# Momentum distribution of particles participating in nuclear stopping

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## Introduction

Central heavy ion collisions (HIC) provide precious information about the nuclear equation of state (EOS), which virtually reflects the properties of hot and dense nuclear matter under the extreme condition of temperature, pressure and density. These parameters determine the degree of thermalization achieved in a dynamical process during the collision of heavy ions. One of the essential observables for analysing the energy spectra as well as the particle densities of compressed nuclear matter at an early stage, is the nuclear stopping. In the past many years, numerous attempts have been made to study nuclear stopping by seeing its effect on isospin dependence of cross-section, mean field as well as nucleon-nucleon cross-section [1]. Despite these observations, role of momentum distribution of fragments in nuclear stopping has been rarely studied. In the present study it has been investigated that which momentum range of particles contribute significantly towards the nuclear stopping at a specific energy and impact parameter. Simulations have been carried out within isospin dependent quantum molecular dynamics (IQMD) model [2]. The IQMD model along with the QMD version have been quite successful in explaining various phenomena of heavy ion physics [3].

## Results

For the present analysis, several thousand events have been simulated for the reactions of ${}^{197}_{79}Au +{}^{197}_{79} Au$ and ${}^{58}_{28}Ni +{}^{58}_{28} Ni$ at reduced impact parameter $\hat{b} < 0.15$, where $\hat{b} = b/b_{max}$ with $b_{max} = 1.15(A_1^{1/3}+A_2^{1/3})$ with $A_1$ and $A_2$ being the masses of target and projectile nuclei respectively. The choice of impact parameter is guided by the experimental measurements [4]. Simulations were carried out for incident energies ranging between 50 and 250 MeV/nucleon. A soft equation of state along with $0.8\sigma_{nn}^{free}$ has been employed that also include standard symmetry potential. The phase space of nucleons suffering collisions has been tested for several events and it has been found that change in momentum before and after the collision is of the order of few hundreds of MeV/c. On the basis of these observations, to further explore the participation of nucleons in stopping with a specific momentum, the whole momentum has been divided into different bins MBIN(I), MBIN(II), MBIN(III) and MBIN(IV). The momentum range of different bins is listed in Table I.

TABLE I: Momentum ranges for different momentum bins

| BIN | MOMENTUM RANGE (MeV/c) |
|---|---|
| MBIN(I) | $0< p \leq 100$ |
| MBIN(II) | $100< p \leq 200$ |
| MBIN(III) | $200< p \leq 300$ |
| MBIN(IV) | $300< p \leq 400$ |

In the present paper, nuclear stopping is described by using the observable which involve the ratio of transverse to the longitudinal rapidity distribution, denoted by VARXZ.

$$VARXZ = \frac{\sigma^2(x)}{\sigma^2(z)} \;\; ; \;\; \sigma^2 = variance \quad (1)$$

To achieve the state of complete stopping, the value of VARXZ should be close to unity.

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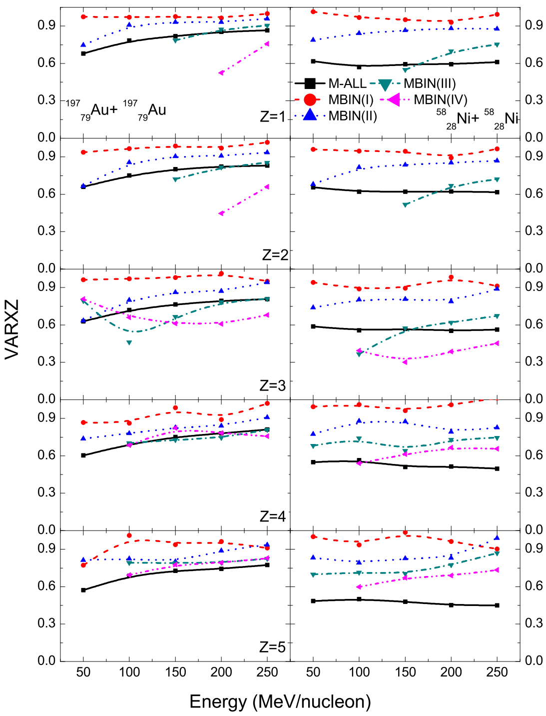


FIG. 1: VARXZ as a function of incident energy for ${}^{197}_{79}Au + {}^{197}_{79}Au$ and ${}^{58}_{28}Ni + {}^{58}_{28}Ni$ for different Z and momentum bins defined in table I.

Fig.1 displays the stopping ratio VARXZ as a function of incident energy for the selected range of momentum bins. A slight increase in the stopping ratio with increase in the incident energy is observed for all momentum bins. The argument is true for all the fragments irrespective of the reactions considered. It also shows that MBIN(I) particles contribute maximum towards stopping. With increase in the incident energy, one expects a progressive increase in the nucleon-nucleon collisions at the expense of nuclear mean field. Due to this, there is a rapid increase in the transverse energy, which boosts up the nucleons to get stopped. For the light charge fragments, particles with large momenta are available only at high incident energies. Whereas, for the heavy charge fragments (Z $\geq$ 3) particles with large momentum exists through-out the energy range. Comparison of the results of ${}^{197}_{79}Au +{}^{197}_{79} Au$ with ${}^{58}_{28}Ni +{}^{58}_{28} Ni$ reveals that less stopping is observed for the lighter system. This is due to the fact that stopping is governed by the participant zone only and depends on the mass of colliding nuclei. Moreover, for lighter systems distance between two successive collisions is comparable to the diameter of the system. This results in more transparency.

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