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Projectile fragment emission in the fragmentation of silicon on carbon and polyethylene targets at 800 A MeV

Zhen Feng[a] , Hui-Hui Ao[a], Ya-Qin Sun[a], Man-Man Tian[a], Dong-Hai Zhang[a],*

Jun-Sheng Li[a], S. Kodaira[b], N. Yasuda[c]

[a]Institute of Modern Physics, Shanxi Normal University, Linfen 041004, China.
[b]Radiation Measurement Research Section, National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage, Chiba 263-8555, Japan.
[c]The Research Institute of Nuclear Engineering, University of Fukui, Kanawa 1-2-4, Tsuruga, Fukui, 914-0055, Japan.

Abstract

The emission angle and the transverse momentum distributions of projectile fragments (PFs) produced in fragmentation of silicon on carbon and polyethylene targets at 800 A MeV are measured. It is found that the angular and transverse distribution of PFs do not evidently depend on the mass of target nucleus, the averaged emission angle and transverse momentum decrease with increase of the charge of PF for the same target, and no obvious dependence on the target mass is found for the same PF. The cumulated squared transverse momentum distribution of PF can be well explained by a single Rayleigh distribution. The temperature parameter of PF emission source is determined, which is about 2-4 MeV and independent of the target and PF size.

Keywords: Heavy ion collision; angular distribution; transverse momentum distribution; temperature.

1. Introduction

Heavy ion fragmentation at intermediate and high energies is very important in nuclear physics, astrophysics and medical physics. Such study can help to understand not only the fundamental nuclear physics processes involved in nuclear collisions but also the origin and propagation process of galactic cosmic rays (GCR). One of the major interests in the study of intermediate and high energy heavy ion collisions is the understanding of the

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* Corresponding author. Tel.: +00-86-357-2051347; fax: +00-86-357-2051347.
*E-mail address:*zhangdh@dns.sxnu.edu.cn

multifragmentation phenomenon and its connection with liquid-gas phase transitions. For this it has to be assumed that in a heavy ion collision at some stage a part of the system is both in thermo-dynamical equilibrium and instable. Such a configuration is often termed a freeze-out configuration. The multifragmentation process would reflect the parameters of this source, i.e. its temperature and density. Experimentally the fragment energy spectra are described in terms of such freeze-out models to extract these parameters. The information of these quantities is also sought from isotope rations of fragments and from excited state populations. Furthermore, silicon ions are also copiously produced in the fragmentation of iron ions and other heavier ions. So the fragmentation of silicon ions is not only relevant to the space radiation but also to the understanding the fragmentation mechanism.

The total charge-changing cross sections and the partial cross sections of the fragmentation of ^{28}Si ions on various targets at different energies have been investigated by many groups, such as Zeitlin et al. (2007), Price et al. (1991), Brechtmann et al. (1989), Gupta et al. (2013), Cecchini et al. (2008), Flesch et al. (2001), and Webber et al. (1990). The temperature parameter of PFs emission source is also investigated by many groups using the PFs kinetic energy distribution, isotope rations of PFs and excited state populations methods, such as Serfling et al. (1998), Odeh et al. (2000). The typical temperature of PFs emission source is about 5-6 MeV based on the isotope thermometer, it is lower than that based on PFs kinetic energy spectrum method which is about 10 to 12 MeV.

In this paper we present the results of the emission angular distribution, transverse momentum distribution and the temperature of PFs emission source in fragmentation of 800 A MeV ^{28}Si on C and CH$_2$ targets respectively.

2. Experimental details

Stacks of C, and CH$_2$ targets sandwiched with CR-39 detectors were exposed normally to 800 A MeV ^{28}Si beams at the Heavy Ion Medical Accelerator in Chiba (HIMAC) at the Japanese National Institute of Radiological Sciences (NIRS). The beam fluence is about 1250 ions/cm^2. The configuration of sandwiched target is shown in Fig.1. A type of HARZLAS TD-1CR-39 sheet manufactured by Fukuvi Chemical Industry Co., LTD., about 0.8 mm in thickness, is placed before and after the targets. The thickness of carbon and polyethylene targets is 5 and 7 mm, respectively. After exposure, the CR-39 detectors are etched in 7N NaOH aqueous solution at temperature of 70°C for 15 hours. Then, the beam ions and their fragments manifest in the CR-39 as etch-pit cones on both sides of CR-39 sheets. The images of ion tracks are scanned and analyzed automatically by HSP-1000 microscope system and the PitFit track measurement software provided by Seiko Precision Inc. (2014), then checked manually. ^{28}Si trajectories and the ones of secondary PFs are reconstructed in the scanned stack. Details of track tracing and reconstruction, identification of charge of PFs can be found in our papers by Zhang et al. (2013) and Li et al. (2014).
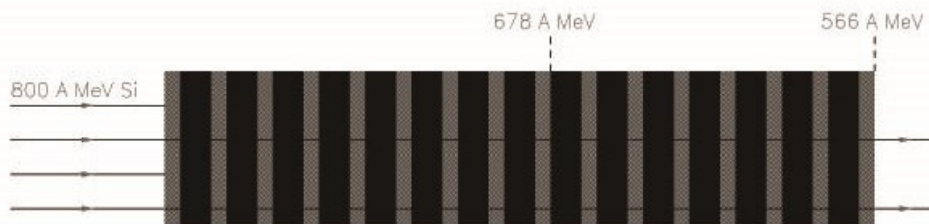

Fig. 1. Sketch of the target-detector configuration.

3. Results and discussions

Emission angular distribution and transverse momentum distribution of PFs provide the information of the nuclear structure and the mechanism of the interactions, which are also important in designing experiments with radioactive nuclear beams.

Emission angle (θ) of each PF related beam direction is calculated from the coordinates of track positions on the top and bottom surfaces of CR-39 sheet after the target. The mean reflection angles of beam related normal direction are 0.80° and 1.42° for C and CH$_2$ targets respectively. Then the transverse momentum per nucleon (p_t) of PF is