N/Z dependence of nuclear stopping for Ca isotopes

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Introduction

Heavy ion collisions (HIC) at intermediate energies provide us a unique opportunity to investigate the properties of nuclear matter under extreme conditions of temperature and density. The major phenomena that occur at intermediate energies are multifragmentation, collective flow and nuclear stopping. Nuclear stopping [1] i.e. partial, full or transparency is a state of disassembly of nuclear matter from a completely fused state, whereas the complete destruction of nuclear matter is termed as global stopping. To get the complete knowledge of nuclear stopping we should also know what is the dependence of isospin on nuclear stopping.

Momentum dependent interactions (MDI) also play a very important role at intermediate energy HIC. The effect of MDI is very strong during the initial phase of the reaction. The particles propagating with MDI are accelerated in the transverse direction, which results in lesser number of collisions and increase in transverse flow. In this letter we focus our attention to isospin dependence of nuclear stopping using momentum dependent interactions. For this purpose we probe different isotopes of calcium with N/Z ratios varying from 0.7 to 1.85. It has been observed that density dependent symmetry energy and isospin dependent cross-section play very small role in fragmentation, because saturation density reached for fragmentation is below normal density. To probe the role of isospin dependence of cross-section nuclear stopping is the most appropriate parameter. Isospin dependent Quantum Molecular Dynamic (IQMD) model [2] is being used here for calculations which is the modified form of the QMD [3] model. Since in IQMD $3\sigma_{nn}= 3\sigma_{pp}= \sigma_{np}$. Due to this we expect that there will be a considerable effect of isospin dependent cross section on nuclear stopping.

Results:

The degree of stopping can be described with the help of different parameters [1] which are discussed below.

Anisotropic ratio:

$$R= \frac{2}{\pi}\frac{[\sum_i^A |p_\perp(i)|]}{[\sum_i^A |p_\parallel(i)|]}$$

Where $p_\perp = \sqrt{{p_x}^2 + {p_y}^2}$ and $p_\parallel = p_z$

Quadrupole moment:

$$Q_{zz} = \sum_i^A [\, 2p_z^2(i) - p_x^2(i) - p_y^2(i)]$$

Rapidity distribution:

$$Y(i) = \frac{1}{2}\ln\frac{E(i)+p_z(i)}{E(i)-p_z(i)}$$

Here, $E(i)\ and\ p_z(i)$ are the energy and momentum of i[th] particle.

In fig.1. We display the rapidity distribution of free particles, LCP's and IMF's for different isotopes of Ca. It is clear that with the increase in total mass number of the system, the rapidity of all the fragments also increases. For free particles a single narrow Gaussian is observed, whereas for LCP's and IMF's the single Gaussian split into two Gaussians. The first Gaussian is indicating the projectile and the other is indicating the target rapidities. One can also conclude from here that with the increase in neutron number the collision suppressed and stopping increases.

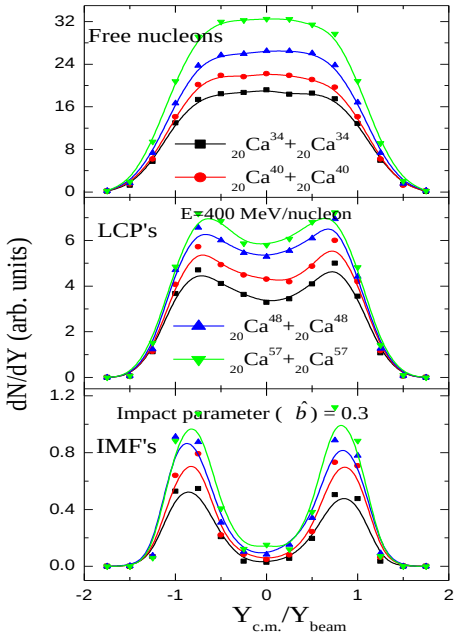

Fig. 1. The rapidity distribution *dN/dY* as a function of $Y_{c.m.}/Y_{beam}$ for free nucleons(a), LCP's (b) and IMF's(c) at energy = 400 MeV/nucleon and 0.3 impact parameter .The results are obtained with HMD.

Results are displayed in fig. 2 for the reactions of $_{20}Ca^{34}+_{20}Ca^{34}$ (N/Z=0.7), $_{20}Ca^{40}+_{20}Ca^{40}$ (N/Z=1), $_{20}Ca^{48}+_{20}Ca^{48}$ (N/Z=1.4), $_{20}Ca^{57}+_{20}Ca^{57}$ (N/Z=1.85) having same Z and different A in the presence of symmetry energy =32 MeV and isospin dependent cross-section. With the increase in N/Z ratio the number of neutrons decreases and hence the number of collisions increases. This in turn increase the stopping parameters (R and $\frac{1}{Qzz/nucl.}$). From the above displayed results one may conclude that the nuclear stopping and LCP's can also be used as a tool to investigate the stopping nature of nucleons in the presence of MDI's.

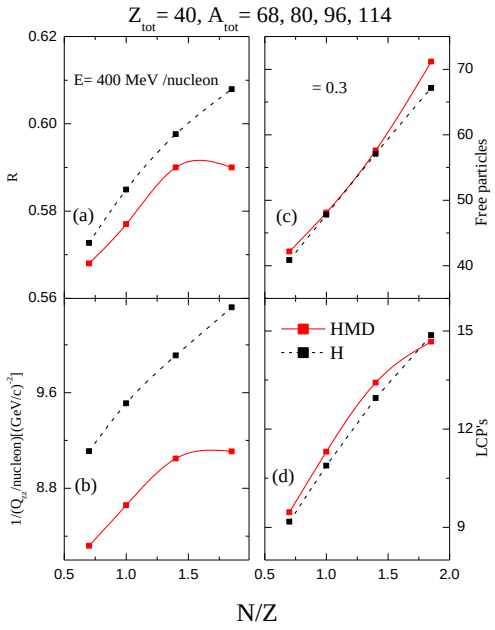

Fig. 2. N/Z dependence of R (a), $\frac{1}{Qzz/nucl.}$ (b), free particles (c) and LCP's (d) in the presence of symmetry energy and HMD.

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