Effect of Cross-section and Gaussian width on nuclear stopping

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Introduction

Nuclear reactions are requisite to demonstrate the relative motion and stopping of fragments in heavy ion collisions (HICs) from lower to higher incident energies. Heavy ion collisions provide a unique opportunity to study the nuclear stopping. Bauer and Bertsch [1, 2] pointed out that the nuclear stopping at intermediate energies in heavy-ion collisions is determined by the mean field and in-medium nucleon-nucleon(NN) cross-sections. Nuclear stopping governs most of the dissipated energy in the central collisions and nuclear stopping provides information about the nuclear equation of state, nucleon-nucleon cross section, as well as degree of equilibrium reached in heavy-ion collisions. INDRA and ALADIN collaboration proved experimentally that at high energies nuclear stopping depends upon the total mass of the system and near Fermi energy region, role of isospin content of the colliding system is negligible [3–6]. In the literature, many observables have been suggested to study the nuclear stopping. One definition of stopping observable is R_P [7]:

$$R_P = \frac{2}{\pi}\frac{(\sum_i |p_\perp(i)|)}{(\sum_i |p_\parallel(i)|)} \qquad (1)$$

where summation runs over all nucleons. The transverse and longitudinal momenta are $p_\perp(i) = \sqrt{p_x^2(i) + p_y^2(i)}$ and $p_\parallel(i) = p_z(i)$, respectively. Collision between two nucleons depends on the minimum distance of approach [8]. This distance depends on the interaction range of each nucleon (Gaussian width [9]and strength of nucleon nucleon (NN) cross section) so we wish to focus on the investigation of nuclear stopping using different cross-section values and varying the Gaussian width.

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IQMD Model

The IQMD model [10] is a semi classical model and an improved version of QMD model [8]. The hadrons propagate using classical Hamiltonian equations of motion, which are use to calculate space and momentum coordinate of each nucleon after each collision are :

$$\frac{d\vec{r_i}}{dt} = \frac{d\langle\ H\ \rangle}{d\vec{p_i}}\ ;\ \frac{d\vec{p_i}}{dt} = -\frac{d\langle\ H\ \rangle}{d\vec{r_i}} \qquad (2)$$

with

$$\langle\ H\ \rangle = \langle\ \sum_i \frac{p_i^2}{2m_i}\ \rangle + \langle\ V^{tot}\ \rangle \qquad (3)$$

where

$V^{tot} = V_{Skyrme} + V_{Yukawa} + V_{Coul} + V_{mdi} + V_{sym}$

$V_{Skyrme}, V_{Yukawa}, V_{Coul}, V_{mdi}, V_{sym}$, respectively, are the local (two and three-body) Skyrme, Yukawa, Coulomb, momentum dependent and symmetry potentials.

Results and discussion

For the present study, we have simulated the symmetric reaction $^{197}_{79}Au + ^{197}_{79}Au$, for incident energy range between 10 MeV/nucleon

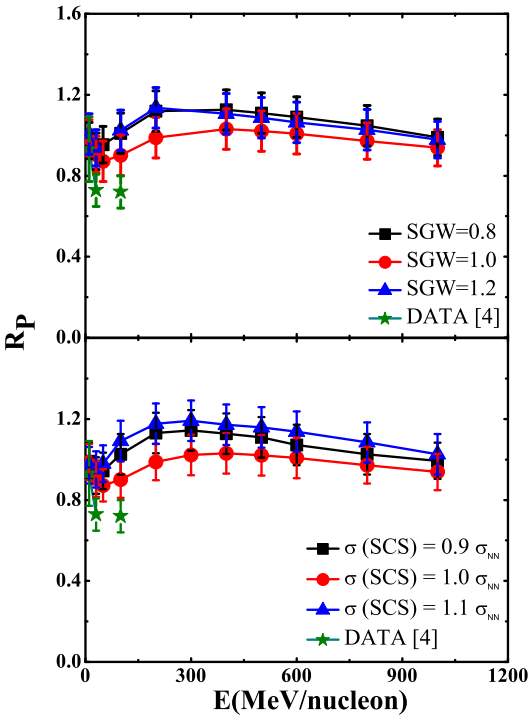

FIG. 1: Stopping observables (R_E and R_P) as a function of incident energy for the reaction $^{197}_{79}Au +^{197}_{79} Au$ at t=200 fm/c .

and 1000 MeV/nucleon. The simulations are carried out for different scaled Cross-section values (SCS = $0.9\sigma_{NN}$, $1.0\sigma_{NN}$ and $1.1\sigma_{NN}$) and varying the scaled Gaussian width (SGW = 0.8, 1.0 and 1.2). To obtained maximum stability of nucleus, mass dependence Gaussian width has been included in IQMD model. Scaled Gaussian width stand for ratio of enhanced or reduced value of Gaussian width to actual value of Gaussian width used in IQMD model. The collisions have been performed at central geometry, leading to the maximal overlap between the two colliding nuclei. Doing so, one can extract information concerning the nuclear stopping. In the FIG1., from 10 to 40 MeV/nucleon, a sharp decrease in the stopping value due to the decreasing role of the mean field is observed. Above the Fermi energy, reaction dynamics are dominated by nucleon-nucleon (NN) collisions. Maximum stopping is observed around 300 MeV/nucleon [3], also when energy exceeds 300 MeV/nucleon, the value of nuclear stopping falls gradually because of the ineffective role of Pauli-blocking. At lower incident energies, nucleon-nucleon collisions do not play any strong role and mean field will take the long time to thermalize the nuclear matter. Our study reveals that no major change is observed in both the stopping observables using different forms of scaled Gaussian width and scaled cross-section because stopping is a global phenomenon. We put statistical error bars on the theoretical results and also compared our theoretical results with the data [4] at lower energies.

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