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Characteristics of antiproton tracks in CR-39

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Abstract

CR-39 detectors were exposed to 5.9 MeV antiprotons at CERN. After exposure, the detectors were etched in 6N NaOH solution at 70 °C. Antiproton tracks were revealed after 135 min of etching and their further growth was studied as a function of etching time. Antiproton track diameter and track density were measured after each of several etching steps leading to the total etching time of 290 min. Track diameter increases with etching time whereas track density decreases with etching time. The decrease in the track density is attributed to the discontinuous nature of 5.9 MeV antiproton tracks. Antiproton annihilation with constituents of CR-39 detector is expected to play a minor role in decreasing antiproton track density with etching. However, etching-removal of large angle (with normal to CR-39 surface) tracks of particles, formed after annihilation of antiprotons in target nuclei near the end of range, is expected to have a considerable effect on the decrease of track density.

Keywords: Antiprotons; CR-39; Track diameter; Track density, Annihilation

1. Introduction

Antiprotons are a rare component of secondary cosmic radiations produced in the atmosphere by the interaction of primary particles with air (Pfeifer et al., 1996). These can also be produced using high energy accelerators. The interaction of an antiproton with matter is more complicated compared with that of a proton. A fast antiproton may annihilate in flight (although the probability is low) or can be stopped like a proton in any material. After getting stopped, an antiproton is captured by the coulomb field of the atom to form an antiprotonic atom. This atom deexcites and antiproton proceeds to lower orbits, and finally reaching the nuclear surface where it annihilates with one of the nucleons of the atom, mainly producing pions. It is important to understand the interaction of antiprotons with matter as it can be used as a probe. Already, antiproton annihilation is being used to explore the structure of nucleus (von Egidy, 1987). The aim of this study was to understand the damage produced (in the form of nuclear tracks) in the target material due to interactions of antiprotons before they annihilate.

CR-39 is the most widely used solid state nuclear track detector (SSNTD). Here, we present a study on characteristics of antiproton tracks in CR-39 detector. Measurements of different features of antiprotons tracks, including diameter and track density, are presented. Results are compared with published proton track results.

2. Experiment

2.1. Antiproton exposure at CERN

CR-39 plates (Pershore Mouldings Ltd., UK) of area 25 cm^2 and thickness 1000 μm were exposed with 5.9 MeV antiproton beam in air at the LEAR (low energy antiproton ring) facility at CERN. The secondary LEAR beam line leading to the PS194 was used for the antiproton exposure. The distance between the mylar window at the end of the beam pipe and target detector was 10 cm. The momentum (convertible to energy) of antiprotons was measured using a secondary electron device, which consisted of a thin foil, a secondary electron accelerating system and a photomultiplier. The integrated intensity of antiprotons during exposure was 5.72×10^7, which was measured using scintillating fiber monitor. Details about energy and

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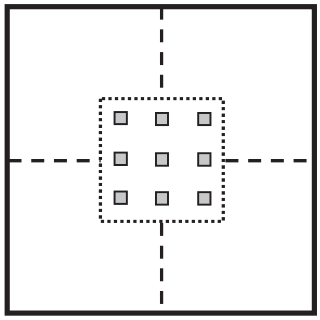

Fig. 1. Schematic showing the measurement of diameter and density of antiproton tracks. Track diameter and density measurements were performed at 9 locations (smallest gray rectangles) in the $2 \times 2\,cm^2$ central area of the CR-39 detector.

intensity measurements of antiprotons at LEAR are given by Fernandez-Figueroa and Molinar (1992).

2.2. Etching of exposed CR-39 plates

Irradiated detectors were etched in 6N NaOH solution at 70 °C. Variation in set value of etching temperature was not more than ±1 °C. A standardized process was adopted during etching of the detectors. Efficient stirring was maintained during the etching process to produce uniform convection in the etching bath. This is essential to avoid the buildup of etch products. The buildup of etching products at the surface of detector can affect etching rate and may produce misleading results. The concentration of etchant remained nearly constant stationary by using the fresh etchant after each etching interval (10–25 min). After etching, the CR-39 detectors were rinsed in running water and then in an ultrasonic bath to remove etchant and etch products from the surface of the detector and etch pits. A total of 13 etching steps were carried out resulting in a total cumulative etching time of 290 min. The total number of etching steps after which tracks appeared microscopically was 7. Tracks from antiprotons in CR-39 detectors appeared after 135 min of etching in 6N NaOH solution at 70 °C, but measurement of track diameters was only possible after 140 min of etching.

2.3. Measurement of antiproton tracks

Diameters and density of antiproton tracks were measured using a Leitz DAILUX 22EB optical microscope with a magnification of 400–1000×. Fig. 1 shows $2 \times 2\,cm^2$ central area of the CR-39 detector with 9 square regions used for measurement of track parameters. All the tracks in these gray regions were counted for track density measurement and diameters of 12 tracks at the center of each of these 9 regions (108 tracks in total) were measured after each etching step. Average diameter, based on measurement of 108 tracks, and average track density, based on measurement of 9 square regions, were determined and reported here.

3. Results and discussion

Fig. 2 shows the SEM photograph (with magnification of 3000×) of the antiproton tracks in CR-39 after 290 min of etching under above-mentioned etching conditions. Track diameters were measured (as described in the previous section) after each etching interval. Fig. 3 shows a plot of the mean track diameter as a function of etching time. The time-intercept in this plot is defined as the etch induction time (EIT). The value of EIT for 5.9 MeV antiprotons in CR-39 under above-mentioned etching condition is determined to be 85 min.

The value of EIT depends on charge and energy of track forming particle, properties of detector material, and etching

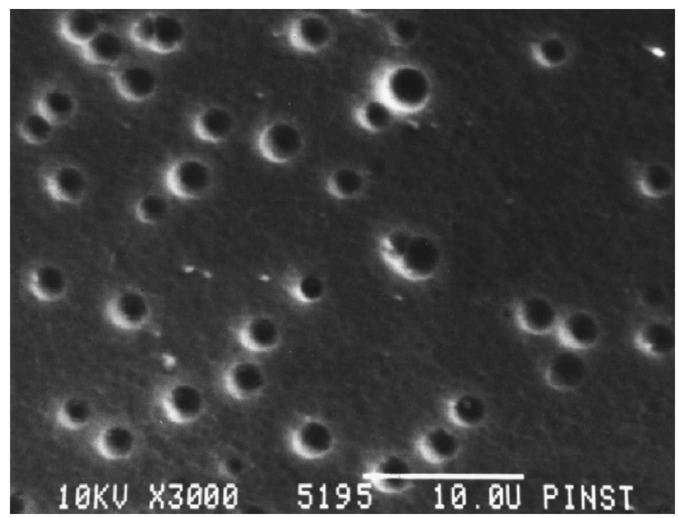

Fig. 2. SEM photograph of track distribution of 5.9 MeV antiprotons revealed in CR-39 detector after etching in 6N NaOH solution at 70 °C for 290 min.

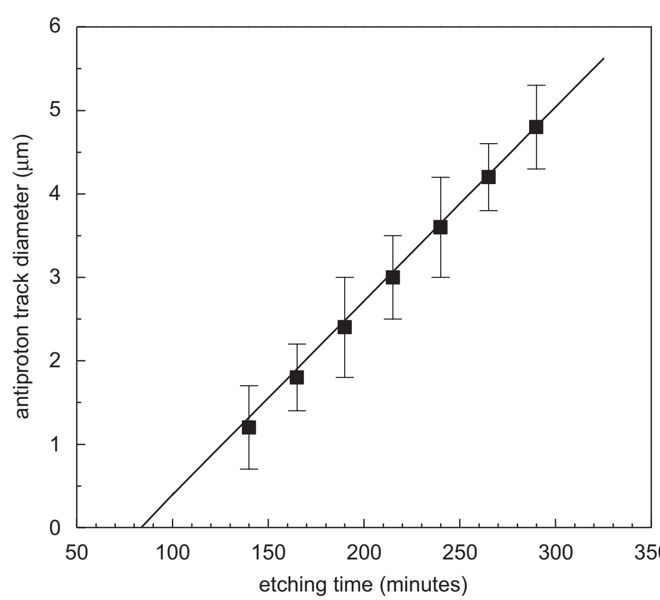

Fig. 3. Growth of antiproton track diameters during etching.