An Unusual Cosmic Ray Track

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INTRODUCTION

In the course of scanning a group of 200 micron, Eastman Kodak NTB3 nuclear photographic emulsions which had been exposed to cosmic radiation at an altitude in excess of 93,000 ft. an unusual particle track was observed which did not lend itself readily to any simple explanation. An extended analysis was made of this track by Glazer in an effort to determine if possible the mass of the particle causing it.

EXPERIMENTAL DETAILS

The track in question enters the top of the emulsion, proceeds downward at a slight dip for 2170 microns to a point, hereafter designated as X, 3 microns above the bottom of the emulsion, at which the gross external appearance of the track suggests that the particle underwent large angle scattering and then continued upward for a distance of approximately 137 microns before coming to a stop in the emulsion. For purposes of clarity, the 2170 micron track will hereafter be referred to as the long track and the 137 micron track will be referred to as the short track.

ANALYSIS

The following possibilities suggest themselves:

I. The particle causing the long track underwent large angle scattering in the neighborhood of the point X.

II. The particle causing the long track decayed at point X to another particle which caused the short track. Alternatively the event might be due either to a 2-prong star, on the absorption at point X of the particle causing the long track with the subsequent emission of a particle causing the 2nd track.

III. The particle causing the short track entered the emulsion in the neighborhood of point X and was not associated with the event causing the long track.

IV. The particle causing the short track had its origin in the emulsion, passing out of the emulsion in the neighborhood of point X.

A very large difference in grain density between the long and short track in the vicinity of point X, coupled with the apparent absence of a recoil nucleus eliminates the first possibility.

To examine possibility (II) the ratio of the proton mass M_p to the mass M_l of the particle causing the long track was determined from grain counting and multiple scattering measurements as $M_p/M=6.07$ and $M_p/M_l=6.30$ respectively. These values when compared with the accepted value $M_p/M_\pi=6.44$ indicate that the long track was caused by a π meson. Statistical fluctuations and distortions in the emulsion are such, however, that there is a possibility that the long track could have been caused by a μ meson. In order to check the possibility of the well known decay schemes $\pi^+ \rightarrow \mu^+$ and $\mu^+ \rightarrow e^+$ an attempt was made to determine the mass of the particle causing the short track. Unfortunately, the length of the short track is such that it does not lend itself to unambiguous analysis by either grain counting or multiple scattering.

A very rough approximation of $M_l/M_s=13.8$ (M_s is the mass of the particle associated with the short track) was obtained as follows: Grain density vs. residual range curves were plotted for the long and short tracks. Measurements of grain density made at either end of the short track gave the change in grain density between the two ends of the track. The interval of the grain density vs. residual range curve of the long track which had an identical change in grain density was found. This interval was then matched to a portion of the abscissa which had a length equal to the length of the short track. The two ranges thus found provide us with a ratio of

$$\frac{R_l}{R_s} = \frac{M_l}{M_s} = 13.8.$$ An estimate of the minimum value of M_s was determined by again making use of the grain density vs. range curves. The mean grain density of the short track was determined from the grain counting data, and as stated earlier the minimum range for the short track was known to be 137 microns. By finding the range of the long track corresponding to a value of grain density equal to the mean grain density of the short track, one can then form the ratio of this latter range to the minimum range of the short track and obtain an approximation of the minimum value of M_s. A value of $$\frac{R_l}{R_{s(min)}} = \frac{M_l}{M_{s(min)}} = 18.1$$ was obtained.

The ratios thus secured suggest a particle whose mass would lie somewhere in the range from *15.3* to *20.6* electron masses. The former figure should be regarded as a lower limit. Unfortunately we have no way of knowing how good the value of 13.8 is.

Examining the possibility that the event might be a $\pi^+ \rightarrow \mu^+$ decay an estimation of the range of a μ meson (having an average value of grain density as measured on the short track) yielded 2490 microns which is much larger than the accepted value of 619 microns characteristic of the decay in the particular type of emulsion used.

Examining the possibility that the event might be a $\mu^+ \to e^+$ decay it was found that the range of a positron having the measured initial track grain density would be about 15 microns which is considerably less than the measured value of 137 microns. Further, Leighton, Anderson and Seriff (2) have shown that the decay electrons of $\mu^+ \to e^+$ have an energy spectrum which extends from 9 Mev. to 55 Mev. thus making it highly improbable any tracks of such decay electrons would be found in NTB3 emulsions which are sensitive only to electrons having energies less than 400 Kev.

The idea that the event is a 2-pronged star with origin at point *X* is ruled out by the fact that the grain density of the long track increases as one approaches the origin showing that the particle which caused the long track was moving through the emulsion toward point *X*. There is however, an alternative possibility that the particle causing the long track was absorbed by a nucleus at point *X* with the subsequent emission of the particle causing the short track, the abrupt end of the short track being due to an annihilation process.

Consider next possibility III. If the short track is a fortuitous event and not associated with the long track then it certainly cannot have been produced by an electron, as shown previously. A singly-charged particle of mass greater than the electron is ruled out by the small grain density at the end of the short track unless we speculate that the abrupt end of the short track is due to the generating particle combining with a particle of opposite sign and disappearing in the form of radiation. For the special case of a positive μ meson, an annihilation scheme has been proposed by Johnson (1). Although there has been as yet no experimental evidence confirming this event, the possibility of such an annihilation process must be considered, not only for a μ^+ meson, but for any particle which travelled from *X* to the end of the short track.

If next we examine (IV), we rule out the possibility that the short track represents a particle which was produced by the decay of a neutral particle, since no other track is visible leading away from the point of origin and such an explanation would not be consistent with the principle of conservation of charge. Further, the absence of any other track in the neighborhood of the assumed origin of the short track seems to show that a charged particle could not have been responsible for the event in question but this conclusion must be made with some reservation as the particle might have come vertically upward from the bottom of the emulsion. in which case its track would be extremely difficult to recognize. Conservation of charge could be explained if a nucleus in the emulsion absorbed a neutral particle with subsequent emission by the excited nucleus. However, the emission of just one charged particle of high energy by an excited nucleus, although possible, is a highly improbable event.

Finally, it should be remarked that the grain density increases in a regular manner from *X* to the end of the short track. This could be interpreted as indicating that the particle moved from *X* to the other end of the short track. Unfortunately, no great faith may be placed in this interpretation as the total change in grain density along the short track is no greater than some of the larger statistical fluctuations in grain density along the long track.

DISCUSSION

It is evident that no positive identification can be made of the particle causing the short track with the information available to us. Additional instances of an event of this type will have to be found before definite conclusions can be drawn as to the validity of the interpretation suggested in this paper, namely, the possibility of the existence of a particle whose mass is of the order of 20 electron masses.

LITERATURE CITED

1. JOHNSON, M. H. 1952. Annihilation radiation from μ mesons. Phys. Rev. 85: 719.

2. LEIGHTON, ROBERT B., CARL D. ANDERSON AND AARON J. SERIFF. 1949. The energy spectrum of the decay particles and the mass and spin of the mesotron. Phys. Rev. 75: 1432-1437.