Observation of heavy ions using Polyethylene Terepthalate (PET) detector at mountain altitude

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Abstract: We exposed three stacks of Polyethylene Terephthalate (PET) detectors, at an altitude of 2200 m (atmospheric pressure 765 hPa). This particular brand of OHP transparencies is found to have a charge detection threshold (Z/β > 140). These stacks of detectors were kept, each of thickness 100 µm and area 21 cm.X 31 cm at Darjeeling, India (North East Himalayan Range) in the open air for 182 days in the following configurations. One of the stacks was hemispherical in shape to study the arrival direction of cosmic rays, another stack was shaded with a perspex plate to block cosmic rays so as to study the local radiation and third one was kept horizontal. After etching with 6.25 N NaOH under suitable conditions heavy ion tracks were observed.

Introduction

The search for massive exotic particles (eg. Strangelets) in cosmic rays is an active field of research. To investigate such rare events one needs a large area detector. An obvious choice for such large area detectors to be set up at mountain altitudes are solid state nuclear track detectors (SSNTD). In our course of study with such detectors we came across a commercially available polymer (A particular brand of overhead projector transparencies) which was identified to be Polyethylene Terephthalate (PET) by elemental analysis and FTIR spectroscopy with the chemical formula $(C_5H_4O_2)_n$ and found that it could be used as a SSNTD. We investigated the charge response characteristics of this detector and established [1-3] that PET has a much higher detection threshold ($Z/\beta > 140$) compared to other widely used SSNTDs eg. CR39(DOP 1%) with $Z/\beta \sim 6$ [4] , CR39(HCB 0.5%) with $Z/\beta \sim 10$ [5] and Lexan Polycarbonate with $Z/\beta \sim 57$ [6]. Because of its high detection threshold, the PET detector will not record protons or α-particles in cosmic rays and by virtue of its ability to eliminate this huge low Z noise is an ideal choice for a detector for studying heavier ions and other exotic particles in cosmic rays. As part of the standardization procedure we exposed three stacks of such detectors each of thickness 100µm and area 21cm × 30 cm at Darjeeling, India (North East Himalayan Range) at an altitude of 2200m (atmospheric pressure 765 hPa). The detector stands were made of Perspex and were kept 1 m apart. One of the stacks was kept horizontal with 2π steradian exposure to open air. The second stack was bent in a hemispherical shape to study the arrival direction of cosmic rays. In the third case a 5 mm thick slab made of Perspex were placed 2 cm above the detector sheets in an effort to block the cosmic rays in order to study the local radiation environment. The detectors were kept in such configuration for 182 days (~ 1.57×10^7 s) before they were removed and studied.

Results and Discussions.

The recovered stacks were etched in 6.25N NaOH solution at 55.0±0.1 °C for three hours. These etching conditions are similar to our calibration experiments with the same PET detector with ^{16}O and ^{238}U ions

[1-3].The etched detectors were then studied under the dry objectives of a Leica DMR microscope interfaced with a computer for automated image analysis. Etch-cones of various diameters and cone lengths could be seen. For the first stack which was kept in a horizontal position etch cones of diameter ranging between 6 – 15 µm and cone lengths between 6 – 12 µm could be seen. When measured under the ×100 dry objective the error in diameter measurement is 1 pixel (0.132 µm) and for depth measurement it is 0.625 µm. Most of the etch pit openings are almost circular suggesting that most of the particles are impinging on the detector almost vertically. The measured flux of such tracks is ~ 1.1×10^{-1} / m^2–sr–sec.

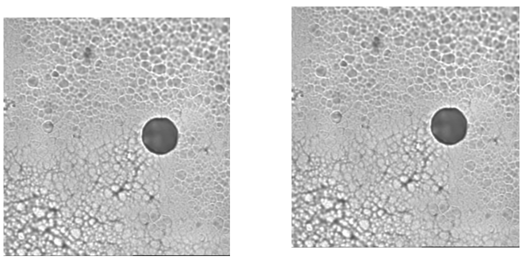

Figure 1: Two Image Frames of the PET detector from Stack 1 kept horizontally and given open air cosmic ray exposure.

These tracks are obviously not light ion tracks because as previously mentioned our studies with PET [1-3] has shown that it does not record proton or α - particles because of the high Z/β detection threshold of this detector.

In case of the detector bent in the form of hemisphere also tracks were observed with diameters ranging from 7–13 µm and cone lengths between 6 – 15 µm. Those tracks were clustered more on the top of the hemisphere compared to the sides. At a distance of 15 cm from one edge i.e. near the middle, the track density is found to be 0.41×10^{-1} / m^2–sr–sec whereas 7 cm from that edge the flux was determined to be 0.12×10^{-1} / m^2–sr–sec. This too suggests that the charged particles are coming from above and falling on the detectors vertically.

Even in the case of the third stack which was shaded with a 5 mm thick slab of perspex in an effort to block cosmic rays we could see tracks on the top layer.

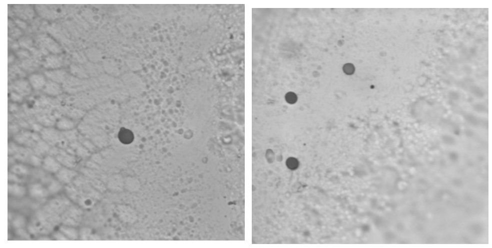

Figure 2: Smaller tracks seen on the PET detector even when they were shaded with a perspex slab on top.

The flux density of those tracks was found to be 7.65×10^{-1} / m^2–sr–sec which is of the same order as the previous two stacks, although the diameters are much lower (between 2–5 µm) with correspondingly lower etch – cone lengths (between 2–4 µm). By using the code SRIM-2006 we found that the energies required by ions like nitrogen and oxygen to pass through 5 mm of similar material is 700 MeV or higher. The origin of these heavy ion tracks needs to be further investigated. One possibility is that cosmic ray secondaries are interacting and imparting enough energy to atmospheric air molecules to form such tracks.

Conclusions:

It appears that certain heavy ions with very high energies are impinging on the PET detectors kept at mountain altitude. The exact nature of those ions and their acceleration mechanisms are to be investigated further as the cosmic ray literature does not contain any mention of any appreciable flux of heavy ions at that altitude.

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