NOTES FROM THE BARTOL RESEARCH FOUNDATION.

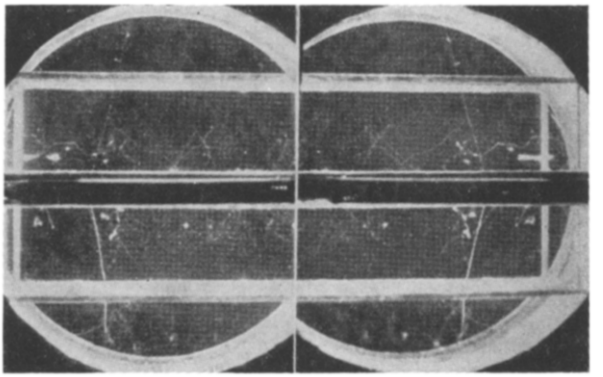
DIRECT EVIDENCE OF A PROTON COMPONENT OF THE COSMIC RADIATION.*

BY

T. H. JOHNSON, J. G. BARRY AND R. P. SHUTT.

A number of investigations [1] have resulted in more or less indirect evidence that a part of the cosmic radiation consists of protons. In a series of photographs in a large Wilson cloud chamber containing three lead plates we have obtained a few tracks which seem to be those of protons near the end of their range. The track most definitely that of a proton is shown in Fig. 1. This ray had come into the chamber from the top after having passed through fifteen centimeters of lead

FIG. 1.



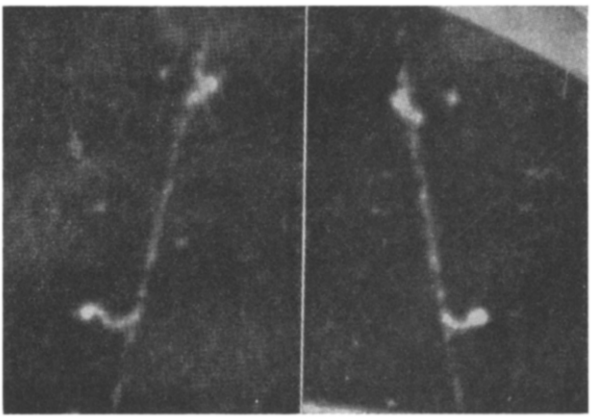
This may be viewed stereoscopically by placing a mirror before the right eye at an angle such that the image of the right projection is superposed upon the left projection when viewed directly with the left eye.

* Reprinted from *The Physical Review*, **57**, 1047 (1940).

[1] T. H. Johnson, Rev. Mod. Phys. **11**, 208 (1939); T. H. Johnson and J. G. Barry, Phys. Rev., **56** 219 (1939); D. Hughes, Phys. Rev. **57**, 592 (1940); J. G. Wilson, Proc. Roy. Soc. **172**, 517 (1939).

placed between two coincidence counters used for triggering the expansion of the chamber. In the chamber the ray has passed through three lead plates 1 cm., 5 cm., and 1 cm. thick, respectively, and it has passed out through the bottom of the chamber after having veered slightly into the shadow in the lower compartment. In the 5-cm. lead block the ray was deflected about 25° and it was slowed down so that its track in the third compartment is noticeably heavier than previously. It is significant that although its density in the third compartment seems to be about four times greater than that of a fast particle, the ray still had sufficient energy to pass through the lower plate, 1 cm. thick, and upon emerging to produce the smooth, heavy, straight track characteristic of a slow proton. In the first compartment shown enlarged in Fig. 2 the ray produced two delta-rays, or slow electrons,

FIG. 2.



Enlargement of the track in the first compartment.

the second of which produced a track about 17 mm. long in 1.3 atmospheres of argon. From its range we estimate that this ray had an initial energy of about 55,000 volts. A ray of this energy would be emitted by a particle of infinite momentum at 77.5°. Our best estimates of its initial direction as determined from a graphical analysis of the two stereoscopic photographs lie somewhat below this angle in the range 65° to 75°.

We may consider four possibilities as to the nature of this ray. (1) The entering ray is a meson which loses energy by ionization as described by the Bethe-Heitler formula [2] and is brought nearly to rest in the lower compartment. (2) The entering ray is a proton which also loses energy by normal ionization and is brought nearly to rest in the lower compartment. (3) The entering ray is a meson which knocks a proton from a lead nucleus at an angle of 25° by an elastic collision. The subsequent path of the meson would then lie within the lead plate and the proton is that which appears in the lower compartments. (4) The entering ray is a proton with high energy (ionization less than 1.2 that of a "fast" particle) and more energy is lost in the 5-cm. lead plate than can be accounted for by ionization. For each of these assumptions the lower limit of the energy in each compartment and the corresponding upper limits of the ionization have been computed, and are given in Table I. The table also contains the angle

TABLE I.

Lower Limit of the Energy in Each Compartment and Upper Limits of the Ionization Computed Upon Various Hypotheses.

Hypothesis.	Energy of the Ray (Mev.) in Compartment.			Ionization Compared to that of a Fast Particle in Compartment.			Angle of Delta-Ray of 55,000 Volts.
	1	2	3	1	2	3	
(1) Meson	120	106	33	1.0	1.1	1.66	75.8°
(2) Proton	280	256	87	1.7	2.0	4.0	69.5°
(3) Meson-proton	480	465	87	1.0	1.0	4.0	77.3°
(4) Proton-abnormal energy loss	666	653	87	1.2	1.3	4.0	74.2°

of the delta-ray in the first compartment computed from each assumption.

From the density of the track in the third compartment it seems certain that the ray appearing in the lower half of the chamber must be a proton. The ionization in the upper half is not as heavy as would have been expected on assumption (2) and although the measured angle of the delta-ray favors

[2] S. H. Neddermeyer and C. D. Anderson, Rev. Mod. Phys. **11**, 191 (1939).

assumption (4) the accuracy of the measurement is hardly sufficient to distinguish against assumption (3).

Out of 4,000 photographs we have obtained three tracks of slow protons identified by an abnormally dense ionization while the ray had still sufficient energy to penetrate 1 cm. of lead. Nineteen tracks have been found of particles either stopped or appreciably slowed down by the lead in the chamber, and in each of these photographs the observed ray had passed through the 15 cm. of lead above the chamber. It therefore appears that some fifteen per cent. of the penetrating rays reaching the "slow" state are protons. Since the range of a proton is ten times that of a meson of the same velocity about 1.5 per cent. of the fast cosmic rays can be protons.

Acknowledgment is made of the support given these studies by the Carnegie Institution of Washington.

FURTHER EVIDENCE FOR THE EXISTENCE OF MESOTRON SHOWERS.*

BY

W. F. G. SWANN and W. E. RAMSEY.

The data here recorded were obtained by an apparatus [1] which we have devised for cosmic-ray shower measurements, and which comprises several Geiger counter areas, each 20 cm. in side, arranged as a coincidence set as regards the individual areas, and designed so that each individual counter which becomes excited within 10^{-4} sec. of an event, records separately, the event being the passage through the apparatus of a ray which penetrates more than 18 cm. of lead. One tray was above the 18-cm. block, and the others were distributed at different distances below.

With the foregoing apparatus the theory of knock-on electron showers has been investigated experimentally.[1] Certain of the shower rays, a very small number, in fact, are

* Reprinted from *The Physical Review*, **57**, 1051 (1940).

[1] W. F. G. Swann, Rev. Mod. Phys. **11**, 242 (1939).