Effect of nuclear charge radii parameterizations and Fermi momentum on the transverse momentum and multiplicity of light fragments

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Introduction

Theoretical study of nuclear reactions have been carried out in literature by using various theoretical nuclear models (e.g. Inter Nuclear Cascade (INC) model [1], Isospin dependent Boltzmann-Uehling-Uhlenbeck (IBUU) model [2] and Isospin dependent Quantum Molecular Dynamics (IQMD) model [3] etc.), which includes many steps of reaction mechanism from initialization of nucleus at ground state in the Fermi sphere of radius (R) with Fermi momentum (p_f) associated with the nucleons to the final product of the nuclear reaction. For a long time, it was assumed that the nuclear charge radius has the form as proposed by liquid drop model (LDM) [4]. But later on, various experimental as well as theoretical studies proposed different nuclear charge radii parameterizations which are based on many calculations like the deformation effects in the nucleus and isopin parameter ($I = (N-Z)/A$) [5]. In literature, these radii parameterizations are proved to be a good probe to study the multifragmentation and collective flow [6, 7]. The study reveals that the increment in radius of colliding nuclei ,due to different radii parameterizations, enhance the multiplicity and the energy of vanishing flow (EVF). The multifragmentation of the heavier colliding nuclei is more sensitive towards the change in radius compared to the lighter colliding nuclei. Also, the small change in radius can make large difference in EVF for lighter systems whereas, for heavier system the influence of change in radius on EVF is weaker. These studies on multifragmentation and EVF are performed by keeping the p_f same for all nuclear charge radii parameterizations. However, an attempt has been done to throw light on the transverse momentum dependence of elliptical flow of neutrons and protons for different radii parameterizations by keeping the p_f of nuclei constant as well as according to its calculated radius [8]. The initialization effect via only nuclear charge radii parameterizations (constant p_f) is negligible on the elliptical flow, whereas, stronger squeeze-out flow has been observed by keeping the Fermi momentum according to radii parameterizations used. In this manuscript, our aim is to explore the influence of Fermi momentum of nuclei associated with its nucleons on the multifragmentation and the rapidity distribution of transverse momentum within the framework of IQMD [3] model.

Result and Discussion

In the present study, we simulated the isospin asymmetric reactions ($N/Z = 1.5$) over wide range of system mass from $^{50}_{20}Ca + ^{50}_{20}Ca$ to $^{197}_{79}Au + ^{197}_{79}Au$ at an incident energy of 50 MeV/nucleon along with linear density dependent symmetry energy and soft equation of state using IQMD [3] model. Figure 1 (a) and (b) displays the rapidity distribution of transverse momentum ($p_t = \sqrt{p_x^2 + p_y^2}$) of free nucleons (FNs) for lighter ($^{50}_{20}Ca + ^{50}_{20}Ca$) and heavier ($^{197}_{79}Au + ^{197}_{79}Au$) colliding nuclei pair by using two radii parameterizations, R_{LDM} [2] (isospin independent) and R_{RR} [5] (isospin dependent). Figure 1 (c) and (d) represents the system mass dependence of the multiplicity of FNs and LMFs (light mass fragments). Here,

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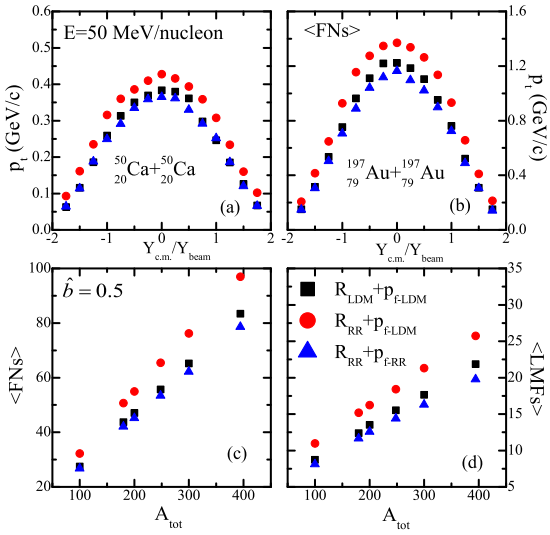

FIG. 1: (a) & (b) represents the rapidity distribution of transverse momentum of FNs for $^{50}_{20}Ca +^{50}_{20} Ca$ and $^{197}_{79}Au +^{197}_{79} Au$ and (c) & (d) represents system mass dependence of multiplicity of FNs and LMFs at E = 50 MeV/nucleon.

p_{f-LDM} and p_{f-RR} symbolize the Fermi momentum calculated with R_{LDM} and R_{RR} respectively. Radius calculated using R_{RR} parameterizations is larger compared to R_{LDM}.

The figure reveals that, with increase in radius, the transverse momentum of FNs increases throughout the rapidity range and this influence is more at maximum compressed zone of the reaction. Also the multiplicity of FNs and LMFs has been enhanced throughout the mass range of periodic table (see $R_{LDM} + p_{f-LDM}$ and $R_{RR} + p_{f-LDM}$). This influence is only due to the increase in radius because the p_f is kept fixed for both radii parameterizations. The influence of change in radius on transverse momentum distribution and the multiplicity of fragments is more for heavier colliding partners compared to lighter one, which is in agreement with Ref. [7]. However, a slight reduction in the transverse momentum of FNs has been observed when one includes the p_f as per the radius parameterizations (see $R_{LDM}+p_{f-LDM}$ and $R_{RR}+p_{f-RR}$). Due to this, the multiplicity of FNs and LMFs reduces. This is because, for R_{LDM}, the p_f is a constant value (i.e. 268 MeV/c in IQMD model) and for R_{RR}, Fermi momentum varies as a function of mass and isospin parameter of the nuclei.

From above discussion, one can say that the role of change in radius, with constant p_f is more on the multifragmentation as compared to the case when the p_f is kept according to radii parameterizations used. Further studies in this direction are in progress.

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