as 10^{18} ev, and that the primary spectrum remains for these energies of the form (1). We only wish to call attention to the fact that up to now all measurements on the extensive cosmic-ray air showers fit this hypothesis satisfactorily.

[1] D. V. Skobeltzyn, G. T. Zatsepin and V. V. Miller, Phys. Rev. **71**, 315 (1947).
[2] B. Rossi and K. Greisen, Rev. Mod. Phys. **13**, 240 (1941).
[3] G. Moliére, *Vorträge über Kosmische Strahlung* (Berlin, 1943), p. 24.
[4] W. Heisenberg, *Vorträge über Kosmische Strahlung* (Berlin, 1943), p. 10.

Altitude Dependence of High Energy Atmospheric Showers

HENRY L. KRAYBILL, *The University of Chicago, Chicago, Illinois*
AND
PAUL J. OVREBO, *Aircraft Radiation Laboratory, Dayton, Ohio*
June 28, 1947

MEASUREMENTS of the frequency of high energy atmospheric showers above 15,000 feet have been obtained on a B-29 plane flown by the U. S. Army Air Forces. The altitude dependence of the showers was indicated by the counting rate of a simple arrangement of counters in threefold coincidence, separated by a horizontal distance of eleven feet. The counter geometry is shown in Fig. 1.

Each counter had a sensitive area of 1 inch by 13.5 inches and was mounted just below the roof of the pressurized cabin of the airplane. An estimated 1.3 g/cm^2 of material consisting of aluminum and wood were above the counters. A shielded low capacity cable led from the counters to the coincidence circuit, which had a resolving time of 3 microseconds. The circuits, counters, and all batteries supplying power for the vacuum tube circuits were electrostatically shielded. The coincidences were registered by a mechanical impulse counter, which was read periodically during flight.

The variation of counting rate with altitude was determined in the vicinity of Wright Field, Dayton, Ohio, between 48° N and 51° N geomagnetic latitude. Measurements were made at five separate elevations between 15,000 feet and 33,000 feet. The results are shown in Table I.

In addition to the flights near Wright Field, data were also collected at 33,000 feet between 0° and 25° geomagnetic latitude during a flight between Wright Field and Lima, Peru. The average counting rate between 0° and 25° was 32.1±1.0 counts per hour. The good agreement of this value with the counting rate at the same altitude between 48° N and 51° N strongly indicates that the observed showers do not show a latitude effect and hence must originate from high energy particles which do not carry an extremely high charge.[1]

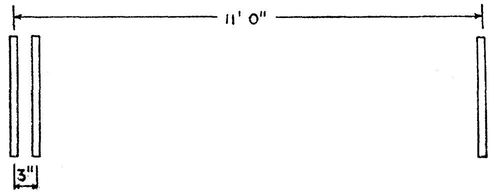

FIG. 1. Arrangement of the counters.

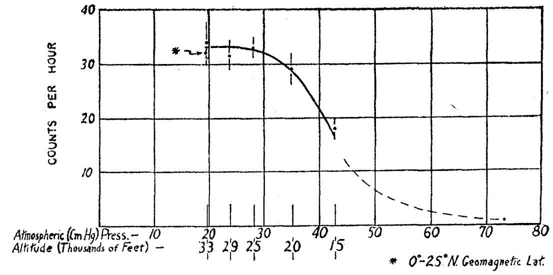

FIG. 2. Variation of the triple coincidence counting rate with the atmospheric pressure (altitude).

TABLE I. Counting rate *versus* altitude of extensive atmospheric showers.

Altitude	Pressure	Time	Total counts	Counting rate
1000 ft	73.4 cm	1368 hrs.	1001	0.73±0.3/hr.
15,000	43.0	4.5	80	18±2
20,000	35.0	3.0	86	29±3
25,000	28.0	6.0	197	33±2
29,000	23.6	3.8	118	31±3
33,000	19.7	2.2	74	34±4

Figure 2 shows the threefold counting rate plotted against atmospheric pressure. The dashed curve represents data published by Hilberry[2] between sea level and 14,300 feet. For comparison, his results have been multiplied by a constant factor in order to make his counting rate equal to our counting rate at sea level.

The solid curve shows that the counting rate first increases rapidly up to an altitude of 25,000 feet and is then constant within experimental error between 25,000 and 33,000 feet.

If one assumes that the observed showers originate from electrons near the top of the atmosphere with an integral energy spectrum of the form $E^{-1.8}$, it can be shown that showers from electrons of 10^{12} ev energy have insufficient particle density to contribute to the observed counting rate above 15,000 feet. Therefore, the observed showers are believed to arise predominantly from particles of energy definitely higher than 10^{12} ev. However, showers produced by vertically incident electrons of such high energies would reach their greatest number of electrons in regions below 33,000 feet, and would consequently produce a definite peak in the curve of counting rate *vs.* altitude at an elevation below 33,000 feet. On the other hand, particles incident from varying zenith angles will cause the region of maximum counting rate to be higher in the atmosphere and less sharply defined than for showers from vertically incident particles alone. The fact that the observed counting rate curve shows a broad plateau instead of a definite peak thus indicates that many of the observed showers arise from particles incident at large zenith angles.

We wish to thank Professor M. Schein for many helpful suggestions. Gerhard C. Willecke, Elmer Winterland, and Lt. S. H. Seeleman of Wright Field assisted in carrying out the experiments.

[1] O. Klein, Arkiv. f. mat. astr. och fysik **31A** [14] (1944–45).
[2] N. Hilberry, Phys. Rev. **60**, 1 (1941).