Effect of different nuclear radii parameterizations on the equilibrium using collision dynamics

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Introduction

The study of nuclear stopping provides the information about the thermalisation as well as expansion of the system [1]. The degree of equilibrium depends on the reaction geometry, incident energy, various isospin dependent model ingredient as well as on the number of collisions any individual nucleon suffers [2, 3]. The preservation of the initial memory of nucleons is directly related with the number of collisions one suffers. In heavy ion collisions (HICs), a nucleon of one nucleus can collide with many nucleons of other nucleus and after each collision it loses some part of its energy. The amount of energy lost describes the nuclear stopping. Now, it would be of great interest to ruminate that how many collisions are sufficient to stop the nucleon completely. In the recent publication, the observable of nuclear stopping is found to dependent on the nuclear charge radii parameterizations [4]. The increment in radius intensifies the transverse and longitudinal momentum of nucleons, which enhances the multiplicity of fragments. Whereas the probability of transformation of initial longitudinal momentum into transverse momentum is less with the larger radii. The increase in radius due to different nuclear charge radii parameterizations causes the transformation of the longitudinal motion into transverse direction which consequently affects the degree of thermalization of the system. Therefore, in the present study, we intend to study the effect of different nuclear charge radii parameterizations on the equilibrium using collision dynamics within the framework of isospin-dependent Molecular Dynamics (IQMD) model [5]. we chose four parameterizations in such a way that the calculated radius of nuclei follows the pattern: $R_{LDM} < R_{NGO} < R_{PP} < R_{RR}$. One can refer to Ref. [6] for the details of these radii.

Results and Discussion

The influence of different nuclear charge radii parameterizations on the degree of global equilibrium has been investigated using stopping observable $< varxz >$, defined as the ratio of the longitudinal and transverse variances of the rapidity distributions. Mathematically, it is represented as [7]:

$$< varxz >= \frac{< varx >}{< varz >} = \frac{< \sigma_x^2 >}{< \sigma_z^2 >}. \quad (1)$$

Here $< varx >$ and $< varz >$ are the transverse and longitudinal variances of the rapidity distribution along transverse and longitudinal directions respectively. The value of $< varxz > = 1$; or < 1; or > 1 indicates complete stopping, partial transparency and super-stopping respectively. The value of nuclear stopping greater than 1 can be explained by the preponderance of transverse momentum [8].

Fig.1 displays the dependence of $< varxz >$ on collision number of protons at an incident energy of 400 MeV/nucleon and $\hat{b} < 0.15$ for the reactions of $^{50}_{20}Ca +^{50}_{20} Ca$ (upper panel) and $^{197}_{79}Au +^{197}_{79} Au$ (lower panel). The figure reveals that, more the particle collides, more equilibrium is achieved and hence the nuclear stopping increases. Earlier study carried out by using QMD model, suggested that the nucleon suffering at least 10 collisions is the most

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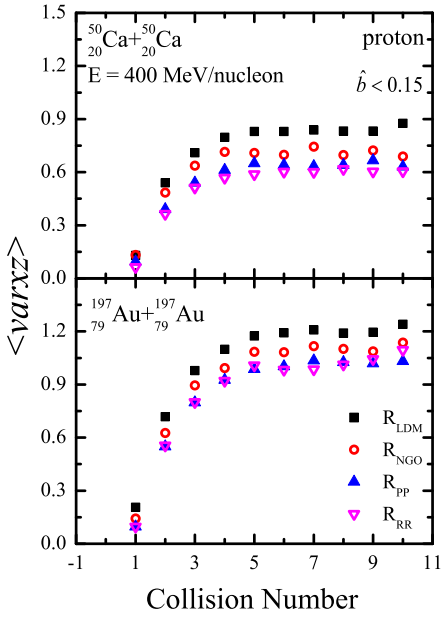

FIG. 1: The collision number dependence of $< varxz >$ for the reactions of Ca+Ca (upper panel) and Au+Au (lower panel) at E = 400 MeV/nucleon for different radii parameterizations.

thermalize and hence close to complete equilibrium [3]. But here, in IQMD calculations, one can interestingly notice that the nuclear stopping variable $< varxz >$ becomes almost independent of collision number as the collision number exceeds from 5 which means that on average those nucleons which have experience at least 5 collisions are close to complete equilibrium. This observation is appropriate for both reactions as well as for all the radii parameterizations.

It has been observed that the change in radius has sizeable effect on the nuclear stopping. The value of $< varxz >$ decreases with increase in radii. The percentage change in the magnitude of nuclear stopping (above 5 collision) is $\sim 30\%$ for the reaction of Ca+Ca and $\sim 14\%$ for the reaction of Au+Au as one switches from R_{LDM} to R_{RR}. Therefore, the lighter systems are good probe to study role of nuclear charge radius on the nuclear stopping observable.

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