Study of Coulomb effect on balance energy at VECC energies

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Introduction

The possible nuclear reaction at the K500 superconducting cyclotron (SCC500) being developed in Variable Cyclotron Centre (VECC) will give us an insight to study the collective transverse flow which results due to two major interactions (i) the attractive nuclear mean-field and (ii) the repulsive nucleon nucleon interactions [1]. Among various observables in heavy-ion collisions, collective transverse flow is one of the most sensitive and sought after phenomena at intermediate energies. The collective transverse flow is the sideward deflection of the reaction products in phase space and is due to the interactions inside the reaction zone. This quantity vanishes 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 the balance energy by taking into account entrance channel 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 respectively. The $\eta = 0$ corresponds to the symmetric reactions, whereas, non-zero value of η define different mass asymmetries 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 entrance channel mass 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 dependence of transverse in-plane flow. Therefore, we study the effect of Coulomb interactions on balance energy for various colliding nuclei in terms of mass asymmetry. We plan to adress this question using isospin-dependent quantum molecular dynamics (IQMD) model.

The Model

The model is the 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 Coulomb interactions, we have fixed ($A_{TOT} = A_T + A_P = 152$) and varied the mass asymmetry of the reaction just like this: ${}_{26}Fe^{56} +_{44} Ru^{96}$ ($\eta = 0.2$), ${}_{24}Cr^{50} +_{44} Ru^{102}$ ($\eta = 0.3$), ${}_{20}Ca^{40} +_{50} Sn^{112}$ ($\eta = 0.4$), ${}_{16}S^{32} +_{50} Sn^{120}$ ($\eta = 0.5$), ${}_{14}Si^{28} +_{54} Xe^{124}$ ($\eta = 0.6$), ${}_{8}O^{16} +_{54} Xe^{136}$ ($\eta = 0.7$). Here, mass of the projectile varies between 16 and 56 units which is possible at SCC500 accelerator. We display in Fig.1, mass asymmetry dependence

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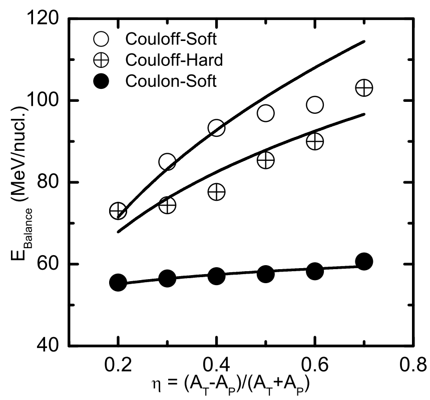

FIG. 1: Power law dependence of balance energy with mass asymmetry of the reaction using different equations of state.

of balance energy for hard and soft nuclear equation of state (NEOS) by switching off the Coulomb interactions. In addition, for a comparative study, the results in the presence of Coulomb interactions with soft NEOS are also shown. All the lines are fitted with power law of the form $E_{bal} = C(\eta)^{\tau}$, where C and τ are the constants. The values of τ in the absence of Coulomb interactions for soft and hard NEOS are 0.375 and 0.282, respectively, while in the presence of Coulomb interactions for soft NEOS is $\tau = 0.06$.
If we compare the mass asymmetry dependence of balance energy with the mass dependence of balance energy, the trend is opposite [2]. It is also clear from the figure, that shift in the balance energy is observed due to Coulomb interactions as well as due to different NEOS with mass asymmetry of the reaction. The shift is more due to Coulomb interactions in comparison to NEOS, indicating the importance of Coulomb interactions in intermediate energy heavy-ion collisions. The higher balance energy is obtained with Coulomb-off + soft NEOS followed by Coulomb-off + hard NEOS and finally Coulomb-on + soft NEOS. This study shows that the balance energy is affected by the Coulomb interactions as well as different nuclear equations of state. The preliminary results calculated theoretically will be of great use for scientists at VECC. This study is further in progress.

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