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Investigation of nuclear stopping observable in heavy ion collisions

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Abstract

Detailed analysis has been made on nuclear stopping using various observable. Transport model, isospin dependent quantum molecular dynamics model (IQMD) has been used to study stopping over the whole mass range at incident energies between 10 MeV/nucleon and 1000 MeV/nucleon. Our study proves that ratio of width of transverse to longitudinal rapidity distribution i.e., $< varxz >$ is the most suitable parameter to study nuclear stopping. Also, it has been observed that light mass fragments (LMF's) emitted from participant region can be used as barometer to study nuclear stopping.

Keywords: Nuclear stopping; IQMD; Isospin; Heavy ion collisions; Light mass fragments; Nuclear equation of state; Density dependence of the symmetry energy

1. Introduction

Heavy ion collisions (HIC) has provided a unique opportunity to produce a small amount of nuclear matter having high density and temperature in a controlled fashion. The properties of hot and compressed nuclear matter e.g. nuclear equation of state (EoS) can be studied by measuring the final products of the collisions. Recently heavy ion reactions motivated by hadron beam

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therapy have been used in cancer treatment [1]. When two heavy-ion collide, the nucleons which suffer collisions leads to formation of participant zone. In the participant zone, the nucleons lose a large part of their energy due to two body or three body collisions. Nucleon slows down as it passes through the nucleus, this energy loss is called nuclear stopping. Nuclear stopping in heavy-ion collisions has been studied by means of rapidity distributions [2,3] and non-uniform momentum distribution of nucleons. It is also well accepted that, nuclear stopping governs most of the energy dissipated in the central heavy-ion collision at intermediate incident energies. The degree of nuclear stopping is affected by various factors like incident energy, colliding geometry, mass of the colliding nuclei. It is also influenced by both binary collisions [4] as well as by the in-medium effects such as Fermi motion and Pauli-blocking [5–7].

Nuclear stopping has been studied theoretically as well as experimentally [8–13]. Fruitful attempts have been made to extract the information about the nuclear equation of state and isospin effects through nuclear stopping both experimentally as well as theoretically. Bauer and Bertsch [14,15] in 1988 pointed out the nuclear stopping at intermediate energies in heavy-ion collisions is determined by the mean field and in-medium nucleon–nucleon (NN) cross-sections. INDRA and ALADIN collaborations reveal negligible effect of isospin content of the colliding nuclei on nuclear stopping [12]. The investigations performed by Kumar et al. [16] spotlight the effect of an isospin-dependent nucleon–nucleon (NN) cross-section and symmetry energy on nuclear stopping. Nuclear stopping has been examined by the FOPI Collaboration using various observable [18]. In the recent communication [19] nuclear stopping at incident energies between 10 and 1200 MeV/nucleon for Au + Au system has been studied. Their study revealed that the mean value of nuclear stopping reaches minima near Fermi energy and maxima around 400 MeV/nucleon. The global stopping observable $< varxz >$ is strongly dependent on the isospin dependence of nucleon–nucleon cross section [18,19], widely examined by FOPI Collaboration [8] at incident energies between 90 and 1500 MeV/nucleon for mass symmetric as well as for mass asymmetric nuclear reactions. Recently nuclear stopping, light charged particle emission has been studied [20] and compared to the three transport model calculations. The stopping observable exhibit different sensitivities. It is of high interest to learn, which is the best observable to study the stopping. Interestingly, no systematic study is available in the literature on the most suitable nuclear stopping parameter. To be strict, the deed of the present analysis is two-fold:

- To understand, which stopping observable is suitable to study nuclear stopping.
- To pin down the correlation between stopping observable and fragments emitted from participant zone.

The present study is carried out within the isospin-dependent quantum molecular dynamics (IQMD) model discussed in section 2. Results are presented in section 3. Lastly, we summaries the results in section 4.

2. The model

Among several theoretical models, that ranges from the statistical and dynamical models, QMD [21] model and its isospin-dependent version IQMD [22] adore the special status since these are based on the molecular dynamic picture. The isospin-dependent quantum molecular dynamics (IQMD) model treats different charge states of nucleons, deltas and pions explicitly. The IQMD model has been used widely for the analysis of a large number of phenomenon from low