Total, partial charge changing and charge pick-up cross-sections of 300 A MeV Fe^{26+} ion beam in Al target with new system

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Introduction

Fragmentation of heavy ions in various targets is relevant in various fields of fundamental and applied sciences, nuclear physics, hadrontherapy, cosmic ray physics and astrophysics [1-2]. Manned missions to space and moon cause health risks to astronauts due to the galactic cosmic rays [3]. Due to fragmentation of energetic cosmic rays in the spacecraft walls enhances the radiation effects on human body. Therefore, an accurate knowledge of nuclear fragmentation is essential for a good shielding design.

In the present work, total, partial charge changing and charge pick-up cross-section for 300 A MeV Fe^{26+} ion beam in Al target were calculated using a new system of analysis.

Experimental

A stack was composed of two CR39 detectors (of size 11.5 × 11.5 cm^2) upstream and ten CR39 detectors downstream of 0.3 cm Al target and was exposed to 300 A MeV Fe^{26+} ion beam at BNL, USA at normal incidence. After exposure, the detectors just before (CR39-2) and just after (CR39-3) the target were etched from single sides [4] in an aqueous solution of 6N NaOH + 1% ethyl alcohol at 70 ˚C for 48 hours. After etching, the detectors were washed in deionized water for at least one hour in an ultrasonic water-bath. The diameter of tracks in CR39 detectors was measured by using Leica DM 6000 M optical microscope under 20X objective. The microscope consists of a CCD camera, a frame grabber and a personal computer (PC) consisting of hardware and software interface. The microscope is equipped with a motorized X/Y stage with an accuracy of better than 1 µm. The microscope can be operated via several menu levels on the Leica SmartTouch which displays the current microscope settings. The computer system attached with the microscope is installed with image processing software Leica QWin Plus for the study of tracks-images captured by CCD camera for gathering useful information or data for further analysis. Various parameters can be measured using Leica QWin Plus. e.g. length, area, x and y position, roundness, centroid, perimeter, diameter, counts, brightness etc.

Results and discussion

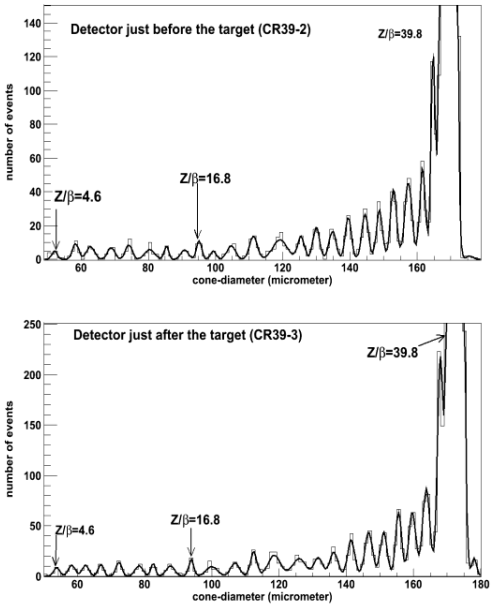

Fig. 1 Diameter distribution of etched tracks with multiple Gaussian fittings of 300 A MeV Fe^{26+} ions and their fragments in (a) CR39-2 and (b) CR39-3.

Fig. 1 shows diameter distributions of tracks due to beam particles and their fragments on an area of ~12 cm^2 in the front faces of

detectors CR39-2 and CR39-3, respectively. Both distributions for CR39-2 and CR39-3 detectors were fitted with multiple Gaussians using the ROOT software analysis toolkit.

Total charge changing cross-section

The total charge changing cross-section of 300 A MeV Fe^{26+} ions in an Al target was computed by using the relation in [5]. From Gaussian fitting of the diameter distributions as shown in Fig. 1, the numbers of incident and survived ions were determined to be 1491 cm^{-2} and 1447 cm^{-2} with a confidence level of 99.7%. Then the total charge changing cross-section was calculated (1663 ± 236) mb. The measured cross-section was reasonably comparable with the results in [6].

Partial charge changing cross-section

Partial charge changing cross-section was calculated via the relation in [5].

Table 1: Partial charge changing cross-cections for 300 A MeV Fe^{26+} ion beam in Al target.

ΔZ	**$\sigma_{\Delta Z}$ (mb)**	**ΔZ**	**$\sigma_{\Delta Z}$ (mb)**
-1	472 ± 66	-13	47 ± 7
-2	345 ± 39	-14	93 ± 7
-3	138 ± 31	-15	27 ± 4
-4	117 ± 27	-16	49 ± 7
-5	124 ± 18	-17	20 ± 4
-6	165 ± 21	-18	18 ± 4
-7	98 ± 15	-19	12 ± 4
-8	87 ± 14	-20	11 ± 4
-9	46 ± 11	-21	18 ± 4
-10	169 ± 14	-22	11 ± 4
-11	86 ± 18	-23	10 ± 3
-12	51 ± 11		

From the multiple Gaussian fitting of diameter distributions, the number of events corresponding to each fragment peak is counted within 95.5% confidence levels and the number of incident and survived beam ions were counted within 99.7% confidence levels. Using the formula in [5], the relative partial charge changing cross sections for ΔZ = -23, -22,...., -1 were calculated and presented in Table 1.

Charge pick-up cross-section

Some charge pick-up events (ΔZ=+1) [7] in CR39-3 detector have been observed as shown in Fig. 1 (b). The charge pick-up cross-section for these events was calculated using the relation in [7]. From Fig. 1(b), N_{27} (charge pick-up events) was calculated 29 within the confidence level of 95.5%. Using these values, the charge pick-up cross section was calculated (92 ± 6) mb.

Conclusions

The total charge changing cross-section of 300 A MeV Fe^{26+} ion beam was measured more accurately in the Al target. The partial charge changing cross-section was calculated for ΔZ = -23, -22, ... , -1. On average, the partial charge changing cross-sections decrease with increasing ΔZ.

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