Consequence of colliding geometry and rapidity range on anisotropic flow

Anupriya Jain[1*] and Suneel Kumar[1]
[1] *School of Physics and Material Science,*
Thapar University, Patiala - 147004, INDIA

Rajeev K. Puri[2]
[2] *Department of Physics, Panjab University, Chandigarh-160014, India*

Introduction

Anisotropic flow, anisotropy of the particle azimuthal distribution in momentum space with respect to the reaction plane, is a sensitive tool in the quest for the quark-gluon plasma and the understanding of bulk properties of the system created in heavy ion collisions. Anisotropic flow is defined as the different n^{th} harmonic coefficient v_n of the Fourier expansion for the particle invariant azimuthal distribution [1]:

$$\frac{dN}{d\phi} = 1 + 2\sum_{n=1}^{\infty} v_n Cos(n\phi) \qquad (1)$$

where ϕ is the azimuthal angle between the transverse momentum of the particle and the reaction plane. The first harmonic coefficient v_1 is known as sideward flow and second harmonic coefficient v_2 is known as elliptical flow.

$$\langle v_1 \rangle =< Cos\phi >= \langle \frac{p_x}{p_t} \rangle \qquad (2)$$

$$\langle v_2 \rangle =< Cos2\phi >= \langle \frac{p_x^2 - p_y^2}{p_x^2 + p_y^2} \rangle \qquad (3)$$

where, p_t (p_t=$\sqrt{(p_x^2 + p_y^2)}$), and p_x is projection of particle transverse momentum in the reaction plane. For the first time, it has been reported by Bonasera *et al.* [2] and later on by many others that collective flow is negative at low incident energies, that turns positive at a reasonable higher incident energies. At a particular incident energy, however, a transition occurs. The energy at which this transition observed is dubbed as the transition energy E_{trans}. Anisotropic flows generally depend on both particle transverse momentum and rapidity. Due to this dependence, our aim in the present paper is two fold first to study the excitation function of v_1 by dividing the rapidity distribution into different cuts in terms of the parameter $\frac{Y_{c.m.}}{Y_{beam}} = Y^{red}$, which is given as:

$$Y(i) = \frac{1}{2} ln \frac{E(i) + P_Z(i)}{E(i) - P_Z(i)}, \qquad (4)$$

where E(i) and $P_Z(i)$ are the total energy and longitudinal momentum of i^{th} paritcle. Second, is to stuy the effect of colliding geometry on elliptical flow. Calculations are carried out within the framework of Isospin dependent Quantum Molecular Dynamics (IQMD) [3] model, which is a modified version of QMD [4] model.

Results and Discussion

For the present analysis, simulations are carried out for the reactions of $^{40}_{20}Ca_{20} +^{40}_{20} Ca_{20}$ and $^{197}_{79}Au_{118} +^{197}_{79} Au_{118}$ at scaled impacct parameter $\hat{b}$ = b/b_{max} = 0.5, where b_{max} = $1.12(A_P^{1/3} + A_T^{1/3})$ and A_P and A_T are the mass of projectile and target respectively. The analysis is performed for light mass fragments (LMF's) (2 ≤ A ≤ 4). The rapidity distribution is found to vary drastically throught the range of $|Y_{red}| \leq 1.75$. The mid-rapidity region (-0.1 ≤ $\frac{Y_{c.m}}{Y_{beam}}$ ≤ 0.1) corresponds to the collision (participant) zone and hence signi-

---

[*] Electronic address: `npryjn111@gmail.com`

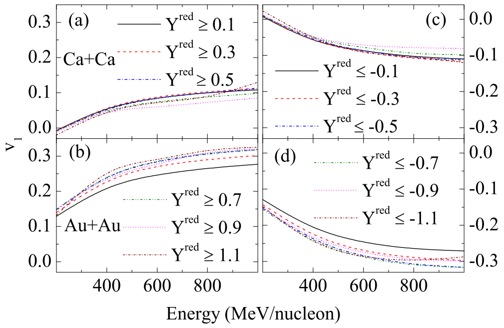

FIG. 1: Incident energy dependence of v_1 for LMF's. [Panels (a) and (b)] the contribution for the fragments is from PL matter only. [Panels (c) and (d)] is from TL matter only.

fies compressed matter. On the other hand, $\frac{Y_{c.m}}{Y_{beam}} \neq 0$ corresponds to the spectator zone, $(\frac{Y_{c.m}}{Y_{beam}} \leq -0.1)$ corresponds to target like (TL) matter and $(\frac{Y_{c.m}}{Y_{beam}} \geq 0.1)$ corresponds to projectile like (PL) matter. To study the effect of different rapidity cuts on excitation function of v_1, we display in Fig.1, the incident energy dependence of v_1 for LMF's. Panels (a) & (b) represents the contribution for the fragments is from PL matter only and Panels (c) & (d) the contribution for the fragments is from TL matter only. It has been observed that, v_1 increases with incident energy. This is due to the increase in the component of particle transverse momentum in the reaction plane. Moreover, as we move away from the participant zone either toward the PL region or towards the TL region the value of v_1 increases. This happens because, v_1 does not exist in the mid-rapidity zone. More we move participant contribution towards the spectator contribution the more will be the value of v_1. This is true for TL region as well as for PL region. Mass dependence of the v_1 can be clearly seen from the figure. Fig.2, represent the comparison of the theoretical results with the experimental findings of the FOPI collaboration [5] for the excitation function of elliptical flow for the reaction of ${}^{197}_{79}Au_{118}+^{197}_{79}Au_{118}$. We present the results for two different centrality bins [BIN 1 (7.5-9.5 fm), BIN 2 (5.5-7.5 fm)]. It has been observed that, the elliptical flow shows a transition from the preferential in-plane to the out-of-plane emission (squeeze-out). This is because, at low energies, the dominance of the mean field occur. But as the incident energy increases, the mean field does not play any significant role. The nucleon-nucleon collisions dominate at higher incident energies. Due to the high incident energy, larger compression produced in the participant zone and this results in the squeeze-out-of the nuclear matter. In fact, the shadowing of spectator matter makes the flow negative at higher energies.

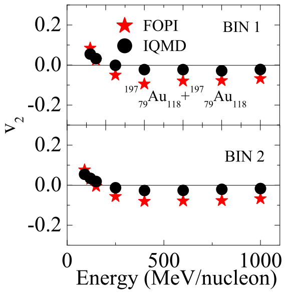

FIG. 2: Energy dependence of v_2 for the reaction of ${}^{197}_{79}Au_{118} +^{197}_{79} Au_{118}$.

Acknowledgment

This work has been supported by a grant from the university grant commission, Government of India [Grant No. 39-858/2010(SR)].

References

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

[2] A. Bonasera, L. P. Csernai, Phys. Rev. Lett. **59**, 630 (1987).

[3] C. Hartnack *et. al.*, Eur. Phys. Journal A **1**, 151(1998).

[4] J. Aichelin, Phys. Rep. **202**, 233(1991).

[5] A. Andronic *et al.*, Nucl. Phys. A **679**, 765 (2001).