Influence of density dependent of symmetry energy on neutron-proton directed transverse flow (v_1)

Rubina Bansal,* Anupriya Jain, and Suneel Kumar
School of Physics and Materials Science, Thapar University Patiala-147004, Punjab (India)

Introduction

From the last two decade, the density dependence of symmetry energy is a topic of wide interest for the nuclear physics community. Large amount of work has been done both theoretically as well as experimentally on the density dependence of symmetry energy [1]. One of our collaborator has studied the effect of density dependence of symmetry energy on multifragmentation [2], nuclear stopping [3] and on elliptical flow [4]. All these phenomena have been found to be sensitive towards the different forms of density dependence of symmetry energy. Recently, it has been reported that the neutron-proton differential transverse flow, the neutron-proton elliptical flow difference [5] and the ratio of the elliptical flow parameters of neutrons with respect to protons or hydrogen isotopes [6] can be taken as sensitive observable to the density dependence of symmetry energy [7]. In this paper, we plan to address two different aspects related to differential transverse flow. First is the sensitivity of the neutron-proton differential transverse flow towards the different forms of density dependence of symmetry energy for lighter as well as for heavy mass systems and the second is to see wether the total system mass play any role or not to probe the symmetry energy and its density dependence for the neutron-proton differential transverse flow. To achieve our goal, we use isospin quantum molecular dynamics (IQMD) model [8].

Results and discussion

For the present study, we simulated the reactions of ${}^{26}_{11}Na_{15} +^{26}_{11} Na_{15}$ and ${}^{129}_{54}Xe_{75} +^{129}_{54} Xe_{75}$ with N/Z $\approx$ 1.4 at scaled impact parameter, $\hat{b} = \frac{b}{b_{max}} = 0.5$, where $b_{max} = 1.12\ (A_T + A_P)^{\frac{1}{3}}$, here A_T and A_P are the masses of target and projectile. The analysis has been carried out at an incident energy of E = 80 MeV/nucleon. This energy region is of central interest because relativistic effects as well as sub-threshold particles production is less below 100 MeV/nucleon. The calculations are performed with soft equation of state as well as energy and isospin dependent reduced cross-section at saturation time of 200 fm/c. Collective flow is the azimuthal correlation between the reaction plane and departing particles. It can be represented by the Fourier coefficients of the Fourier expansion given by Voloshin [9]. At low incident energy very small values of higher order anisotropic flow is obtained. But, first order anisotropic flow, described by directed transverse flow (v_1) give a measurable value at low energy. It is define as $\langle v_1 \rangle = \langle cos\phi \rangle = \langle \frac{p_x}{p_t} \rangle$, here $p_t = \sqrt{(p_x)^2 + (p_y)^2}$, where p_x and p_y are projections of particle transverse momentum, parallel and perpendicular to the reaction plane, respectively. Directed transverse flow depends on both rapidity distribution as well as on particle transverse momentum. To study the comparative effect of Coulomb potential and density dependence of symmetry energy on the differential transverse flow we display in Fig.1, the differential transverse flow for ${}^{26}_{11}Na_{15} +^{26}_{11} Na_{15}$ in upper panels and for ${}^{129}_{54}Xe_{75} +^{129}_{54} Xe_{75}$ in lower panels for the different forms of density dependence of symmetry energy. Gaussian shape distribution is observed for lighter as well as for heavier systems. One can see that, the directed transverse flow decreases with system mass. This happens due to the energy ef-

*Electronic address: rubinabansal98@gmail.com

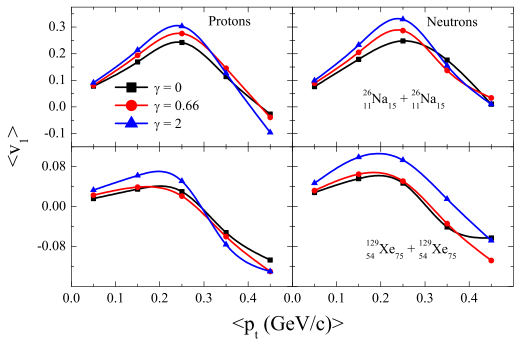

FIG. 1: Differential transverse flow for ${}^{26}_{11}Na_{15}+{}^{26}_{11}Na_{15}$ and ${}^{129}_{54}Xe_{75}+{}^{129}_{54}Xe_{75}$ for different values of γ at scaled impact parameter $\hat{b} = 0.5$ and incident energy E = 80 MeV/nucleon. Upper (lower) panel represents for protons (neutrons).

fect because the incident energy is less than the balance energy of both the collidng nuclei. Moreover, the value of directed transverse flow increases with increase in compressibility factor (γ). This is due to the large compression which results in large expansion. Further, the flow is large for neutrons compared to protons. This is because the symmetry energy is attractive for protons and repulsive for neutrons [10]. The differential transverse flow of neutron is large. This is due to the strong repulsions produced by the symmetry potential between the neutrons at density above the normal nuclear matter density. At high density Coulomb potential produces repulsions between the protons and symmetry potential produce attractive forces between the protons. From figure, one can see that the effect of density dependence of symmetry energy is more for the lighter colliding nuclei compared to the heavier nuclei. From this we can conclude that, neutron/proton differential transverse flow of lighter colliding nuclei can act as probe for symmetry energy and its density dependence. Moreover, a comparative study of neutrons protons differential transverse flow at low energy signifies that the symmetry energy and its density dependence plays a more significant role as compared to the Coulomb effect.

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