

Fragmentation cross sections of projectile with intermediate-energy Fe and ultra heavy nuclei ($Z > 26$) on hydrogen using CR-39 plastic nuclear track detector

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Abstract. It is essential for the study of galactic cosmic ray origin to know cross section of projectile fragmentation for heavy ion on hydrogen and helium target. We carried out precise measurements of projectile fragmentation cross section for Fe, and Kr as a ultra heavy nucleus ($Z > 26$) on hydrogen and carbon targets at the energies of 0.1 – 1 GeV/n using CR-39 plastic nuclear track detector. Previously, only a few experiments studying the projectile ultra heavy nuclei with intermediate energy have been reported^{[1][2]}. No experimental results for Kr with energies of 0.1~0.5 GeV/n have been reported. We investigated discrepancies between the measured cross sections and calculated ones using those formulae and models for Fe and Kr. The total and partial charge changing cross sections are preliminarily analysed, and then comparison between experiments and calculations will be reported in the presentation at 31st ICRC.

Keywords: Fragmentation cross section, CR-39, ultra heavy nuclei

I. INTRODUCTION

It is very important for the study of galactic cosmic ray origin to measure precise cross section of nuclear fragmentation for heavy ion on interstellar material (ISM) target such as hydrogen, helium and carbon at intermediate energy^[3]. Many experimental and theoretical works on the heavy ion fragmentation reaction have been carried out by many investigators from the interests of not only cosmic ray astrophysics but also another fields such as radiobiology, space dosimetry and radiation shielding, since the first acceleration of heavy ions at the Princeton Particle Accelerator and the Bevatron at the Lawrence Berkeley Laboratory in the early seventies^{[4][5][6]}. However, there remain considerably inconsistent results between experiments and models. The agreement within the error of 10~15% between experimental data and models is desirable for use in many astrophysical models^{[7][8]}. However, the level of disagreement between them ranges over a factor of

about 6 at worst^[9]. Therefore, we aim to perform the precise and accurate measurements of the fragmentation cross section systematically for intermediate energy heavy ions from C up to ultra heavy nuclei ($Z > 26$) on some hydrogen targets using CR-39 plastic nuclear track detectors (PNTDs).

The CR-39 PNTD has two more excellent advantages rather than active spectrometers such as scintillation counter, Si detector, and Cherenkov counter mostly used in the previous works. One is position sensitivity with a micron accuracy and the other is charge resolution for a wide range of projectile elements with atomic number (Z) greater than three at the intermediate energy. These advantages provide us more rich information on heavy ion fragmentation, e.g., reaction point in target material determined with a few micron accuracy, emission angle of fragments, branching ratios of produced fragments in multi-fragment events such as $C \rightarrow 3\alpha$, and so on. These information enable us to measure more precise and detailed cross sections rather than the previous measurements. Because of these backgrounds, we have developed the new measurement system for the projectile fragmentation cross section using the CR-39 PNTD^{[10][11][12]}. In this work, we carried out the measurements of projectile fragmentation cross section for Fe and Kr on hydrogen and carbon targets using the measurement system.

II. EXPERIMENT

For the measurements, we used a stack consisting of CR-39 PNTDs and carbon (C) /polyethylene (CH₂) targets. Fig.1 shows the typical stack configurations for Fe and Kr beams. The beam exposures were carried out at HIMAC (at National Institutes of Radiological Sciences) and AGS (at Brookhaven Nuclear Laboratory) accelerators. The stacks were exposed perpendicularly to Fe and Kr beams at the energies of 0.1~1 GeV/n. Generally, $\sim 10^5$ counts for each run were obtained. The CR-39 PNTDs were etched in 7 N NaOH solution and PEW (Potassium-Ethanol-Water) solution^[12]. The etching condition and stack configuration used in this work are com-

piled in another paper in this issue^[13]. After etching, the sizes of ion tracks produced on the CR-39 PNTD surface were measured and analyzed automatically using the HSP-1000 microscope system^[10]. The tracks were traced through the stack and the trajectories of projectile and fragments were reconstructed^[11]. The cross sections are derived from the number of particles with individual charges counted in front of and behind the target. The hydrogen cross section (σ_H) is obtained from the carbon and polyethylene data according to the relation $\sigma_H = 0.5(\sigma_{CH_2} - \sigma_C)$.

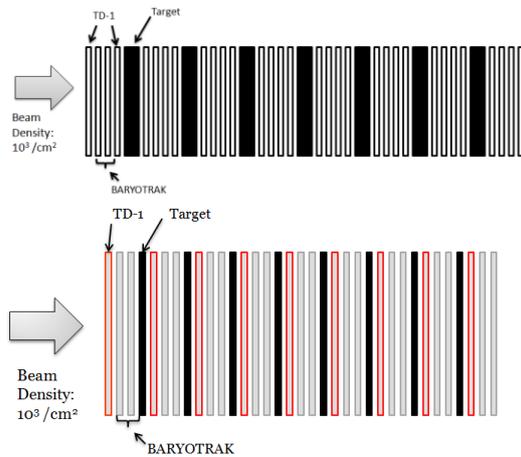


Fig. 1: Schematic drawing of Fe (up) and Kr (bottom) experimental stacks.

III. PRELIMINARY RESULTS

In this paper, we show the preliminary results of analysis of Fe + C experiments at the energies of 250 – 500 MeV/n. Fig. 2 shows the charge spectrum of 350 MeV/n Fe projectile and fragments obtained behind a carbon target. It is very easy to identify the charge of projectile and fragments very precisely. The numbers of ions with respective atomic number (Z) were determined from the charge distribution fitted with a Gaussian function.

Fig. 3 shows the number of charge changing reactions for Fe projectiles on C. The estimation of the number of reaction by Webber data is also shown in the figure. Error of our results includes only statistical one. Our results are about 5% higher than the estimation by Webber. However, they totally showed good agreement with the estimation. This result suggests the good agreement of total charge changing cross section for Fe on C target between our experiment and Webber. Now we are analyzing the partial charge changing cross sections in progress.

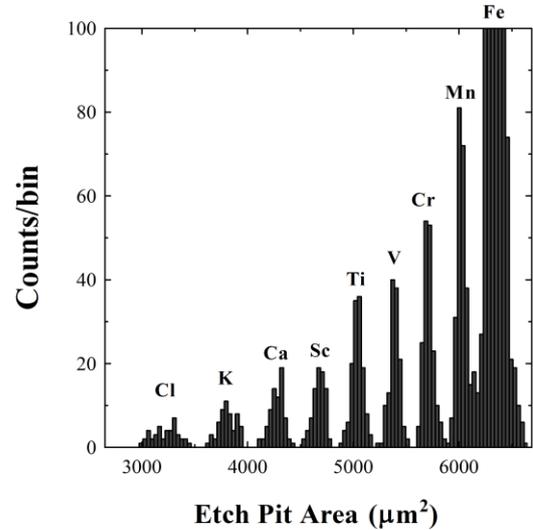


Fig. 2: Charge spectrum of Fe projectile and fragments

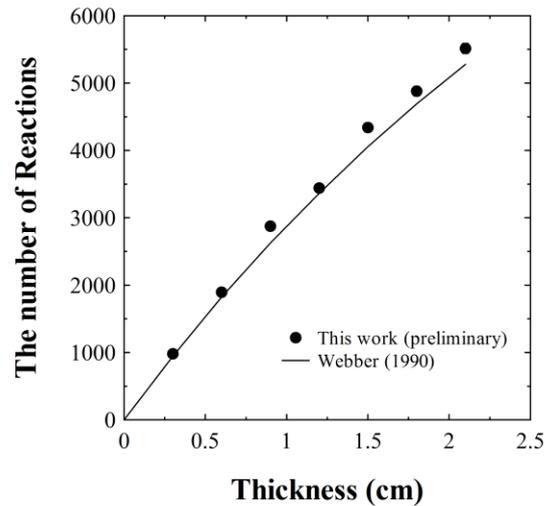


Fig. 3: The number of charge changing reactions for Fe on C

IV. SUMMARY

Our preliminary results suggested the good agreement of total charge changing cross section for Fe on C target. In the presentation at 31st ICRC, the total and partial charge changing cross sections for Fe and Kr on hydrogen target will be reported in more detail, as the improvement of statistics will greatly be made then.

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