impact parameter of $\hat{b} = 0.7$. A soft equation of state along with linear density dependence of symmetry energy has been employed for the analysis of elliptical as a function of transverse momentum. Here, we have fixed the target nucleus and mass asymmetry of the reaction changes by varying the mass of projectile. The elliptical flow is defined by second order Fourier coefficient from azimuthal distribution of detected particles at mid-rapidity region. The excitation function of elliptical flow is represented as [8],

$$\langle v_2 \rangle = \langle \cos(2\phi) \rangle = \left\langle \frac{p_x^2 - p_y^2}{p_t^2} \right\rangle$$

Here, ϕ is the azimuthal angle between the transverse momentum $p_t = \sqrt{p_x^2 + p_y^2}$ of the particle and the reaction plane.

Fig. 1 display, the transverse momentum dependence of the elliptical flow for free nucleons (FN's A=1) and fragments having mass A=2 with and without Coulomb potential in mid-rapidity region.

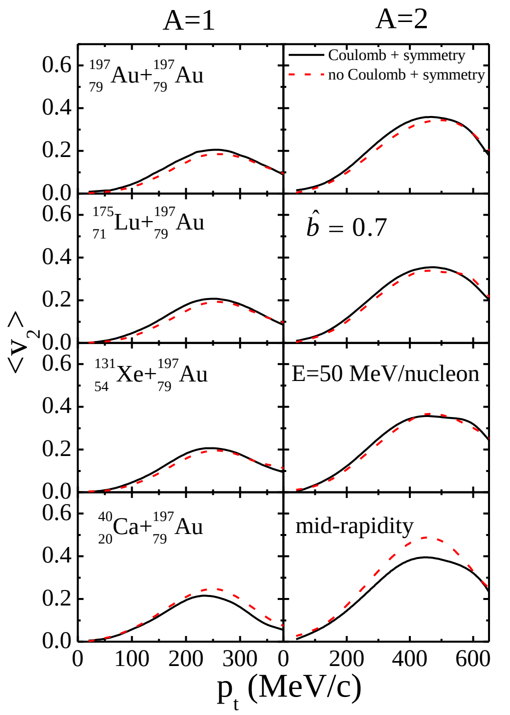

Fig. 1 Transverse momentum dependence of elliptical flow at mid-rapidity region for A=1 (left panel) and A=2 (right panel) at an incident energy of 50 MeV/nucleon.

The percentage change in the peak value of the elliptical flow with and without Coulomb potential for the reactions of $^{197}_{79}Au + ^{197}_{79}Au$, $^{175}_{71}Lu + ^{197}_{79}Au$, $^{131}_{54}Xe + ^{197}_{79}Au$ and $^{40}_{20}Ca + ^{197}_{79}Au$ in case of FN's (A=1) is 9.5%, 7.23%, 5.6% and 12.6%, respectively and for fragments having mass A=2 is 4.3%, 4%, 2.3% and 19.6% respectively. This percentage change is due to repulsive nature of Coulomb potential. On excluding Coulomb potential the repulsive forces reduces in the interaction region which leads to more squeeze-out as compared in the presence of Coulomb potential. Moreover, the role of Coulomb potential on transverse momentum dependence of elliptical flow with mass asymmetry parameter is negligible.

A weaker squeeze-out has been observed (both for A=1 and A=2) for the reaction of $^{40}_{20}Ca + ^{197}_{79}Au$. This is because the projectile nucleus is very small as compared to the target nucleus. As the reaction is highly asymmetric (η=0.7) and impact parameter is very high $\hat{b} = 0.7$, therefore, the passing time is very large which leads to lack of compression in participant zone. Hence due to less binary collisions there is in-plane emission of FN's and fragments having mass A=2, which originates from participant zone.

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References

[1] J. Y. Ollitrault, Nucl. Phys. A **638**, 195 (1998).
[2] Y. Zhang *et al.*, Phys. Rev. C **74**, 014602 (2006).
[3] S. Kumar *et al.*, Phys. Rev. C **81**, 014611 (2010).
[4] K. S. Vinayak *et al.*, Eur. Phys. J. A **47**, 144 (2011).
[5] A. Jain *et al.*, Phys. Rev. C **85**, 064608 (2012).
[6] K. J. Eskola, Nucl. Phys. B **323**, 37 (1989).
[7] Ch. Hartnack *et al.*, Eur. Phys. J. A **1**, 151 (1998); Ch. Hartnack et al., Phys. Rep. **510**, 119 (2012).
[8] A. Andronic *et al.*, Nucl. Phys. A **679**, 765 (2001); A. Andronic et al., Phys. Lett. B **612**, 173 (2005).