CROSS SECTION DISTRIBUTIONS OF FRAGMENTS IN THE CALCIUM ISOTOPIES PROJECTILE FRAGMENTATION AT THE INTERMEDIATE ENERGY

C. W. MA*, Y. F. ZHANG, AND H. L. WEI
Department of Physics, Henan Normal University, Xinxiang, Henan Province 453007, China
*E-mail: machunwang@126.com

The cross sections of fragments ($\sigma_f$) produced in the 100 $A$ MeV even $^{36-52}$Ca projectile fragmentation reactions are evaluated in the framework of the statistical abrasion-ablation model. The distributions of $\sigma_f$ are compared and the similarities of $\sigma_f$ distributions are investigated.

Keywords: Heavy-ion reactions; The statistical abrasion-ablation model; Isospin phenomenon.

1. Introduction

The constructions of the third generation of radioactive nuclear beam facilities around the world have greatly stimulated the research in phenomena in heavy-ion collisions induced by the very neutron-rich nucleus, of whom has big isospin freedom. Due to the difficulties to study the density distribution of neutron in the very neutron-rich nucleus directly, phenomena related to density distributions of neutrons and protons are explored to extract information of neutron indirectly.

2. Model and Results

The SAA model was developed to describe heavy-ion collisions both at high and intermediate energies. This model takes independent N-N collisions for participants in an overlap zone of the two colliding nuclei and determines the distributions of abraded neutrons and protons. The details of SAA model can be found in Refs.

Using the SAA model, the cross sections of fragments produced in the 100 $A$ MeV even $^{36-52}$Ca$+^{12}$C are calculated and plotted in Fig. 1. Fitting
Fig. 1. (Color online) Cross sections of fragments produced in the 100 A MeV even $^{36-52}$Ca+$^{12}$C using the SAA model. For isotopes, the x axes represent the removed neutron numbers from the projectile($\Delta N = N_p - N_f$); for isotones, the x axes represent the removed proton numbers from the projectile($\Delta Z = Z_p - Z_f$).

these distributions using a Gaussian function, peak positions are obtained and plotted in Fig. 2.

The peak positions of these isotopes or isotones increase linearly except the isotopes or isotones with small $\Delta Z$ or $\Delta N$. The peak positions of isotopes and isotones of $^{40}$Ca have very little difference, while peak positions of isotopes and isotones produced of the neutron-proton asymmetric projectile nuclei become bigger as the n/p ratios of projectile nuclei increase.

In Refs. $^8,^9$ it is discussed that the neutron-removal cross section for isotopes could be used as an observable to extract neutron-skin thickness of neutron-rich nucleus. Fragments isotopes and isotones with small $\Delta Z$ or $\Delta N$ are mostly produced in the peripheral collisions$^8,^{10}$ and the distributions of cross sections could not be fitted using the Gaussian function. Isotopes with $\Delta Z \leq 3$ and isotones with $\Delta N \leq 3$ are plotted in Fig. 3 and Fig. 4. For isotopes, the distributions of the $Z=17$-20 fragments are very similar for the $^{36-40}$Ca projectile. For other Ca projectile, the distributions of isotope fragments show big difference. For isotones, the distributions of
Fig. 2. (Color online) Peak positions of isotopes and isotones in Fig. 1. The open symbols are for isotopes and the filled ones are for isotones.

Fig. 3. (Color online) Cross sections of the $\Delta Z=0$-3 isotopes. The $x$ axes represent the removed neutrons from the projectile.

the $\Delta N=0$-3 fragments are very similar for the neutron-rich $^{46-52}$Ca projectile. For other Ca projectile, the distributions of isotope fragments show big difference. It’s easy to see that for proton-rich and symmetric nuclei the isotopic distributions of fragments are very similar, and for neutron-rich nuclei the isotonic distributions of fragments are very similar. The ratios of isotopic cross sections have been used to extract the symmetry energy using the isoscaling method.\textsuperscript{14} The ratios of isotonic cross section may be used to extract symmetry energy but the method will be more difficult than the isotopic method.
Fig. 4. (Color online) Cross sections of the $\Delta N=0-3$ isotones. For isotones, the $x$ axes represent the removed protons from the projectile.

In summary, cross sections of fragments produced in the 100 $A$ MeV even $^{36-52}$Ca $+^{12}$C reactions are calculated using the SAA model. The distributions of the isotopic and isotonic cross sections are investigated and similarity of the fragment distributions are compared.

Acknowledgments

This work is partially supported by the National Natural Science Foundation of China under contract No. 10905017, and the Youth Foundation in Science of Henan Normal University under grant 2009qk07.

References

8. D. Q. Fang et al., Phys. Rev. C 82, 047603 (2010);