Effect of Isospin degree of freedom on the distribution of nucleons in elliptical flow

Kamaldeep Kaur[1] and Suneel Kumar[1]
[1] Thapar University, Patiala(Punjab)-147004, INDIA

Introduction

The distribution of nucleons is highly effected by the collisions of heavy ions at intermediate energies. Due to these violent collisions, nucleons are deflected in transverse direction[1]. The collective motion of nucleons in a heavy-ion collision can be studied by directed and elliptical flow. But the directed flow is reported to diminish at higher incident energies because of large beam rapidity, therefore elliptical flow[2] is much more suited at these incident energies. The parameter of elliptical flow is quantified by second order fourier coefficient $v_2 = < \cos 2\phi > = < \frac{p_x^2 - p_y^2}{p_x^2 + p_y^2} >$ from the azimuthal distribution of detected particles at mid-rapidity as[3]:

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

where ϕ is azimuthal angle between the transverse momentum of the particles and the reaction plane. The anisotropic flow generally depends on both transverse momentum and rapidity. Positive value of $\cos 2\phi$ depicts a preferential in-plane emission and negative values gives a preferential out-of-plane emission. The reason for the anisotropic flow is orthogonal asymmetry in the configuration space (noncentral collisions) and re-scattering. In recent years, several experimental groups have measured elliptical flow. The FOPI, INDRA, ALADIN and PLASTIC BALL collaborations [1] are actively involved in measuring the excitation functions of elliptical flow from Fermi energies to relativistic energies.

In the present work, we attempt to study the system size dependence by comparing the rapidity dependence of the elliptical flow. For the present study, we use the isospin-dependent quantum molecular dynamics (IQMD)model which is discussed as follows:

Methodology

In IQMD Model[4], the isospin degree of freedom enters into the calculations via Symmetry potential, cross-sections and Coulomb interactions. The nucleons of target and projectile interact via two and three-body Skyrme forces, Yukawa potential and Coulomb interactions. In addition to the use of explicit charge states of all baryons and mesons, a symmetry potential between protons and neutrons corresponding to the Bethe-Weizsacker mass formula has been included.

In IQMD model, baryons are represented by wave packet

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

The centroids of these wave packets propagate using classical Hamilton equations of motion:

$$\frac{d\vec{r_i}}{dt} = \frac{\partial \langle H \rangle}{\partial p_i} \; ; \; \frac{d\vec{p_i}}{dt} = -\frac{\partial \langle H \rangle}{\partial r_i} \quad (3)$$

with

$$\langle H \rangle = \langle T \rangle + \langle V \rangle = \sum_i \frac{p_i^2}{2m_i} + \sum_i \sum_{j>i} \int f_i(\vec{r}, \vec{p}, t) V^{ij}(\vec{r}', \vec{r}) \times f_j(\vec{r}', \vec{p}', t) d\vec{r} d\vec{r}' d\vec{p} d\vec{p}'. \quad (4)$$

Results and Discussions

We have simulated the reactions of ${}^{197}_{79}Au + {}^{197}_{79}Au$, ${}^{96}_{44}Ru + {}^{96}_{44}Ru$ and ${}^{40}_{20}Ca + {}^{40}_{20}Ca$ collisions at incident energy 400 MeV/nucleon for centrality range $0.25 < b/b_{max} < 0.45$. We have used the scaled constraint of momentum ($u_{t0} = \frac{u_t}{u_p}$)>0.4 as done by Reisdorf

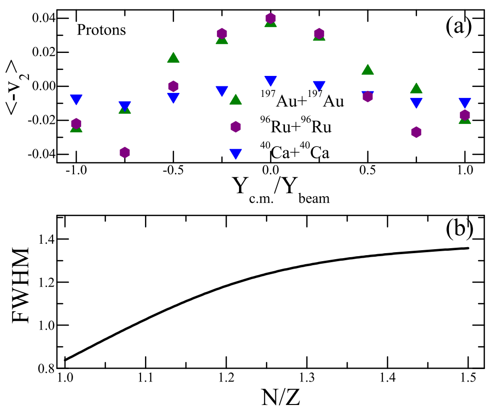

FIG. 1: (a) Rapidity dependence of elliptical flow at centrality $0.25 < b/b_{max} < 0.45$ for different reactions at 400 MeV/nucleon and (b)FWHM(Full-Width Half-Maximum) as a function of N/Z ratio

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et. al.[3], here $u_t = \beta_t\gamma$ is the transverse component of the four-velocity u=(γ, β_γ), the 3d vector $\vec{\beta}$ is the velocity in units of the light velocity and $\gamma = \sqrt{\frac{1}{1-\beta^2}}$ and the index p referring to the incident projectile in the c.m. frame of reference. The v_2 is generally extracted from the mid-rapidity region. The particles corresponding to $Y_{c.m.}/Y_{beam} >$ 0.1 have been defined as projectile-like(PL), whereas $Y_{c.m.}/Y_{beam} <$ -0.1 constitutes the target-like(TL) particles. Fig.1(a) represents the rapidity dependence of elliptical flow for different reacting systems. A Gaussian-type behaviour is seen in all cases. We observe a rather strong effect of the size of system in Fig.1(a). The width of curves goes on decreasing as the system size decreases. It is maximum for $^{197}_{79}Au$+$^{197}_{79}Au$, minimum for $^{40}_{20}Ca$+$^{40}_{20}Ca$ and lies in between for $^{96}_{44}Ru$ +$^{96}_{44}Ru$. Not only the value at mid-rapidity is effected, but the whole shape of the curve is effected.
Fig.1(b) shows the variation of spreading of the curves as a function of neutron to proton ratio(N/Z). The spreading is extracted by the FWHM(Full-Width Half-Maximum). It is observed that the spreading starts increasing with increase in N/Z ratio. This increase is due to the different isospin content or may be due to increase in mass of colliding systems. The work in this direction is in progress.

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