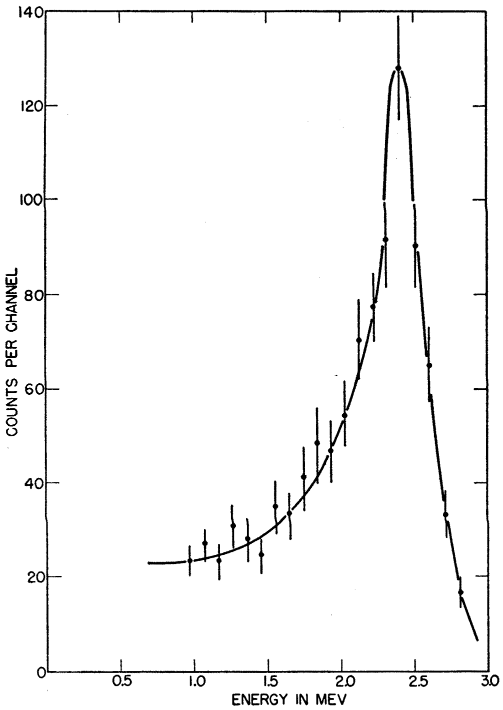

FIG. 2. Neutron peak.

The first measurements have been made with D-D neutrons of energy 2.8 Mev. Figure 2 shows the corresponding peak registered on the kicksorter.

The sensitivity of the instrument to gamma-radiation is very much lower than to neutrons: because of the delay introduced into the coincidence circuit, only fortuitous coincidences can be produced by γ-rays.

We wish to thank the Paul Foundation of the Royal Society for a grant which made this work possible and Lord Cherwell for his interest and encouragement.

Collision of Heavy Primary Cosmic-Ray Nucleus

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IN an investigation of the types of disintegrations caused by heavy primary nuclei in collisions with nuclei in emulsions, an unusually interesting example has been found in a 600-micron Ilford G5 emulsion exposed at about 85,000 feet.[1] The incoming nucleus with $Z=17\pm3$, as estimated by delta-ray counting, makes a collision in which 45 singly charged particles with minimum or near minimum ionization are produced with half-angle $\theta_{\frac{1}{2}}\simeq 12.5°$. There is also a relativistic α-particle at about 3.5° to the forward direction. A microprojection tracing of the event is shown in Fig. 1, and the angular distribution in Fig. 2. Some particles were identified (see the following note), including 5 pions, one proton and a possible kappa-meson, with energies ($p\beta$) approximately 170, 300, 390, 570, 740, 770, and 710 Mev at angles about 36, 35, 11, 6, 10, 15, and 22 degrees relative to the incident direction respectively. An associated electron pair, C, starting about 80 microns from the star center also indicates that neutral pions were emitted.

Conservation of charge before and after the collision rules out silver as target nucleus, and also bromine since we know that there are pions created. There is no detectable heavy recoil. A collision with hydrogen also appears unlikely since the meson multiplicity would be too high for a shower of half-width 12.5°, unless we assume many secondary interactions. Thus it seems probable that the target nucleus was carbon, nitrogen, or oxygen,[2] with a central collision involving fairly complete break-up of the incoming and target nuclei. With oxygen as target, about 22 charged particles must have been created and the identifications made indicate that these were mostly pions. Allowing for 50 percent neutral pions gives about 33 pions created or a multiplicity of two per target nucleon. Consideration of all the nucleons and mesons emitted requires a minimum primary energy of about 2 Bev per nucleon. Even assuming that most of the forward particles are nucleons the width of the shower cone indicates that the primary energy is not much in excess of this limit. It would seem that there were many individual collisions (possibly some secondary) each giving a low pion multiplicity on the average.

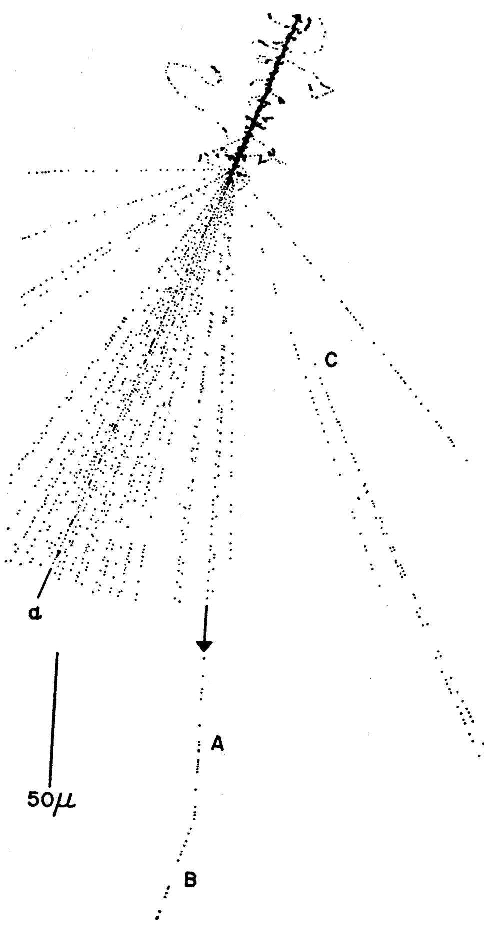

FIG. 1. Collision of heavy primary nucleus, $Z=17\pm3$, in G5 emulsion with almost complete break-up of incident and target nuclei.

In the shower there were two close pairs of tracks[3] and a triple (marked D, E, F in Fig. 2) appreciably off the forward direction, and the statistical chance for each such grouping, based on the average angular distribution for this event, is about 5×10^{-3}. The pair D comprised two of the identified pions, and the energies and angular separation would give a Q value 6 ± 4 Mev if we assume them to result from the decay of a very short-lived neutral meson.[4]

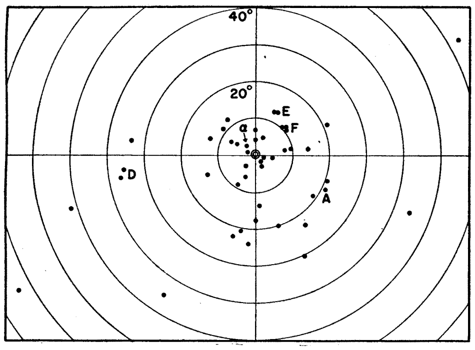

FIG. 2. Projection showing angular distribution of tracks in Fig. 1 relative to direction of the primary, which is perpendicular to the plane of the paper at the origin.

Further measurements will be made for a more detailed analysis of this event. We wish to thank Miss E. Motard for scanning, Mr. H. A. MacDonald for assistance in processing, and Mr. D. W. Rushton for preparing the drawings.

* National Research Council of Canada Fellows.

[1] The emulsions were exposed through a collaborative program of cosmic-ray investigations by the Bartol Research Foundation and the National Research Council of Canada with the cooperation of the ONR project, "Skyhook."

[2] The possibility of sulfur as target nucleus cannot be completely ruled out since it is present in emulsions in the ratio ~1/130 compared with carbon, nitrogen, and oxygen.

[3] J. Y. Mei and E. Pickup, Phys. Rev. **86**, 796 (1952).

[4] Danysz, Lock, and Yekutieli, Nature **169**, 364 (1952); see also reference 3 for the meaning of this result.

A Possible Charged *V*-Particle or Kappa-Meson Event Observed in a Photographic Emulsion

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ONE of the shower particles in the cosmic-ray disintegration described in the preceding note shows a sudden change in direction through 20°, with no sign of a visible recoil. This resembles the charged *V*-particle tracks observed in cloud-chamber investigations,[1] but which have not been reported so far in emulsion experiments. The shower particle, track *A*, is 11,000 microns long and presents a favorable case for mass determination. The secondary track, *B*, is steep and only 700 microns long before leaving the emulsion.

Figure 1 shows the results of grain density and multiple scattering measurements for particle *A*, for six other long shower particles in the same disintegration, and also for five very long neighboring electron tracks (not associated with this event). The grain density shown for each shower particle is the mean value using two counting conventions, expressed relative to the corresponding mean value for electron tracks over the same region of emulsion depth. Values for $p\beta$ were derived from measured chord-angle mean deflections and the Williams-Molière scattering theory. Similar procedures for fast particle identification were used in a recent series of experiments at Bristol.[2-4] The theoretical ionization loss curves were calculated for silver bromide, the polarization plateau in the extreme relativistic region being normalized to the measured plateau for electrons. These curves were recently shown[2] to be in close agreement with experiment, although the treatment of ionization theory with polarization and Čerenkov radiation effects presents serious difficulties.[5]

It is seen from Fig. 1 that five of the other shower particles may be identified as pi-mesons and one as a proton. For track *A*, the combined grain density and scattering results yield a mass of $1210\pm180m_e$. Track *B* shows a grain density 1.14 ± 0.07 times "plateau," and an observed mean scattering deflection $\bar{D}(90\mu)=0.10$ microns. These combined measurements indicate a mass $>600m_e$.

The above results are consistent with either decay in flight or large angle scattering for shower particle *A*. Kappa-mesons[6] decaying at rest in emulsions have a mass $\sim1200m_e$, but appear to decay to mu-mesons and two neutral particles. A recent analysis[7] has shown that most of the available data on charged *V*-particles can also be similarly explained, although a pi-meson secondary is indicated in some cases.[8] The shower particles with masses $\sim1200m_e$ recently observed at Bristol[3] were also tentatively identified as being the same as kappa-mesons. For the present event a kappa-mu decay appears to be ruled out. A possible interpretation here is that of charged *V*-particle decay into a tau-meson and one or more neutral particles. An alternative interpretation is that of scattering of a kappa-meson, presumably nuclear scattering because of the large angle (20°) and short deBroglie wavelength ($\sim2\times10^{-14}$ cm).

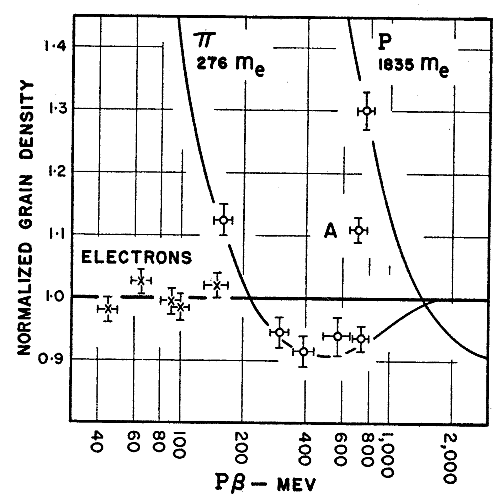

FIG. 1. Grain density, relative to the plateau for high energy electrons, plotted *versus* $p\beta$, the product of momentum and particle velocity. The indicated uncertainties are those derived solely from estimated statistical probable errors in grain counting and multiple scattering measurements. Approximate theoretical ionization loss curves are also shown for pi-mesons and protons.

Further work is in progress for this event, including refinements of measuring techniques, tracing the secondary track *B* into the facing plate, and calibration of mass resolution. One of the particles analyzed for calibration also appears to have a mass of $1330\pm200m_e$.

The author wishes to thank Dr. E. Pickup for discussions on this investigation.

[1] G. D. Rochester and C. C. Butler, Nature **160**, 855 (1947).

[2] L. Voyvodic, Bristol Conference Report (Dec. 1951).

[3] Daniel, Davies, Mulvey, and Perkins, Bristol Conference Report (Dec. 1951).

[4] Danysz, Lock, and Yekutieli, Bristol Conference Report (Dec. 1951).

[5] See M. Schonberg, Nuovo cimento **9**, 210 (1952).

[6] C. O'Ceallaigh, Phil. Mag. **42**, 1032 (1951).

[7] Armenteros, Barker, Butler, Cachon, and York (to be published).

[8] See H. S. Bridge and M. Annis, Phys. Rev. **82**, 445 (1951).

A Magnetic Effect in Magnesium Titanate*

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INCREASING attention is being given to the study of the magnetic properties of chemical compounds as a source of knowledge about the relation between electrical conductivity and the structure of some selected semiconductors. The high sensi-