Study of elliptical flow at VECC-SCC500 energies

Varinderjit Kaur[1],* Suneel Kumar[1], Rajeev K. Puri[2], and S. Bhattacharya[3]
[1] *School of Physics and Materials Science, Thapar University, Patiala - 147004, (Punjab) INDIA*
[2] *Department of Physics, Panjab University, Chandigarh-160014 INDIA and*
[3] *Variable Energy Cyclotron Center, 1/AF, Bidhan Nagar, Kolkata INDIA*

Introduction

The upcoming facility of K500 Superconducting Cyclotron (SCC500) at Variable Energy Cyclotron Centre (VECC) Kolkata will give scientists an opportunity to study the various phenomena at intermediate energies. The behavior of nuclear matter under the extreme conditions of temperature, density, angular momentum etc., is a very important aspect of heavy-ion physics. One of the important quantities which has been used extensively to study this hot and dense nuclear matter is the elliptical flow. Recently, the analysis of the transverse-momentum dependence of elliptical flow has also been put forwarded [1]. The elliptical flow is shaped by the interplay between the geometry and the mean field and, when gated by the transverse momentum, reveals the momentum dependence of the mean field at supra-normal densities. The elliptical flow describes the eccentricity of an ellipse like distribution. Quantitatively, it is the difference between the major and minor axis. The orientation of the major axis is confined to azimuthal angle ϕ or $\phi+\frac{\pi}{2}$ for ellipse like distribution. The major axis lies within the reaction plane for ϕ; while $\phi+\frac{\pi}{2}$ indicates that the orientation of the ellipse is perpendicular to the reaction plane, which is the case for squeeze out flow and may be expected at mid rapidity [2]. The elliptical flow is quantified by the second-order Fourier coefficient [2]

$$V_2 \;=\; \langle \cos 2\phi \rangle = \left\langle \frac{p_x^2 - p_y^2}{p_x^2 + p_y^2} \right\rangle, \qquad (1)$$

from the azimuthal distribution of the detected particles at mid rapidity as:

$$\frac{dN}{d\phi} = p_0(1+2V_1\cos\phi+2V_2\cos 2\phi+\ldots), \quad (2)$$

where p_x and p_y are the x and y components of the momentum. The p_x is in the reaction plane, while p_y is perpendicular to the reaction plane, and ϕ is the azimuthal angle of the emitted particle's momentum relative to the x-axis. The positive values of $\langle\cos 2\phi\rangle$ reflect preferential in-plane emission, while negative values reflect preferential out-of-plane emission.

The Model

The model is the semi classical microscopic improved version of QMD model [3] where nucleons interact via two and three body interactions. The nucleons propagate according to classical Hamilton equations of motion.

$$\frac{d\vec{r_i}}{dt} = \frac{d<H>}{d\vec{p_i}} \quad ; \quad \frac{d\vec{p_i}}{dt} = -\frac{d<H>}{d\vec{r_i}}. \quad (3)$$

with

$<H>=<T>+<V>$ is the Hamiltonian. The total interaction potential is given as:

$$V^{ij}(\vec{r}' - \vec{r}) \;=\; V^{ij}_{Skyrme} + V^{ij}_{Yukawa} + V^{ij}_{Coul} + V^{ij}_{mdi} + V^{ij}_{sym} \quad (4)$$

where V_{Skyrme}, V_{Yukawa}, V_{Coul}, V_{mdi} and V_{sym} represent, respectively, the Skyrme, Yukawa, Coulomb, momentum-dependent interaction (MDI) and symmetry potentials.

Results and Discussion

For the controlled study of the role of mass asymmetry of a reaction [4], we simulated

*Electronic address: vkaur@thapar.edu

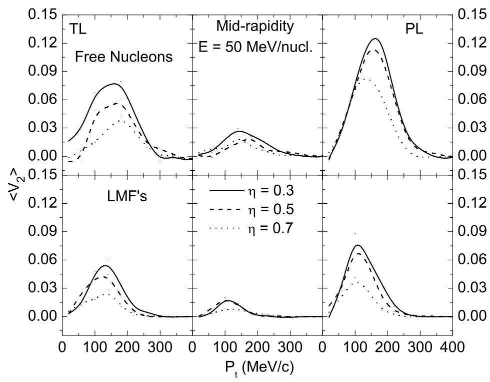

FIG. 1: The transverse momentum dependence of the elliptical flow at E = 50 MeV/nucleon for different mass asymmetries divided into contributions from target-like, mid-rapidity and projectile-like matter, respectively. The upper and lower panels represent the free nucleons and light mass fragments (LMF's), respectively.

several thousands events of various reactions by keeping the total reacting mass (= 152 units). While the total mass stays constant, mass asymmetry parameter η is varied by choosing different combinations of projectiles-targets. These projectile-target combinations are possible at SCC-500 developed at VECC. We have performed exclusive studies of elliptical flow by simulating the reactions of $_{24}Cr^{50} +_{44} Ru^{102}$ ($\eta = 0.3$), $_{16}S^{32} +_{50} Sn^{120}$ ($\eta = 0.5$), and $_{8}O^{16} +_{54} Xe^{136}$ ($\eta = 0.7$) at incident energies between 50 MeV/nucleon for semi-central impact parameter using a soft nuclear equation of state.

Fig. 1 shows the elliptical flow for the free particles (A=1)(upper panel) and light mass fragments (LMF's) [$(2 \leq A \leq 4)$] (lower panel) as a function of transverse momentum (P_t) at an incident beam energy E = 50 MeV/nucl. The different curves in each panel correspond to different mass asymmetries. Moreover, we divide the total elliptical flow into contributions from target-like(TL) (left panels), mid-rapidity (middle panels), and projectile-like(PL) (right panels) particles. From the figure, we see that the projectile-like (PL) nucleons and LMF's feel more squeeze out compared to target-like (TL) nucleons/LMF's. At the larger mass asymmetry, only small fraction of nucleons/LMF's experience squeeze out compared to symmetric reactions. This decrease of squeeze out with mass asymmetry happens due to decreasing participant zone. This is in agreement with earlier calculations where fragments were found to exhibit similar trends. The detailed study in this direction will be fruitful for experimentlists.

References

[1] J. Lukasik, G. Auger, and M. L. Begemann-Blaich *et al.,* Phys. Lett. B **608**, 223 (2005); A. Andronic *et al.,* Nucl. Phys. A **679**, 765 (2001); Phys. Lett. B **612**, 173 (2005).

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

[3] J. Aichelin, Phys. Rep. **202**, 233 (1991); C. Hartnack *et al.*, Eur. Phys. J. A **1**, 151 (1998); R. K. Puri, *et al.*, Nucl. Phys. A **575**, 733 (1994); *ibid.* J. Comp. Phys. **162**, 245 (2000); E. Lehmann, R. K. Puri, A. Faessler, G. Batko, and S. W. Huang, Phys. Rev. C **51**, 2113 (1995); *ibid.* Prog. Part. Nucl. Phys. **30**, 219 (1993).

[4] V. Kaur, S. Kumar and R. K. Puri, Phys. Lett. B **697**, 512 (2011); V. Kaur and S. Kumar Phys. Rev. C **81**, 064610 (2010).