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INVESTIGATING THE ISOTOPIC EFFECTS IN NUCLEAR FRAGMENTATION*

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Modifications for symmetry energy coefficients of nuclear matter at freeze-out density are investigated on the basis of the Statistical Multi-fragmentation Model (SMM). In order to compare our predictions with MSU experimental data we consider the fragmentation of the projectiles ^{124}Sn and ^{112}Sn which were also used for the MSU experiments, and of the projectiles ^{124}Sn, ^{124}La and ^{107}Sn used for the ALADIN experiments. Comparing our results with the experimental data, it is confirmed that a significant reduction of the symmetry term coefficient is found necessary to reproduce the mean $\langle N\rangle/Z$ values of light fragments.

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1. Introduction

Multifragmentation reactions involving neutron-rich nuclei is naturally related to astrophysical events such as stellar evolution and production of nuclei, and can be used for extracting physical information about, for example, the symmetry energy defined by $E^{\mathrm{sym}} = \gamma(A-2Z)^2/A$, where A denotes the fragment mass number, Z the charge number and γ the symmetry energy coefficient. The possibilities of modifications for symmetry energy

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coefficients at freeze-out density are investigated theoretically by means of neutron-to-proton ratios $\langle N \rangle / Z$ on the basis of SMM [1]. It can also be investigated in isoscaling [2, 3, 4].

In this short presentation, we shall discuss the influence of the expected decrease in symmetry energy on the mean neutron-to-proton ratios of light fragments within the Markov chain version of statistical multifragmentation model, which is designed for a better simulation of the decay modes of single sources [5], and then we compare the results with MSU experimental data. Secondly, we present the results of SMM ensemble calculations and their comparison with ALADIN experiment. Further details of SMM ensemble approach were given in Ref. [6].

2. Calculations of the mean neutron-to-proton ratios

The $\langle N \rangle / Z$ dependence of the fragmentation of the projectiles ^{124}Sn and ^{112}Sn has been studied through the MSU experiments [7, 8]. We assume that the central collisions of $^{124}\mathrm{Sn} + {}^{124}\mathrm{Sn}$ and $^{112}\mathrm{Sn} + {}^{112}\mathrm{Sn}$ used for MSU experiments create single nuclei with $A_0 = 186$, $Z_0 = 75$ and $A_0 = 168$, $Z_0 = 75$, respectively, and that they have the same N/Z ratio as those of ^{124}Sn and ^{112}Sn. In the central collisions production of light fragments are influenced by a non-thermal collective flow expected at an energy around 2 MeV/nucleon. In this case only heavy nuclei which are less affected by the flow may be representative for thermal multifragmentation. This may be the main reason for the difference between theoretical and experimental results. In Fig. 1, we show the results of Markov chain calculations for single sources ^{124}Sn and ^{112}Sn, and MSU experimental data. From this figure one may see the variation of $\langle N \rangle / Z$ with charge number up to $Z = 8$ for cold fragments, which occur as a result of second de-excitations of hot fragments, at an excitation energy of $E_x = 5$ MeV/nucleon. We have taken into account three different γ values which are 25 MeV (standard value for low excitation energies), 14 MeV and 8 MeV for the reduced values. Upper panel shows the results for the more neutron-rich system, and lower panel for the more neutron-poor system. In the present interpretation of MSU experimental data, it is seen that a reduction of the symmetry energy coefficient is necessary to reproduce the mean $\langle N \rangle / Z$ for the light fragments up to $Z = 8$. In other words, the symmetry energy coefficient should be less than 14 MeV for the best agreement to MSU experimental data [8]. This was also shown by means of isoscaling analysis for the same single sources. A similar study of the $\langle N \rangle / Z$ dependence in spectator fragmentation was performed at the ALADIN spectrometer with ^{124}Sn primary and ^{107}Sn secondary beams of 600 MeV/nucleon incident energy. The analyses were carried out within the SMM ensemble approach which consists of a dynamical and the statistical multifragmentation models [6]. In the ensemble analyses, the summed bound

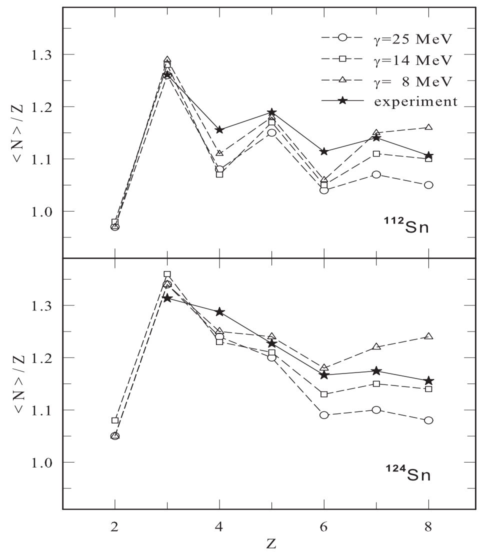

Fig. 1. Mean neutron-to-proton ratios of light fragments as a function of fragment charge Z, at various symmetry energy coefficients for Markov chain SMM (dashed lines and open symbols), and MSU experimental data (solid line and stars).

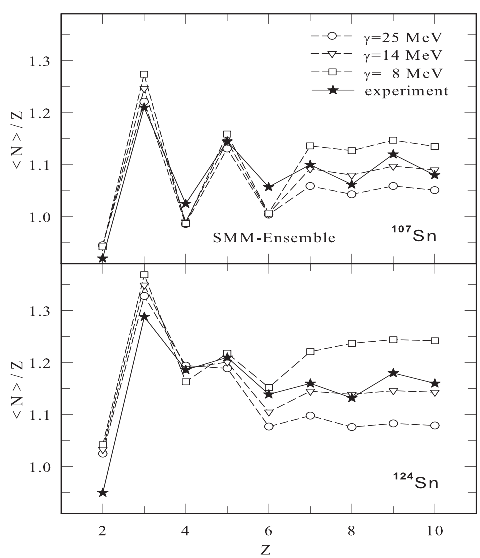

Fig. 2. Mean neutron-to-proton ratios of hot fragments as a function of bound charge $Z_{\rm bound}$, ($Z_{\rm bound}/Z_0 = 0.5$), at various symmetry energy coefficients. The dashed lines and open symbols represent the SMM ensemble calculations, and the solid line and stars represent ALADIN experimental data.

charge of the fragments has been used as an observable instead of excitation energy. In Fig. 2, we show the results of SMM ensemble calculations for these projectiles, with ALADIN data. Here, it was also confirmed that the symmetry energy coefficient is seen to be around 14 MeV for the best agreement to the experimental data for all sources. For the details of the analyses and interpretation of this experiment we refer the reader to Ref. [9, 10]. We have considered Fermi break up for $A < 16$ and the sequential evaporation for larger values of A. This is the main reason why one observes a larger sensitivity for fragments above Be.

3. Conclusions

In conclusion, it has been shown that mean neutron-to-proton ratios of light fragments are sensitive to the variation of symmetry term coefficient. Comparing our results with the experimental data, it is confirmed that a significant reduction of the symmetry term coefficient is found necessary to reproduce the mean $\langle N \rangle / Z$ values. In other words, the symmetry energy coefficient should be less than the value of $\gamma = 14$ MeV for the best agrement to MSU and ALADIN experimental data. From the figures 1 and 2, we have shown that the mean $\langle N \rangle / Z$ ratio of the light fragments decrease slightly with decreasing N/Z ratios of the considered sources. Also, the symmetry energy coefficient for primary hot fragments at the low-density freeze-out is significantly reduced.

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