Influence of Coulomb interactions on directed transverse flow

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Introduction

The heavy-ion physics has attracted much attention during the last three decades [1]. The behavior of nuclear matter under the extreme conditions of temperature, density, angular momentum etc., is a very important aspect of heavy-ion physics. One of the important quantity which has been used extensively to study this hot and dense nuclear matter is the collective transverse in-plane flow. This quantity has a beauty of vanishing at a certain incident energy. This energy is dubbed as balance energy (E_{bal}) or the energy of vanishing flow (EVF) [2].
Here, we have checked the influence of Coulomb interactions on directed transverse flow by taking into account mass asymmetry. The mass asymmetry of the reaction can be defined by the parameter $\eta = \mid (A_T - A_P)/(A_T + A_P) \mid$; where A_T and A_P are the masses of target and projectile. The $\eta = 0$ corresponds to the symmetric reactions, whereas, non-zero value of η define different asymmetry of the reaction. It is worth mentioning that the reaction dynamics in a symmetric reaction ($\eta = 0$) can be quite different compared to asymmetric reaction ($\eta \neq 0$) [3]. The effect of the asymmetry of a reaction on the multifragmentation is studied many times in the literature [3]. Unfortunately, very little study is available for the mass asymmetry of the reaction in terms of transverse in-plane flow.

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The Model

Semi classical microscopic improved version of QMD model [4] which includes Skyrme forces, isospin-dependent Coulomb potential, Yukawa potential, symmetry potential, and NN cross-section. The details about the elastic and inelastic cross sections for proton-proton and neutron-neutron collisions can be found in Refs.[4]. Thus, the total interaction potential is given as:

$$V^{ij}(\vec{r}' - \vec{r}) = V^{ij}_{Skyrme} + V^{ij}_{Yukawa} + V^{ij}_{Coul} + V^{ij}_{mdi} + V^{ij}_{sym} \quad (1)$$

Results and Discussion

To check the effect of frame of reference, we have fixed ($A_{TOT} = A_T + A_P$ = 152) and varied the asymmetry of the reaction just like this: ${}_{26}Fe^{56} +_{44} Ru^{96}$ ($\eta = 0.2$), ${}_{24}Cr^{50} +_{44} Ru^{102}$ ($\eta = 0.3$), ${}_{20}Ca^{40} +_{50} Sn^{112}$ ($\eta = 0.4$), ${}_{16}S^{32} +_{50} Sn^{120}$ ($\eta = 0.5$), ${}_{14}Si^{28} +_{54} Xe^{124}$ ($\eta = 0.6$), ${}_{8}O^{16} +_{54} Xe^{136}$ ($\eta = 0.7$). We display in Fig.1, variation of the asymmetry η on directed flow $< P_x^{dir} >$ in lab. as well as center of mass frame at incident energy of E = 50 MeV/nucleon. The directed transverse flow is calculated using $< P_x^{dir} >$ [2]

$$< P_x^{dir} > = \frac{1}{A} \sum_i sgn\{Y(i)\} P_x(i) \quad (2)$$

where Y(i) and $P_x(i)$ are, respectively, the rapidity and transverse momentum of the i^{th} particle.
The top and bottom panels in the right hand side of the figure are representing the

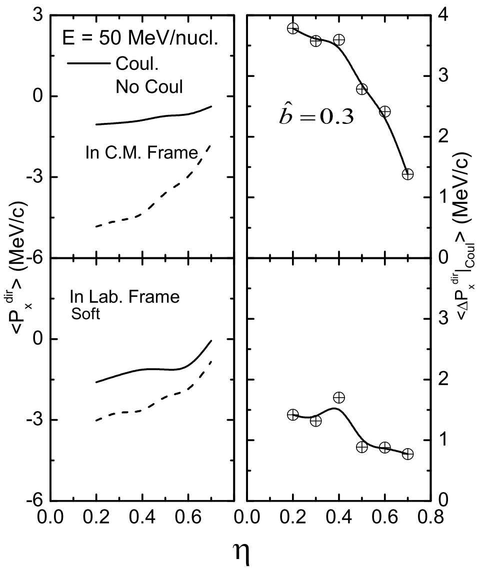

FIG. 1: Asymmetry dependence of directed flow in lab as well as center of mass frame in L.H.S, while, R.H.S for the relative effect of Coulomb interactions. The different lines in the figure are representing the effect of Coulomb interactions.

relative Coulomb effect with respect to the asymmetry of the reaction. As is evident from the figure, directed flow is found to increase in a systematic manner in C.M. as well as in lab frame at E = 50 MeV/nucleon with asymmetry of the reaction. The inclusion of Coulomb interactions does not alter the conclusions. Note that the increase in the asymmetry is related with the increase in the N/Z ratio. Because the symmetry potential for the neutron rich systems is stronger compared to the neutron poor systems due to large relative neutron strength. Furthermore, the symmetry potential is repulsive for neutrons and attractive for protons. On the other hand, more negative value of directed flow (dominating the mean field) is observed in the absence of Coulomb interactions in center of mass as well as in lab. frames. This is due to the enhancement of the chemical and mechanical instability domains in the absence of Coulomb interactions [5]. Similar type of study and conclusion was also performed for fragmentation in ref. [6].

As is clear from the figure, asymmetric systems are found to be more stable in the center of mass frame compared to the lab frame. Moreover, if one consider lab frame, one is surely missing the effect of asymmetry. To further strengthen the stability of center of mass frame with asymmetry, the relative effect of Coulomb interactions $< \Delta P_x^{dir} |_{Coul}>$ is studied in both frames. The relative effect of the Coulomb interactions is found to decrease with increase in the asymmetry of a reaction. The systematic decrease can be seen in center of mass frame with asymmetry, while very weak dependence of Coulomb interactions on the asymmetry is obtained in lab frame.

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