Strength of directed to the elliptic flow at intermediate energies

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Introduction

Intermediate energy region mainly deals with the phenomenon like collective flow, nuclear stopping, fragmentation and isospin effects etc [1, 2]. In the present work, we aim to study the collective flow and to find out the strength of directed to the elliptic flow. Many theoretical and experimental efforts have been made in studying the collective flow in central and peripheral colliding geometries. Collective transverse flow has been found to depend upon the system size, incident energy, colliding geometry and isospin content of the colliding nuclei [3–5]. Mathematically, anisotropic flow can be defined as the different n^{th} harmonic coefficient of an azimuthal Fourier expansion of the particle invariant distribution [6].

$$\frac{dN}{d\phi} \propto [1 + 2\sum_{n=1}^{\infty} v_n \cos(n\phi)] \tag{1}$$

where ϕ is the azimuthal angle between the transverse momentum of the particles and the reaction plane. In the coordinate system, we assume the beam axis along the Z-axis and the X-axis are labeled as an impact parameter axis. The first harmonic coefficient v_1 represents the directed flow, second harmonic coefficient v_2 represents elliptic flow represented by following equations.

$$v_1 = \langle \cos\phi \rangle = \langle \frac{p_x}{p_t} \rangle \tag{2}$$

$$v_2 = \langle \cos 2\phi \rangle = \langle \frac{p_x^2 - p_y^2}{p_t^2} \rangle \tag{3}$$

where, p_x and p_y are respectively, the projection of nucleon momentum both parallel and perpendicular to the reaction plane and $p_t = \sqrt{p_x^2 + p_y^2}$, is the transverse momentum. The present study is windup within the isospin-dependent quantum molecular dynamics (IQMD) model [7]. The phase space of nucleons generated using IQMD model has been analyzed using the minimum spanning tree (MST) [8] clusterization algorithm.

Results and discussion

For the present analysis, simulations have been carried out for the reaction $^{197}_{79}Au +^{197}_{79} Au$ for the impact parameter range $0.28 < \hat{b} \leq 0.39$. Here, $\hat{b} = b/b_{max}$ with $b_{max} = 1.12(A_1^{1/3} + A_2^{1/3})$. As we are interested in two most important flow observables i.e., directed flow $< v_1 >$ and elliptical flow $< v_2 >$ therefore, we have divided the entire rapidity into bins, where rapidity is defined as [8]

$$Y_i = \frac{1}{2} \ln \frac{(E(i) + P_z(i)c)}{(E(i) - P_z(i)c)} \tag{4}$$

where E(i) and $P_z(i)$ are the energy and longitudinal momentum of the i^{th} nucleon, respectively. Both the observables $< v_1 >$ and $< v_2 >$ are greatly affected by the choice of rapidity bins. The resultant $< v_1 >$ and $< v_2 >$ is due to the interplay between potentials and binary nucleon-nucleon collisions. The excitation function of $< v_1 >$ determines whether the interactions are attractive or repulsive in nature. At low energies due to attractive scattering the net flow is negative but the opposite behavior is true at higher incident energies

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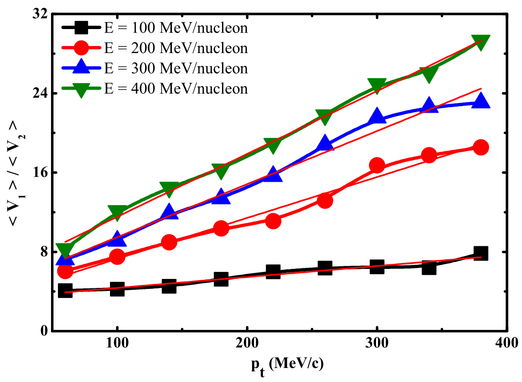

FIG. 1: Strength of ($< v_1 > / < v_2 >$) as a function of transverse momentum at different incident energies.

due to repulsive interactions. Disappearance of $< v_1 >$ occurs at a particular energy known as balance energy [9]. Similarly the excitation function of $< v_2 >$ shows a transition from +ve to -ve on increasing energy. Elliptic flow ($< v_2 >$) becomes zero at a particular energy known as transition energy [10]. To understand the strength of these two flow components the magnitude of both the flow components have been extracted from mid-rapidity zone. Fig 1, depicts the strength of directed flow $< v_1 >$ w.r.t elliptic flow ($< v_2 >$) at an impact parameter $0.28 < \hat{b} \leq 0.39$. Strength of $< v_1 >$ and $< v_2 >$ depends upon various factors like incident energy, impact parameter and mass of colliding systems etc. Directed flow is sensitive to the earliest collisions stage and elliptic flow is a general feature of strongly interacting and compressed system. The ratio of directed flow to the elliptical flow ($< v_1 > / < v_2 >$) as a function of transverse momentum is calculated. Analysis has been performed above the balance energy so that there is no effect of mean field. At these energies $< v_1 >$ increases, but $< v_2 >$ decreases due to its disappearance around transition energy. One can also infer from the ratio that number of nucleons involved in $< v_1 >$ are more than in $< v_2 >$. Slope of the curve increases with energy depicts non linear increase in nuclear flow as a function of energy. This implies that the strength of $< v_1 >$ increases as compared to $< v_2 >$ at all the value of transverse momentum. The important information that can be extracted from Fig.1, is that while varying the incident energy from lower to higher value, the existence of balance as well as transition energies take place.

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References

[1] Deepshikha and S. Kumar, Nucl. Phys. A **977**, 69 (2018).
[2] G. Lehaut *et al.*, Phys. Rev. Lett. **104**, 232701 (2010).
[3] A. Andronic *et. al.*, Phys. Lett. B **612**, 173 (2005).
[4] J. Lukasik *et. al.* Phys. Lett. B **608**, 223 (2005).
[5] R. Pak *et al.*, Phys. Rev. Lett. **78**, 1022 (1997).
[6] S. Voloshin and Y. Zhang, Phys. Rev. C **70**, 665 (1996).
[7] C. Hartnack *et al.*, Eur. Phys. Journal A **1**, 151 (1998).
[8] J. Aichelin, Phys. Rep. **202**, 233 (1991).
[9] D. Krofcheck *et al.*, Phys. Rev. Lett. **63**, 2028 (1989).
[10] A. Andronic *et. al.*, Nucl. Phys. A **679**, 765 (2001).