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Comprehensive study of memory loss for mass symmetric colliding nuclei at intermediate energy

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Abstract

Detailed study of nuclear stopping for the energy ranging from 20 MeV/nucleon to 1000 MeV/nucleon is systematically carried out in this article. We aim to understand the role of nucleon–nucleon cross-sections, equation of state and width of Gaussian wave packet on memory loss of nucleons. It is observed that with increase in the energy more number of nucleons participate in the nuclear stopping and lose their memory. Finally, correlation among allowed collisions and memory loss have been explored.

Keywords: Memory loss; Isospin-dependent quantum molecular dynamics (IQMD) model; Nuclear stopping; Density dependent symmetry energy; Equation of state

1. Introduction

Considerable progress and efforts has been devoted in the past years to study the heavy-ion collisions. Recently, heavy ion beams (carbon), during the therapeutic treatment used to treat cancerous tumors [1]. During this treatment and at the end of the radiation range, heavier carbon mass atoms lead to high dose deposition on the tumor while keeping the surrounding tissues healthy. This is essential nowadays to improve our understanding dynamics of heavy-ion nuclear

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reactions and is one of the key objectives of contemporary nuclear physics. Physics of nuclear reactions is crucial in explaining the relative motion and nuclear stopping of fragments in heavy-ion collisions (HICs). Mean field prevail at lower incident energies, nucleon–nucleon collisions are strongly suppressed due to Pauli blocking. At higher energies the situation is opposite because the mean field becomes less effective and nucleon–nucleon collisions become important [2,3]. Nuclear stopping has been studied experimentally as well as theoretically [4–10,12] in the past few years. It is worth mentioning that various observables have been mentioned in the literature to probe the nuclear stopping. One of these observable involves the ratio of variances of transverse rapidity distribution to the longitudinal rapidity distribution [11]. W. Bauer [5] in 1988, performed an analysis that complete stopping can be accomplished in central symmetrical collisions of heavy systems. Further work has been carried out in this direction for isospin asymmetric nuclear collisions and the observed effect of isospin asymmetry on nuclear stopping is very feeble [13]. Efforts have been made to improve the sensitivity of symmetry energy on nuclear stopping by considering its various density-dependent parameterization [14]. The experimental data provided by INDRA and ALADIN Collaborations reveals negligible effect of isospin content of the colliding nuclei on nuclear stopping observable [9]. FOPI Collaboration [15], widely examined the degree of nuclear stopping in central HICs at incident energies between 90 and 1500 MeV/nucleon for isospin symmetric as well as isospin asymmetric nuclear reactions. In the recent communication, G.Q. Zhang et al. [16], studied the nuclear stopping and their study reveals that the mean value of nuclear stopping reaches a minima near Fermi energy and maxima around 400 MeV/nucleon. E. Bonnet et al. [17], studied the collective radial expansion and stopping in heavy ion collisions at Fermi energies and they concluded that full stopping is achieved for the most central collisions at Fermi energies. Deepshikha et al. [18], studied the nuclear stopping observable and conclude that light mass fragments (LMF's) emitted from participant region can be used as a barometer to study nuclear stopping.

Recently, nuclear stopping has been also intended in terms of memory loss [19,20]. Nuclear stopping can be used as a probe to estimate how many nucleons loss the correlations with nucleons of parent nuclei. Incomplete nuclear stopping implies that in an event at central collisions nucleons do not drain all memories, with respect to the entrance channel. Assuming that if at the central collisions nucleons lose their all entrance channel memories, the luminosity of memory loss contemplates to be one. Moreover the zero value of memory loss indicates that central collisions keep all the entering or initiation channel memories. Motivated from Jun Su et al. [19], study memory loss in heavy-ion collisions at intermediate energy has been carried out in the present study. It is of high interest to learn how the mass dependence of memory loss and its linear correlation with the allowed collisions varies. In the present work we study the nuclear stopping in terms of memory loss. Interestingly, no systematic study is available in the literature. The intention of the present study is two fold:

- To study the memory loss in heavy-ion collisions using soft and hard equation of state.
- To present mass dependence of memory loss and its correlation with allowed collisions.

2. The model

The present study is carried out within the isospin-dependent quantum molecular dynamics (IQMD) model [21]. IQMD model contain essential physics and can demonstrate the various phenomena like collective flow [17,22–25], multi-fragmentation [26–30], particle production [31,32], nuclear stopping [18,33] and isospin dynamics [34] etc. The pion channels are not

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