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Isoscaling in projectile fragmentation reaction induced by ^{40,48}Ca and ^{58,64}Ni

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The reactions of ^{40,48}Ca+^{9}Be and ^{58,64}Ni+^{9}Be at 140A MeV were studied by using the heavy ion phase-space exploration(HIPSE) model. Isoscaling behavior was observed. By introducing different evaporation method for the hot (before evaporation) fragments, the effect of evaporation on the isoscaling behavior by HIPSE model has been discussed.

1. Introduction

Recently, the isoscaling property has been found in the analysis of multifragmentation experiments[1,2]. This new phenomenon is based on the isotope yields $Y(N,Z)$ of two similar, but isotopically different, reactions. More precisely, the yield ratio of a given fragment obtain from the two reactions, follows the relation, $R_{21}(N,Z) = (Y_2(N,Z))/(Y_1(N,Z)) = C\exp(\alpha N + \beta Z)$, where 2 denotes the more neutron-rich system. In the equation, α and β are the scaling parameters and C is an overall normalization constant. According to recent research, isoscaling has been shown to be a phenomenon existing in many different types of heavy ion reactions[3–7]. However, most studies focus on light particles. For better understanding of the isoscaling behavior for both light and heavy fragment, the reaction systems of ^{40,48}Ca+^{9}Be and ^{58,64}Ni+^{9}Be were chosen. In this paper, we concentrate our attentions on the isoscaling features for projectile-like fragments by using Heavy Ion Phase Space Exploration(HIPSE) model[8]. The effect of evaporation on the isoscaling parameters will also be investigated.

2. Model Description

As an event generator, HIPSE model can conveniently simulate nuclear collisions in the intermediate energy range at all impact parameters. Based on a macroscopic-microscopic "phenomenology", it accounts for both dynamical and statistical aspects of nuclear collisions. HIPSE model considers three different stages of the reaction: the approaching phase, the cluster formation, and the secondary deexcitation process. Classical two-body dynamics of the center of masses of the target and the projectile nuclei is assumed in the entrance channel. The secondary decay is achieved using the SIMON event generator[9].

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There are three important parameters in the model: the parameter describes the hardness of the potential α_a, the percentage of nucleons transferred between the projectile and target x_{tr}, and the percentage of nucleon-nucleon collisions in the overlap range x_{coll}.

3. Calculations and Discussion

To study the isoscaling effect in projectile fragmentation, we have chosen the reaction systems of ^{40,48}Ca+^{9}Be and ^{58,64}Ni+^{9}Be at 140 MeV/nucleon. Since HIPSE's parameters are energy dependent, the values of α_a=0.55, x_{tr}=0.09, x_{coll}=0.18 were chosen for beam energy of 140 MeV/nucleon[10]. Though HIPSE model is not developed to describe the projectile fragmentation process, the agreement of the fragment production cross sections between the calculated results and experimental data is quite reasonable[8,10]. We extract the yield ratio $R_{21}(N, Z)$ from the calculated yields $Y_i(N, Z)(i = 1, 2)$ where index 2 refers to the neutron-rich system. Fig 1 shows the yield ratios of cold (after evaporation) fragments as a function of the neutron number N for selected isotopes and proton number Z for selected isotones of the ^{40,48}Ca+^{9}Be and ^{58,64}Ni+^{9}Be reaction systems. In these figures, different isotopes and isotones are shown by alternating filled and opened symbols. The dashed and solid lines are just drawn to guide the eye.

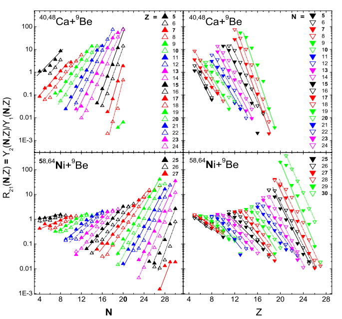

Figure 1. Yield ratios as function of N and Z for two reaction systems.

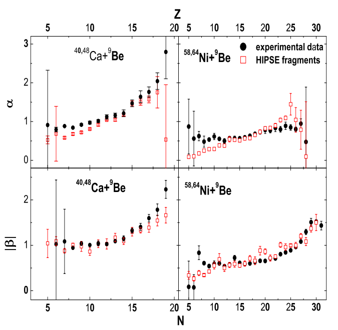

Figure 2. Isoscaling parameters as a function of N and Z for two reaction systems.

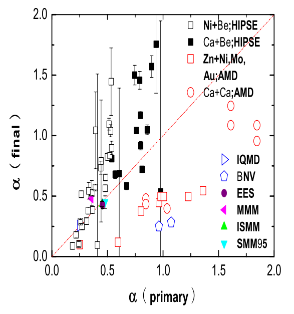

Figure 3. Effect of sequential decays on isoscaling parameter α.

In Fig 1, isoscaling behavior is observed. The yield ratio exhibits a remarkable exponential behavior. By fitting the calculated points with exponential function of the form $C \exp(\alpha N)(C \exp(\beta Z))$, isoscaling parameters α and β are obtained for all isotopes and isotones. Using the same method, we have also extracted the isoscaling parameters from experimental fragment production cross section data[11]. For cold fragments calculated by the model, the increase of α and $|\beta|$ with increase of Z and N is predicted. Similar trend is observed in the isoscaling parameters extracted from experimental data. From Fig 2, we can see that HIPSE model reproduce the isoscaling parameters of experiment data for both projectile-like and light fragments quite well of the two different systems.

Sequential decay codes are important to both dynamical and statistical models. The sequential decays effects are very different by statistical multifragmentation models and dynamical model[12,13]. In most dynamical models, sequential decays effects reduce α values and the reduction is larger than 50%. While the effects are small in statistical model and its trend is not very clear. In Fig 3, we present the α values before (horizontal axis) and after (vertical axis) sequential decays obtained from different models. The solid and open squares are the calculated results of HIPSE model, the other data are taken from Ref.[12] and references therein. For HIPSE model, sequential decays effects increase the value of the parameter α from ^{40,48}Ca+^{9}Be and ^{58,64}Ni+^{9}Be reaction systems, especially for heavy fragments. Since in HIPSE model the secondary deexcitation is describe with SIMON code and this code is not a reasonably model to reproduced isoscaling phenomenon[13,10], the difference of sequential decays effects between HIPSE and other models may be mainly due to this evaporation program. For a comprehensive understanding of sequential decays effects, a detailed study of the evaporation process is necessary.

4. Conclusions

In summary, the extracted isoscaling parameters for HIPSE model calculations are in good agreement with recent experimental data for both projectile-like and light fragments. HIPSE model could be used to investigate the isoscaling phenomenon in central and peripheral collisions. Sequential decays effects have some effects on isoscaling parameters, especially for heavy fragments.

5. Acknowledgements

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