Transverse momentum dependence of elliptical flow for different radius parameterizations

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Introduction

The pressure gradient developed during highly compressed stage of nuclear matter can be explained by collective flow and it has been proven a good probe to study isospin dependence of nuclear equation of state (EOS). Among the different kinds of collective flow, the elliptical flow enjoys a special status due to its sensitivity towards entrance channel parameters and reaction dynamics. The excitation function of elliptical flow is represented as [1],$\langle v_2\rangle = \langle cos(2\phi)\rangle = \langle \frac{p_x^2-p_y^2}{p_t^2}\rangle$. Here, ϕ is the azimuthal angle between the transverse momentum $p_t = \sqrt{p_x^2+p_y^2}$ of the particle and the reaction plane. The isospin content of the colliding nuclei and the isospin dependence of the nucleon-nucleon cross-section affects the transverse momentum dependence of elliptical flow [2]. It has been reported that, the elliptical flow difference $v_2^n - v_2^p$ is sensitive to the density dependence of the symmetry energy [3]. The isospin effects studied via isospin dependent nuclear charge radius reveals that the radius decided at initial state has significant influence on the transverse directed flow [4].
However, study is silent about the influence of nuclear charge radii parameterizations on elliptical flow. Moreover, the previous study has been done by keeping the Fermi momentum (p_f) associated with nucleons same for all nuclear charge radii parameterizations, however it should change with change in radius of a particular nuclei. Therefore, in present manuscript we aim to address this problem using IQMD [5] model.

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Model

The Isospin quantum molecular dynamics (IQMD) [5] model treats different charge states of nucleons, deltas and pions explicitly. The nucleons are primarily initialized in a sphere of radius in accordance with the liquid drop model (LDM) [6] i.e. isospin independent. In order to study the influence of isospin dependent nuclear charge radii, we have introduce the parameterized form of nuclear charge radii proposed by Royer and Rousseau (RR) [7] in the model. The hadrons propagate using Hamilton equations of motion:

$$\begin{aligned}\langle\ H\ \rangle &= \langle\ T\ \rangle + \langle\ V\ \rangle \\ &= \sum_i \frac{p_i^2}{2m_i} + \sum_i\sum_{j>i}\int f_i(\vec{r},\vec{p},t)V^{ij}(\vec{r}',\vec{r}) \\ &\quad \times f_j(\vec{r}',\vec{p}',t)d\vec{r}d\vec{r}'d\vec{p}d\vec{p}'. \qquad (1)\end{aligned}$$

The nucleons of the target and projectile interact by two- and three-body Skyrme forces, Yukawa potential and Coulomb interactions. A symmetry potential between protons and neutrons corresponding to the Bethe-Weizsacker mass formula has also been included. In addition, Pauli blocking (of the final state) of baryons is taken into account by checking the phase space densities of the final states.

Results and discussion

We simulated the reaction of $^{197}_{79}Au+^{197}_{79}Au$ at E = 50 MeV/nucleon for different nuclear charge radii parameterizations (i.e. R_{LDM} and R_{RR}) at scaled impact parameter of $\hat{b} = b/b_{max} = 0.6$ and 0.9, where

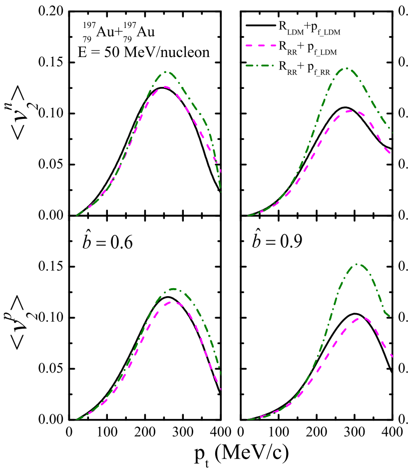

FIG. 1: Transverse momentum dependence of elliptical flow of neutrons (upper panels) and protons (lower panels) at an incident energy of 50 MeV/nucleon at $\hat{b}$ = 0.6 (left panels) and 0.9 (right panels).

$b_{max} = (R_P + R_T)fm$, here R_P and R_T are respective radii of target and projectile. A soft equation of state and nucleon-nucleon cross-section $\sigma = 0.9\,\sigma_{nn}^{free}$ with linear density dependence of symmetry energy has been employed for the analysis of elliptical flow as a function of transverse momentum. The different lines in Fig.1 displays the transverse momentum dependence of elliptical flow of neutrons (v_2^n) (upper panels) and protons (v_2^p) (lower panels) using $R_{LDM} + p_{f\_LDM}$, $R_{RR} + p_{f\_LDM}$ and $R_{RR} + p_{f\_RR}$. Here, p_{f_LDM} and p_{f_RR} denotes the Fermi momentum associated with nucleons according to LDM radius and RR radius respectively. It is worth to mention that the calculated radius of $^{197}_{79}Au$ nucleus increases with R_{RR} parameterization. The figure reveals that, if one keep the p_f same for both parameterizations then the structural effects on elliptical flow of neutron and proton are negligible. Where as, for isospin dependent nuclear charge radius parameterization, when the p_f is kept according to its calculated radius, the probability of in-plane emission of particles increases. It has been observed that, the influence of isospin dependent nuclear charge radius increases with increase in impact parameter. Moreover, at $\hat{b} = 0.6$ the influence of radius parameterization on the peak value of elliptical flow for neutrons is more compared to elliptical flow of protons which is because of neutron-rich colliding pairs. But, at $\hat{b} = 0.9$ this influence is more on elliptical flow of proton. This may be because of high momentum of the protons compared to neutrons and another reason may be the coulomb repulsive interactions which are prevalent at 50 MeV/nucleon.

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References

[1] A. Andronic *et al.*, Nucl. Phys. A **679**, 765 (2001); A. Andronic *et al.*, Phys. Lett. B **612**, 173 (2005).

[2] A. Jain *et al.*, Phys. Rev. C **85**, 064608 (2012).

[3] Y. Wong *et al.*, Phys. Rev. C **89**, 044603 (2014).

[4] R. Bansal, et al., Phys. Rev. C 87 (2013) 061602(R); S. Gautum, Phys. Rev. C 88 (2013) 057603.

[5] Ch. Hartnack *et al.*, Eur. Phys. J. A **1**, 151 (1998); Ch. Hartnack *et al.*, Phys. Rep. **510**, 119 (2012).

[6] A. Bohr and B. Mottelson, Nuclear Structure (W. A. Benjamin Inc., New York, Amsterdam) Vol. **1**, p.268 (1969).

[7] G. Royer and R. Rousseau, Eur. Phys. J. A **42**, 541-545 (2009).