Measurement of total charge changing cross-section for 10 A GeV Fe^{26+} ion beam in polyethylene and CR39 media

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Introduction

Heavy ion fragmentation at high energy in various targets is a field of great interest in nuclear physics, astrophysics, cosmic ray physics, applied physics [1,2], spacecraft shielding design and treatment planning for hadrontherapy [3]. Galactic cosmic rays (GCR) contain particles of almost all charges like protons (87%), helium (12%) and heavy charged particles (1%) with energies in the range from a few MeV/n to greater than 10^{15} MeV/n [4]. Fe^{26+} ions are observed to be the heaviest ions in GCR of significant importance because of its high relative biological effectiveness (RBE). These radiations may cause health risk to the astronauts. Therefore a good shielding design [5] is required to minimize the radiation risks.

In this paper, we calculated the total charge changing cross-section of 10 A GeV Fe^{26+} ion beam on CR39 $(C_{12}H_{18}O_7)_n$ and polyethylene (CH_2) media using CR39 nuclear track etch detectors by cone-height measurements**.** CR39 detector is versatile in terms of their sensitivity for a wide range of charges down to $Z/\beta=6$ in the relativistic regions [6-7].

Experimental

A stack composed of CR39 foils and CH_2 target was joined with another stack composed of CR39 foils and CR39 target and then exposed to Fe^{26+} ion beam of energy 10 A GeV at Brookhaven National Laboratory (BNL), USA using AGS (Alternating Gradient Synchrotron) at normal incidence with total ion density of ~2000/cm^2. After exposures, the very last sheet of CR39 detector in the stack after the target was taken from the stack. From the previous experience of cone-height measurements [6], the chemical etching was performed on one side of the detector in 6N NaOH solution + 1% ethyl alcohol at 70 ˚C for 95 hours in two steps by applying silica gel on back surface of the detector to avoid the shadow effects.

After etching, the detector was washed in deionised water and then washed for at least one hour in an ultrasonic water-bath to clean up the etchants from inside the pores. After cleaning and drying, the detector was used for scanning under Leica DM6000 M optical microscope. 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. This stage can be controlled in dual ways; by using Remote control element and by computer. By the Remote control, movement of the stage along X-axis, along Y-axis, focus adjustment and some other functions can be performed. A part of the microscope is the Leica SmartTouch which displays the current microscope settings. The microscope can be operated via several menu levels on the Leica SmartTouch. Fig. 1 shows the image of CR39 detector irradiated with 10 A GeV Fe^{26+} beam after etching of 95 hours.

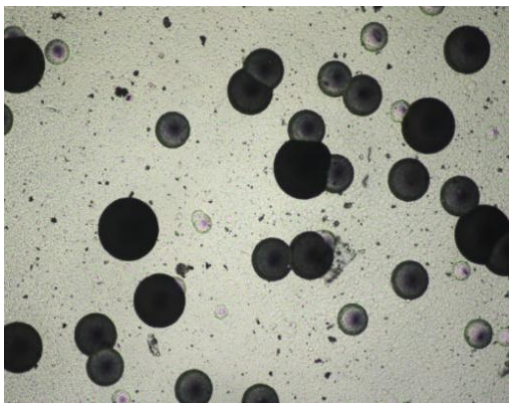

Fig. 1 Image of a CR39 detector exposed to 10 A GeV Fe^{26+} ion beam after etching of 95 hours

Results and Discussion

Fig. 2 shows the distribution of cone-height of the etched tracks for Fe^{26+} ions and their fragments measured manually by the microscope on an area of ~ 2.68 cm^2 on front face of the CR39 detector and the cone-height of almost 11300 tracks was measured. The peaks are well separated for the incident beam ions and for the fragments and a charge was assigned to each of these peaks from Z/β = 26.1 down to 7.0 as shown in Fig. 2.

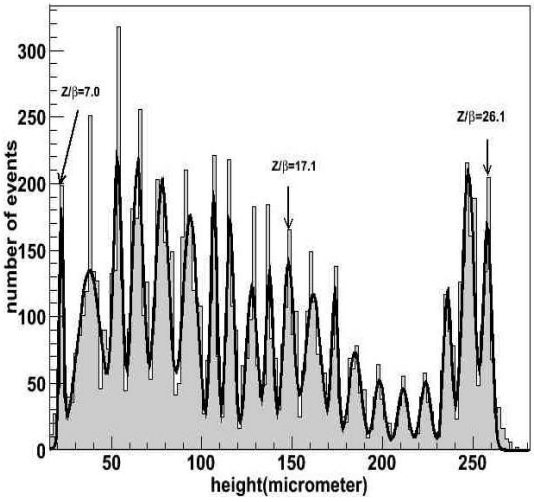

Fig. 2 Cone height distribution of etched tracks in CR39 detector from 10 A GeV Fe^{26+} ions and their fragments

Measurement of Total Charge Changing Cross-Section

Total charge changing cross-section of 10 A GeV Fe^{26+} ion beam in CR39 and CH_2 as combined target was experimentally calculated by the formula in [1]. The number of incident Fe^{26+} ions was 2000 cm^{-2}. Average atomic mass number and density of CR39 and CH_2 target materials are 7.0 and 1.266 g cm^{-3} respectively. There were 32 sheets of CR39 detector each of thickness 0.15 cm in the stack. The number of survived ions was obtained by the Gaussian fitting of height distribution as shown in Fig. 2 and was 250 cm^{-2}. Using formula [1], the calculated value of total charge changing cross-section was σ_{tot} = (2694 ± 142 mb). The total charge changing cross-section is independent of energy in the relativistic region [8]. The calculated value of the total charge changing cross-section of 10 A GeV Fe^{26+} ion beam was compared with the experimentally calculated values by Webber, et al. [8] and Zeitlin, et al. [9] and the results are in good agreement within the limits of experimental errors.

Conclusions

A unique method of one-side etching was used to avoid shadow effects occurring in cone-height measurements. This new technique of one side etching for cone-height measurements is better as compared to both side etching for increasing the track cone height. The total charge changing cross-section calculated by this method is also in good agreement with the result of others.

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