Role of isospin degree of freedom on the production of light charged particles

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Introduction

Nucleus-nucleus collisions at intermediate energies lead to the formation of hot and compressed nuclear matter. The study of properties of the excited nuclear matter shed light on the equation of state of nuclear matter which is important for the nuclear physics as well as for astrophysical studies. The process of break up of the excited matter into fragments is known as multifragmentation. Multifragmentation gives insight about liquid-gas phase transition in the nuclear matter and is sensitive to various entrance channel parameters such as incident energy, colliding geometry, system size, mass asymmetry and isospin of the colliding nuclei. During the multifragmentation, various intermediate mass fragments (IMFs), light charged particles (LCPs), heavy mass fragments (HMFs), medium mass fragments (MMFs) and free nucleons are emitted. The energy dependence of fragmentation has revealed a rise and fall behavior of the fragment's multiplicity with incident energy of the colliding pair [1].

With the availability of radioactive ion beam (RIB) facilities, interest has been shifted towards the collisions of nuclei away from the line of stability. Many studies have been done to observe the isospin effects in multifragmentation. For example, the ALADIN collaboration [2] made a systematic study of the neutron to proton ratio (N/Z) dependence of fragmentation at 600 MeV/nucleon and established that the universal "rise and fall" behavior is preserved for neutron-rich and neutron-poor colliding systems. These studies reveal that the neutron content of a colliding pair affects fragmentation pattern. Another study [3] describes the effect of neutron content of colliding pair on the production of IMFs and its dependence on beam energy.

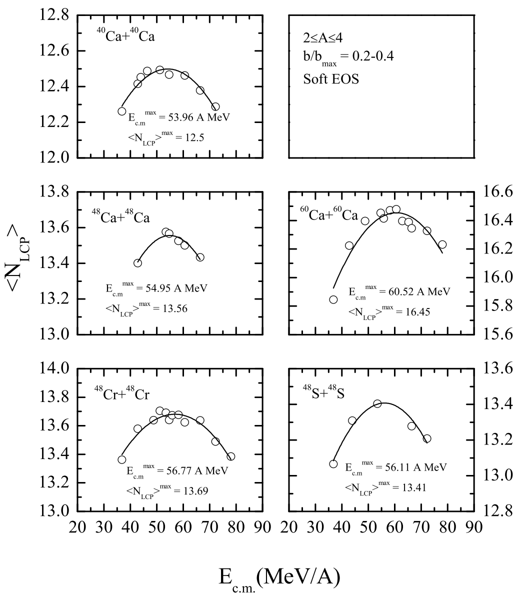

FIG. 1: The energy dependence of multiplicity of light charged particles $< N_{LCP} >$ for isotopic and isobaric colliding pairs at semi- central collisions (preliminary results).

At the same time, light charged particles are also emitted during multifragmentation. These light charged particles carry important information about the hot and dense matter formed during the collision as they are mostly emitted during compressional phase of a reaction. Recently, these LCPs are shown to be

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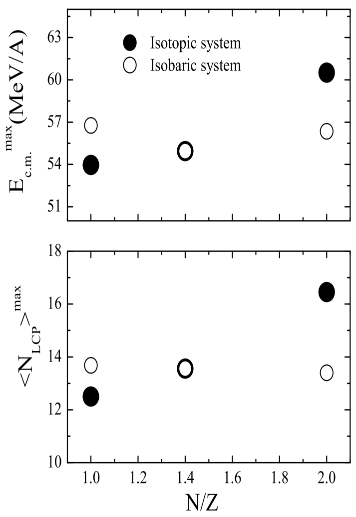

FIG. 2: N/Z ratio dependence of peak center-of-mass energy $E^{max}_{c.m.}$ and maximum multiplicity of LCPs $< N_{LCP} >^{max}$ for isotopic and isobaric colliding pairs at semi-central collisions (preliminary results).

sensitive to symmetry energy [4] and can help to constrain its density dependence which is of interest to nuclear physics community. With this in the mind, we aim to study the energy dependence of the light charged particles and the role of neutron content of colliding pair on their production. The present study is carried out using isospin-dependent quantum molecular dynamics (IQMD) model, the details of which can be found in [5].

Results and Discussion

For the present study, we simulated the reactions of ^{40}Ca + ^{40}Ca, ^{48}Ca + ^{48}Ca, ^{48}Cr + ^{48}Cr, ^{48}S + ^{48}S and ^{60}Ca + ^{60}Ca having different neutron/proton ratio at beam energies between 30 and 350 MeV/nucleon using soft equation of state at semi-central colliding geometry. In Fig. 1, we display the multiplicity of light charged particles with respect to the peak center-of-mass energy for isotopic and isobaric colliding pairs. From the figure, we see that multiplicity of light charged particles first increases with energy, attains a maxima and then decreases. Thus we see that similar rise and fall behavior is observed for LCPs multiplicity also (as predicted for IMFs). In Fig. 2, we display the isospin dependence of $E^{max}_{c.m.}$ (energy corresponding to maximum production of LCPs) and $< N_{LCP} >^{max}$ (maximum multiplicity of LCPs) for isotopic and isobaric colliding pairs. From the figure, we find that $E^{max}_{c.m.}$ increases with neutron content for isotopic pairs. This happen because of increase in system mass (as proton number is fixed) and thus larger energy is required to break the nuclei and corresponding multiplicity of LCPs increases for isotopic pairs (see lower panel). On the other hand, for isobaric colliding pairs, we notice that $E^{max}_{c.m.}$ decreases slightly with increase in the neutron content. Now the system mass is constant, therefore additional neutrons contribute towards boiling of the system at lower energies (may be because of repulsive symmetry potential). Also, multiplicity of LCPs remains constant (almost) for isobaric systems.

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