of external cathode counters during his visit to India. It is a pleasure to record our thanks to Professor R. C. Majumdar for his kind interest in the work. One of us (G.S.B.) is indebted to the AEC for the research fellowship granted to him.

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A Narrow Angle Pair of Particles Produced in Hydrogen*

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A COUNTER-controlled cloud chamber[1] has been used to study penetrating showers and other energetic events produced by cosmic-ray particles in various materials, including liquid hydrogen, at sea level. The dewar containing the hydrogen was cylindrical, with an inside diameter of 15.2 cm and an inside height of 100 cm. The evaporation rate was such that the column of hydrogen was over 3 g/cm^2 (43 cm) for about 25 hours after a filling.

Figure 1 is a drawing of an unusual event which occurred in the liquid hydrogen. Tracks A and B trace to a point in the hydrogen $21^{+4.5}_{-3.0}$ cm above the visible part of the chamber. The stereoscopic pictures of this event were analyzed by reprojecting in the original cameras and by graphical means, using a low power microscope on the negatives. Both methods agreed within the limits of experimental precision.

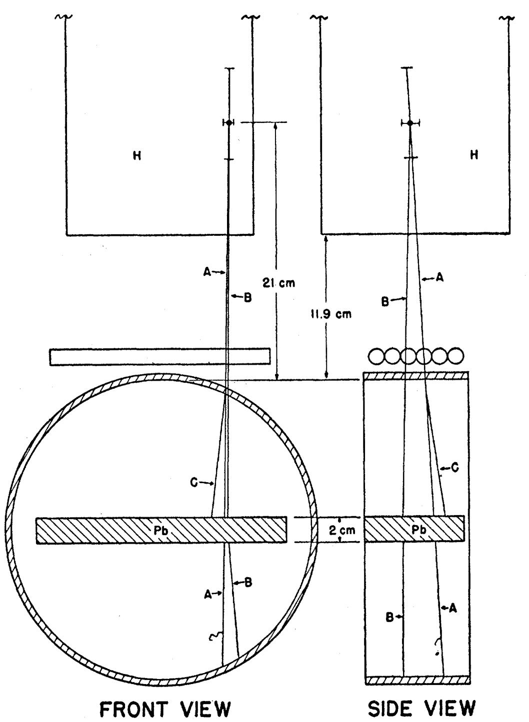

FIG. 1. Schematic drawing of a cloud-chamber event described in the text. The inner walls of the hydrogen dewar, the upper tray of counters, and the chamber are indicated. The rest of the counter control is omitted. The estimated accuracy in the location of the point of origin of the event is shown. An energetic δ-ray is visible along the track A in the lower part of the cloud chamber.

All three tracks, A, B, and C, of Fig. 1 are at minimum ionization. Measurements on track A indicate very little scattering in the 2-cm Pb plate (about 0.3°). According to the theory of multiple scattering, this corresponds to a momentum of 6×10^9 ev/c. Track C meets A at a point in the glass of the chamber and it can be interpreted as a knock-on electron stopping in the lead plate. If A is a π- or μ-meson or a proton, a knock-on electron ejected at an angle of 10°, which is the angle between C and A, should have an energy of approximately 10^7 ev. It would then be expected to stop in the lead plate.

The angle between tracks A and B is $4.3°\pm0.8°$. B is scattered in the lead plate through a projected angle of $5.4°\pm0.2°$. If this deviation should be due to small angle scattering in the 2 cm lead plate, it would indicate that B must carry a momentum of the order of 3×10^8 ev/c, if it is a π- or μ-meson. A proton whose momentum was low enough to correspond to this angle of multiple scattering would be well above minimum ionization. If the deviation should represent nuclear scattering, however, track B could correspond to a proton of energy greater than 10^9 ev. The probability that a proton will make a nuclear collision in 2 cm of lead is about 1 in 8.

A and B cannot be an electron pair because of the high energy of A which is inconsistent with an angle of only 4.3° between the two tracks. This is confirmed by the fact that no secondaries are formed in the lead.

The authors have found similar events at sea level under carbon and lead. In cloud-chamber pictures taken underground George[2] and Braddick *et al.*[3] found a number of pairs of penetrating particles very similar in nature to the pair described here. They report a cross section of 5×10^{-29} cm^2/nucleon if the initiating particle is a μ-meson, a value quite consistent with the observation of such an event in hydrogen during the operating time of this experiment.

It is possible that some of the narrow pairs of penetrating particles produced in beryllium observed by Chang *et al.*[4] are of a similar nature.

It is highly improbable that the event in hydrogen represents the single production of a ζ_0-meson,[5] since the quoted Q-values would not agree with the observed angles and momenta. It is also improbable that the single production of a meson in a high energy nucleon-proton collision is responsible for the observed pair, A, B, because of the small angle between the two tracks. If the above described event in hydrogen is the same as that observed by George and by Braddick and collaborators underground, it is possible that this event is due to a nuclear interaction of a very high energy μ-meson in which the μ-meson produces other penetrating particles.

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1 The chamber was actually located in a magnetic field of 9000 gauss; however, due to unfortunate circumstances in the room the magnetic field could only be used for a fraction of the total running time.

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Interaction of Pions Originating in Penetrating Showers*

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THE total interaction cross sections[1] of high energy pions with carbon, paraffin, and lead have been obtained in a study of the secondary particles emitted in the penetrating showers of cosmic radiation at 11,000 feet. The hodoscope of 196 GM counters in Fig. 1 recorded the trajectories of the secondary particles generated in the penetrating showers in the C and Pb above the tray A. Coincidences ($AA'CDE$) selected the penetrat-