Reduced isospin-dependent cross-section and elliptic flow in heavy-ion collisions

Suneel Kumar[1],* Rajni[1], Sanjeev Kumar[1], and Rajeev K. Puri[2]
[1] School of Physics and Materials Science,
Thapar University, Patiala-147004, Punjab (India) and
[2] Department of Physics, Panjab University, Chandigarh-160014 (India)

1. Introduction

For extracting information about the properties of nuclear matter under the conditions vastly different from that in normal nuclei, such as high density and excitation as well as large difference in proton and neutron number, the term collective flow is used extensively. A lot of theoretical and experimental efforts has been made in studying collective flow in heavy-ion collision [1].

This collective motion of particles can be studied via directed and elliptic flow. The elliptic flow has proven to be one of the more fruitful probe for extracting EOS and dynamics of heavy-ion collision. The parameter of elliptic flow is quantified by the second order fourier coefficient $v_2 = \langle \frac{p_x^2 - p_y^2}{p_x^2 + p_y^2} \rangle$ from the azimuthal distribution of detected particles at midrapidity as

$$\frac{dN}{d\phi} = p_0(1 + 2v_1 Cos\phi + 2v_2 Cos2\phi ...) \quad (1)$$

where ϕ is azimuthal angle of emitted particle momentum relative to x-axis. Positive value for $< Cos2\phi >$ reflects a preferential in-plane emission, negative value for $< Cos2\phi >$ reflects a preferential out-of-plane emission, zero value for $< Cos2\phi >$ shows isotropic distribution in transverse plane. A detailed study of excitation function of elliptic flow in the entire energy region can provide useful information about nucleon-nucleon interaction related to nuclear equation of state[2].

In this paper we study excitation function of elliptic flow in entire energy region for free nucleon and light charged particle's by using isospin dependent quantum molecular dynamics(IQMD)model.

2. IQMD Model

The isospin-dependent quantum molecular dynamics (IQMD)[3] model treats different charge states of nucleons, deltas and pions explicitly[3], as inherited from the VUU model [4]. The IQMD model has been used successfully for the analysis of large number of observables from low to relativistic energies. The isospin degree of freedom enters into the calculations via symmetry potential, cross-sections and Coulomb interaction[4]. The details about the elastic and inelastic cross-sections for proton-proton and neutron-neutron collisions can be found in Ref.[3].

In this model, baryons are represented by Gaussian-shaped density distribution

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

The hadrons propagate using Hamilton equations of motion:

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

with

$$\langle\ H\ \rangle = \langle\ T\ \rangle + \langle\ V\ \rangle$$

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

The baryon-baryon potential V^{ij}, in the

*Electronic address: suneel.kumar@thapar.edu

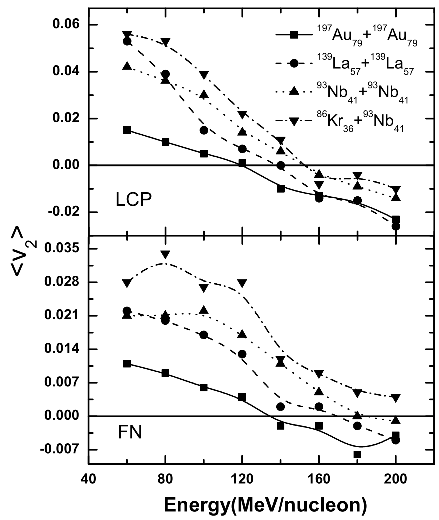

FIG. 1: Variation of the elliptic flow, with beam energy at $|y| = |\frac{y_{c.m}}{y_{beam}}| \leq 0.5$ for different symmetric reactions at midrapidity range for LCP and FN.

above relation, reads as:

$$V^{ij}(\vec{r'},\vec{r}) = V^{ij}_{Skyrme} + V^{ij}_{Yukawa} + V^{ij}_{Coul} + V^{ij}_{mdi} + V^{ij}_{sym} \quad (5)$$

3. Results and Discussion

We here simulate reactions of $^{197}Au_{79}$ + $^{197}Au_{79}$, $^{139}La_{57}$ + $^{139}La_{57}$, $^{93}Nb_{41}$ + $^{93}Nb_{41}$, $^{86}Kr_{36}$ + $^{93}Nb_{41}$ using a stiff equation of state along with reduced isospin dependent cross-section ($\sigma = 0.9\sigma_{NN}$) at incident energies between 60 and 200 MeV/nucleon. The choice of these reactions is based on the availability of experimental balance energies. The phase space generated using IQMD model has been analysed with minimum spanning tree (MST) algorithm [1]. Our aim here is to study the reaction dynamics near the balance energy for elliptic flow in terms of transition energy. In the fig. 1, we display the variation of the excitation function of elliptic flow v_2 for free nucleon, light charge particle (LCP's) over midrapidity region. The free particles and LCP's, which originate from the participant zone, show a systematic behavior with the beam energy as well as with the composite mass of the system. The elliptical flow for these particles is found to become more negative with the increase in the composite mass of system and with the increase in the beam energy. The heavier the system, the greater the Coulomb repulsion and more negative is the elliptical flow.

The elliptical flow is found to show a transition from in-plane to out-of-plane at a certain beam energy known as transition energy in mid-rapidity region. This is due to the change in the rotational behavior into expansion with increase in the incident energy. This transition energy is found to decrease with the composite mass of system as well as with the size of the fragment. We shall parametrize the transition energy as a function of the mass of colliding nuclei.

References

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