Response of the CR39 Nuclear Track Detector to Relativistic Si^{14+} Heavy Ions

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The response of the CR-39 nuclear track detector for 5 A GeV Si^{14+} ions and their fragments has been presented in this work. Well-separated peaks are observed from Z=7 to 14, indicating the detector threshold Z = 7 in the present condition. The charge resolution of the detector is $\sigma_Z \approx 1e$ at Z = 10.

Key Words: Nuclear track detector, CR-39, Detector threshold, Charge resolution, Heavy ions.

INTRODUCTION

Nuclear track detectors (NTDs) are commonly used in many branches of science and technology[1-3]. The most sensitive NTD is the polymeric isotropic material poly-allyl diglycol carbonate, commercially known as CR-39. Rising interest in implementing these materials in radiation safety during high-altitude flights and manned space missions requires deeper and more detailed information about the measuring systems used. Several international experiments are going on in the field with the aim to calibrate the detectors in conditions similar and/or simulating corresponding radiation fields[4-11].

The damaged trail known as *latent track* is generally enlarged by chemically etching in aqueous solutions of NaOH and KOH with different concentration and temperature. It is observed that the addition of ethyl alcohol in the *etc*hant gives enhancement in the *etc*hing process, improves the *etc*hed surface quality of NTDs, but raises the detection threshold. The dynamics of nuclear track formation in polymers is quite complex and depends on the charge and energy of the incident particles. The track structure can be described using the concepts of track core where the density of deposited energy is high, creating a real channel due to high ionization and thermal effects; the core is nearly 10 nm in diameter in the case of relativistic charged particles. For high Z relativistic charged ions, the restricted energy loss (REL) was proposed by Benton[12,13] and widely used for explaining the formation of the track core. It uses cut-off delta ray energy, $\omega = 200$ eV for CR39, considering that the outer part of the track halo does not participate in the etching process and does not contribute to the track etching rate.

The track etching process can be well described with a two etch rates model[1,2,14-17], according to which the two *etc*hing velocities act simultaneously. The bulk etch velocity V_B occurs in the undamaged surface area, while the track *etc*h velocity V_T occurs where the incident track passed and formed the latent track. Usually, the track etch rate is obtained from measurements of the base cone track diameter after definite etching time; it implies that the etched tracks are conical in shape[15], and this is so if the energy loss is constant.

Information about the detector signal p = (V_T/V_B), may be obtained either by measuring the track diameter D or by cone height measurement and by measuring V_B. The aim of the present study is to provide the response of CR39 to Si^{14+} beam and their fragments by measuring the track diameter. This is particularly important in the search for relativistic high-Z cosmic rays and for fragmentation cross-section measurements.

EXPERIMENTAL

A stack composed of CR39 foils of size 11.5 × 11.5 cm^2 with a 1 cm thick polyethylene target was exposed at normal incidence to 5 A GeV Si^{14+} ions in 2005 at BNL, USA. The CR39 material was manufactured by Intercast Europe Co., Parma, Italy using a specially designed line of production[18]. The detector foils downstream of the target recorded the beam ions as well as their fragments. After exposure, a foil of CR39 (located after the target) was etched from one side (by applying silicon gel on other side) along with some unexposed detectors (for obtaining the V_B) in 6 N KOH + 3 % ethyl alcohol at 60°C for 95 h. The etching was performed at Physics Department, University of Bologna, Italy in a stainless steel tank equipped with internal thermo-resistances and a motorized stirring head. The stability of the temperature was within ± 0.1 °C. In order to have a homogeneous solution during the etching and to avoid that etched products deposit on the detector surfaces, the stirring was kept constant during etching. Measurement of V_B is based[19] on the determination of the thickness of the detector at different times during the etching process (with an electronic micrometer with a precision of 1 μm). We measured the mean thickness difference Δx before and after *etc*hing for a time Δt: the $V_B = \Delta x/2t = 1.52 \pm 0.06$. The major and minor axes of about 700 tracks were measured by using an optical microscope with accuracy up to 1 μm and the mean diameters of etched cones were computed.

RESULT AND DISCUSSION

Calibration was performed with relativistic heavy ions Si^{14+} in order to determine the Z thresholds in the CR39 detector and establish the charge resolution. Fig. 1 shows the diameter distribution for Silicon ions and their fragments in CR39; averages were computed from measurements on minor and major axis of the tracks. Well separated peaks are observed from Z = 7 to 14; indicating the detector threshold Z = 7 in this condition. The charge resolution is $\sigma_z \approx 1e$ (half width at half maximum) at $Z \approx 11$; it can be improved by measuring more diameters of the etch pit cones or using advanced automatic analysis system.

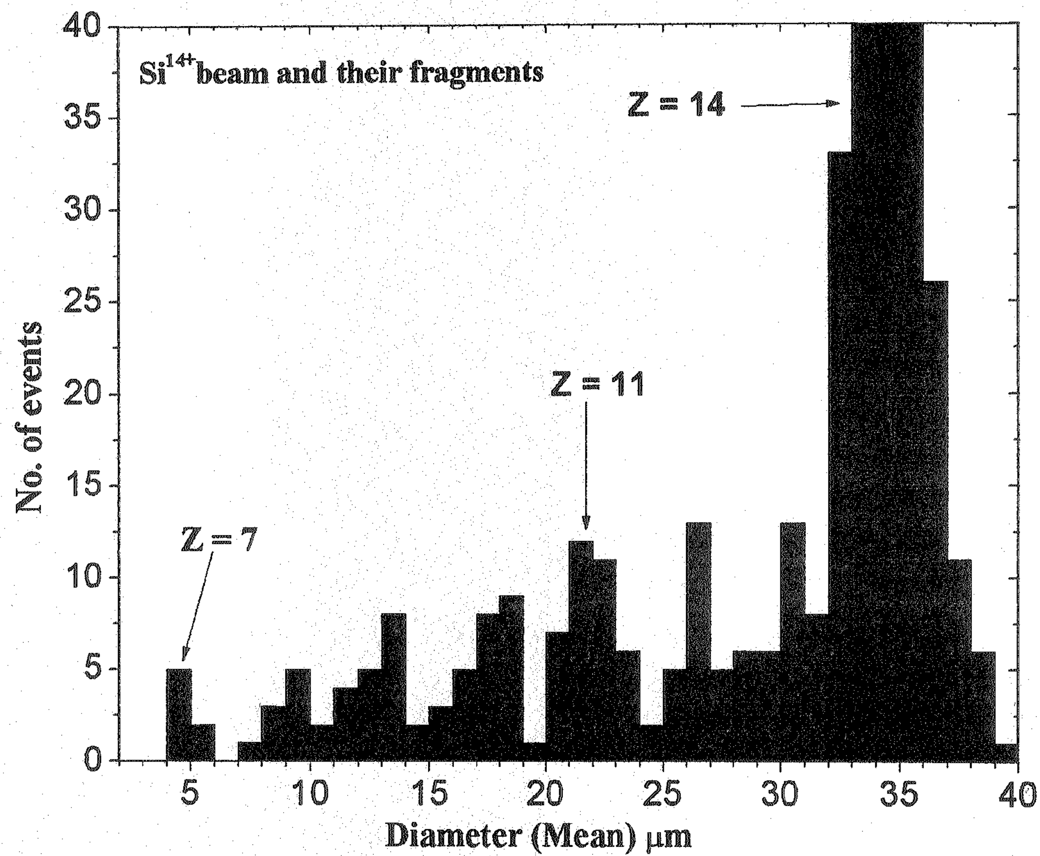

Fig.1. Distribution of the mean diameters of the etched cones produced in CR-39 by 5 A GeV Si^{14+} ions and their fragments etched in 6 N KOH + 3 % ethyl alcohol for 95 h.

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