Effect of isospin momentum dependent interactions on the nuclear stopping of various fragments

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Introduction

Heavy ion collisions at intermediate energies compresses the nuclear matter to 2-3 times the normal nuclear matter density. Within the interaction region, the collisions suffered by the nucleons leads to the reduction in their original longitudnal momentum. This reduction in the momentum is usually known as nuclear stopping and is a salient feature of the heavy ion reaction mechanism. During the heavy ion collisions, an additional repulsion generated due to the momentum dependence of the interactions (MDIs) could help to produce the large observed transverse momentum transfer [1]. Literature reveals that MDIs suppresses the nuclear stopping and it strongly suppresses the sensitivity of nuclear stopping to the symmetry potential while increases the sensitivity of nuclear stopping to the nucleon-nucleon cross section [2]. Unfortunately, all these calculations were silent about the role of isospin dependence of momentum dependent interactions (iso-MDIs). It is worth mentioning that mass asymmetry in the colliding pairs played a significant role in the nuclear stopping [3]. The present work aims to estimate the degree of nuclear stopping attained by various fragments under the influence of MDIs and iso-MDIs for the highly mass asymmetric colliding pair.

Methodology

This study is done within the framework of Isospin-dependent Quantum Molecular Dynamics (IQMD) Model [4]. The propagation of the hadrons under the influence of the potential is given by Hamilton equations of motion and the potential is given by:

$$V_{ij} = V_{ij}^{Skyrme} + V_{ij}^{Yukawa} + V_{ij}^{Symmetry} + V_{ij}^{Coulomb} + V_{ij}^{MDI} \quad (1)$$

The details about the various components of nuclear potential can be found in ref.[4]. Earlier, the isospin effects in the model are added in terms of symmetry potential, Coulomb potential, and isospin dependent nucleon-nucleon cross section. We attempted to add the isospin effects in the MDIs. The expressions for the MDI and iso-MDI potential can be written as:

$$V_{ij}^{MDI} = t_4 ln^2[t_5(p_i - p_j)^2 + 1]\frac{\rho}{\rho_0} \quad (2)$$

where $t_4 = 1.57 MeV$, $t_5 = 5\times10^{-4} MeV^{-2}$, ρ and ρ_0 are respectively the instantaneous and normal nuclear matter densities.

$$V^{iso-MDI} = [1.0 - 0.5T_3^iT_3^j]V^{MDI} \quad (3)$$

where T_3^i and T_3^j are the isospin components of the interacting baryons.

Results and Discussions

The nuclear stopping is studied for the mass asymmetric colliding system $^{16}_{8}O+^{197}_{79}Au$ at incident energies, E=40, 50, 80, 100, 200, 400, and 600 MeV/nucleon and scaled impact parameter, $b/b_{max} = 0.3$ in the nucleus-nucleus center of mass system. For the present analysis, the observable used to quantify the degree of nuclear stopping is the anisotropy ratio (R) defined as

$$R = \frac{2}{\pi}\frac{\sum_i^A |p_{\perp}(i)|}{\sum_i^A |p_{||}(i)|} \quad (4)$$

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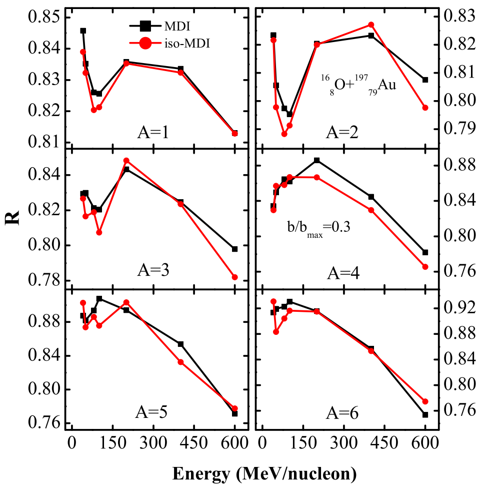

FIG. 1: Degree of stopping achieved by various fragments of ${}^{16}_{8}O + {}^{197}_{79}Au$ at different incident energies under the influence of MDIs (shown by line+square) and iso-MDIs (shown by line+circle).

where A is the sum of the projectile and target mass, $p_{\perp}(i) = \sqrt{p_x(i)^2 + p_y(i)^2}$ and $p_{||}(i) = p_z(i)$ are respectively the transverse and longitudnal components of the momentum of the ith nucleon. Fig.1 displays the variation of the degree of stopping achieved by various fragments of ${}^{16}_{8}O + {}^{197}_{79}Au$ at different incident energies under the influence of MDIs (shown by line+square) and iso-MDIs (shown by line+circle). With increase in the incident energy, the transverse momentum component associated with the nucleon decreases, which causes the decrease in the anisotropy ratio. At fixed colliding geometry, the production of the fragments is not same at all the incident energies, so stopping changes. From 40 MeV/nucleon to about 100 MeV/nucleon, dominant role played by the Pauli blocking prevents the transfer of initial longitudnal momentum to other directions, causing the decrease in the degree of stopping. This scenario is dominant for lighter mass fragments (A=1, 2, 3). From 200 MeV/nucleon to 400 MeV/nucleon, nucleon- nucleon collisions play dominant role, creating more thermalization. Above 400 MeV/nucleon, smaller nucleon-nucleon cross section increases the mean free path of the nucleons between successive collision, and therefore the transparency sets in. For almost all the fragments, the iso-MDIs decreases the stopping power, which may result from its lesser replusive nature, thus preventing the deflection of the nucleons in the transverse direction. Below 400 MeV/nucleon, with increase in the mass of the fragments, the nuclear matter is more stopped, favored by their corresponding multiplicities, but after 400 MeV/nucleon, formation of the heavier mass fragments is less favourable, thereby stopping is less. Beyond the fermi energy regime, the maxima observed in the degree of stopping occurs at different incident energies for different mass fragments because the fragment production is influenced by the incident energy. The sensitivity shown by the iso-MDI towards the degree of stopping is absent in case of symmetric colliding pairs [with lower N/Z ratio (results not shown here)]. The results motivates one to enquire the role of MDI as well as iso-MDI towards the stopping achieved by various mass fragments for different mass asymmetric colliding pairs.

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References

[1] J. Aichelin *et al.*, Phys. Rev. Lett. **58**, 1926 (1987); C. Gale, *et al.*, Phys. Rev. C **35**, 1666 (1987).

[2] S. Kumar *et al.*, Chin. Phys. Lett. **27**, 062504 (2010); Y. F. Yang *et al.*, Chin. Phys. Lett. **18**, 1040 (2001).

[3] V. Kaur *et al.*, Nucl. Phys. A **861**, 37 (2011).

[4] C. Hartnack *et al.*, Eur. Phys. J. A **1**, 151 (1998); C. Hartnack *et al.*, Phys. Rep. **510**, 119 (2012).