Role of isospin degree of freedom in transverse momentum spectra of nucleons

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Introduction

In recent years, lot of interest has been generated to study the properties of asymmetric nuclear matter over wide range of energy using different projectile-target combinations. Recently, Puri and one of us [1] studied the isospin effects on the energy of peak mass production. They found that both $E_{c.m.}^{max}$ (energy at which maximal production of intermediate mass fragments occurs) and $\langle N_{\rm IMF}\rangle^{max}$ (maximum number of intermediate mass fragments) are insensitive to the isospin dependence of the nucleon-nucleon cross section but sensitive to the symmetry energy. A large number of theoretical and experimental studies have been made to see the effect of isospin degree of freedom on collective and elliptic flow as well [2, 3]. Gautam *et al.* [4] investigated the relative contribution of the symmetry energy as well as the isospin dependence of the nucleon-nucleon cross section towards collective flow. They found that the isospin dependence of the nucleon nucleon cross section has little influence toward the sensitivity of the flow compared to the symmetry energy. In an another study, Jain *et al.* [5] checked the effect of isospin degree of freedom on $dN/p_t dp_t$ via isospin dependent nucleon nucleon cross section.

From the literature, it is concluded that the emission of nucleons is greatly affected by the symmetry energy. In the present study, our aim is to see the sensitivity of transverse momentum spectra of neutrons and protons to the symmetry energy [6].

The present study is carried out within the framework of the isospin-dependent quantum molecular dynamics (IQMD) model [7].

Results and Discussion

For the present study, we simulated the reactions of ^{40}Ca+^{40}Ca, ^{52}Ca+^{52}Ca, ^{60}Ca+^{60}Ca and ^{60}Zn+^{60}Zn. The value of impact parameter is in the range of $\hat{b} = 0.2$ to 0.4. Here, we used a soft equation of state along with isospin- and energy-dependent nn cross section reduced by 20% i.e. $\sigma = 0.8\sigma_{nn}^{free}$. For the present calculations, we followed the evolution till 200 fm/c and clusters are formed with the minimum spanning tree method using a clusterization radius of 4.0 fm.

In Fig. 1, we display the normalized transverse momentum distribution of protons and neutrons for the reactions of ^{40}Ca+^{40}Ca, ^{52}Ca+^{52}Ca and ^{60}Ca+^{60}Ca at incident en-

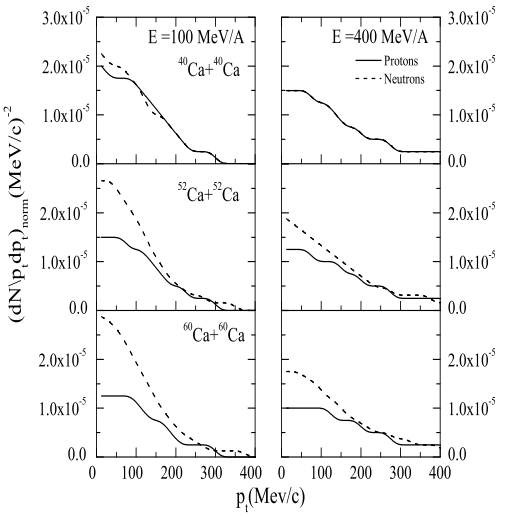

FIG. 1: Normalized final transverse momentum distribution of protons (solid lines) and neutrons (dashed lines) for the reactions of ^{40}Ca+^{40}Ca, ^{52}Ca+^{52}Ca and ^{60}Ca+^{60}Ca at incident energies E = 100 (left panels) and 400 (right panels) MeV/nucleon.

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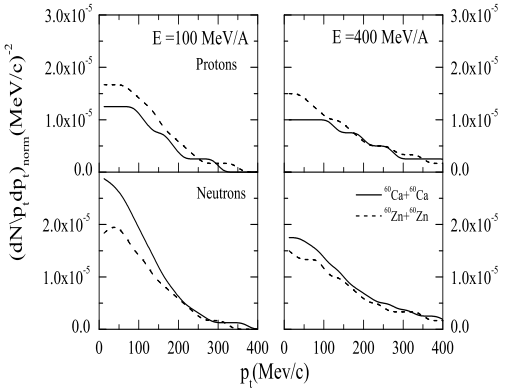

FIG. 2: Normalized final transverse momentum distribution of protons (upper panels) and neutrons (lower panels) for the reaction of ^{60}Ca+^{60}Ca (solid lines) and ^{60}Zn+^{60}Zn (dashed lines) at incident energies E = 100 (left panels) and 400 (right panels) MeV/nucleon.

ergies E = 100 (left panels) and 400 (right panels) MeV/nucleon. We find that as the transverse momentum increases, $dN/p_t dp_t$ decreases. This may be attributed due to the reason that with the increase in the transverse momentum, the number of particles in a particular bin decreases. This shows that most of the nucleons suffer soft collisions. The value of $dN/p_t dp_t$ for neutrons is found to increase with the increase in the isospin asymmetry. In the case of neutron-rich systems, the value of $dN/p_t dp_t$ is more for neutrons compared to protons whereas for symmetric system of ^{40}Ca+^{40}Ca, it is same for neutrons and protons. With the increase in the projectile energy, $dN/p_t dp_t$ decreases for neutrons while it remains nearly constant for the protons.

In Fig. 1, we have compared the transverse momentum distribution of protons and neutrons for different isotopes of Ca, i.e. both mass and isospin asymmetry have increased along the isotopic series. To see the effect of isospin degree of freedom on $dN/p_t dp_t$, we simulate the reactions of ^{60}Ca+^{60}Ca and ^{60}Zn+^{60}Zn (which are having same mass but differ in isospin asymmetry). In Fig. 2, we display the normalized final transverse momentum distribution of protons and neutrons for the reaction of ^{60}Ca+^{60}Ca and ^{60}Zn+^{60}Zn at incident energies E = 100 (left panels) and 400 (right panels) MeV/nucleon. The difference between $dN/p_t dp_t$ of neutrons, for two isobars, is more at lower projectile energy. We find that the value of $(dN/p_t dp_t)_{norm}$ for protons is more for neutron-poor system (^{60}Zn+^{60}Zn) than that of neutron-rich system (^{60}Ca+^{60}Ca) and reverse is the case for neutrons. The effect of isospin asymmetry on the value of $dN/p_t dp_t$ diminishes at higher projectile energy.

We find that $dN/p_t dp_t$ decreases with increase in the transverse momentum as well as with the incident energy and the value of $dN/p_t dp_t$ of neutrons is more for neutron-rich systems. We further find that the effect of isospin degree of freedom on transverse quantities diminishes with increase in incident energy.

Acknowledgments

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