Directional Properties of an Extensive Air Shower Array*

C. B. A. McCusker, D. E. Page, and R. J. Reid
Dublin Institute for Advanced Studies, Dublin, Ireland

(Received March 24, 1958)

The directional properties of an extensive air shower array consisting of three Geiger-Müller counter telescopes have been examined. It is shown that the directional properties of this array show no great improvement over more conventional arrangements. Possible ways of improving the performance of the device are suggested.

I. INTRODUCTION

The origin of the high-energy cosmic radiation which produces extensive air showers is not yet known. One possible method of gaining information about this origin is to study the variations in the rates of extensive air showers with sidereal time. A normal Geiger counter array, however, has a very poor angular resolution. Recently[1] an array has been described which is easy to build and for which the authors claim a much improved angular resolution. The present paper describes a test of this array and some suggestions for possible improvements.

II. EXPERIMENTAL APPARATUS

The apparatus consisted of a sixfold Geiger counter set similar to that described by Shen and Singer. The six counters (each 45 cm×3.3 cm) were arranged in 3 pairs. Each pair of counters could be separated vertically by from 15 cm to 68 cm; or the telescopes could be turned so that all the counters were in the one horizontal plane. The three telescopes were placed at the apices of a triangle of sides 4.0, 3.3, and 2.2 m. Normally a sixfold coincidence of the six counters produced a master pulse and the event was recorded.

For part of the experiment it was arranged that the master pulse from this set should be fed into a large extensive air shower array that has been running for some time. This enabled the electron and the penetrating particle densities of the showers to be measured at a number of points. It also caused cloud chamber photographs to be taken of the shower by two cloud chambers whose axes were at right angles. The axis of one of these chambers was parallel to the axes of all six Geiger counters in the telescopes.

The apparatus was housed in a thin-roofed hut whose temperature was thermostatically controlled. All voltages, including the heater voltages for the tubes, were stabilized. A Servomex AC7 voltage stabilizer was used for this purpose. This stabilizer incorporates a servo operated variable transformer controlled by an ac bridge. The output wave form is undistorted; the output voltage is 220±0.5 volts; the maximum correction rate is 12 volts per second. In addition to this, high voltage for the valve circuits and extra-high voltage for the Geiger counters was obtained from stabilized power packs taking their input from the Servomex stabilizer.

The twofold rate through each telescope was tested twice each week and pulses through the circuit inspected from time to time. Barometric pressure was continuously recorded.

III. RESULTS

When the telescopes are vertical, an apparatus of this type can be set off by three particles which traverse the telescopes in a direction whose projection is close to the vertical in one plane. This is the feature of the apparatus which makes it attractive in the study of air shower directions. For if the axes of the counters point north and south, showers of this type which discharge the apparatus must originate in a rather narrow band of sky about the meridian. The width of the band will depend on the width of the counters and their separation.

However, it is also possible that the counters may be discharged by six independent particles coming from any direction. The purpose of this experiment was to determine the proportions of events of these two different types. Accordingly the rates of showers with four different arrangements of the counters were obtained. These arrangements were (a) telescopes vertical, 15 cm separation; (b) telescopes vertical, 67 cm separation; (c) telescopes horizontal, 15 cm separation; and (d) threefold coincidences between the top three counters in each telescope. These rates, corrected to 1010 millibars pressure, are shown in Table I.

It will be seen that the decrease in rate observed by Shen and Singer when the counter separation in the vertical telescopes was increased was also found in this experiment. However, when all six counters were

Table I. The rates corrected to a pressure of 1010 millibars for four different arrangements.

Description of apparatus	Rate corrected to 1010 millibars	Average barometric pressure of the run (millibars)
Vertical: 15 cm	0.692±0.029 per hr	1004.2
Vertical: 67 cm	0.605±0.039 per hr	1011.4
Horizontal: 15 cm	0.644±0.035 per hr	1011.8
Threefold	1.62 ±0.08 per hr	1004.5

* This work was sponsored by the Office of Scientific Research of the Air Research Development Command, U. S. Air Force through their European Office.

[1] K. Y. Shen and S. F. Singer, Phys. Rev. **106**, 555 (1957).

TABLE II. The numbers of events having directions at various angles to the vertical as measured by the cloud chambers.

0°–5°	5°–10°	10°–15°	15°–20°	20°–25°	25°–30°	>30°
22	17	13	14	8	5	4

arranged horizontally no further decrease in rate was observed. Thus only a very small proportion of the events observed with the counters separated by 67 cm vertically can be due to the three telescopes each being set off by one particle whose direction is near vertical in the appropriate plane. It follows that with the smaller separation about 86% of the events are due to showers which send six independent particles through the six counters and which have the normal dependence of intensity upon zenith angle and that 14% are due to showers of lower electron density whose directions are, in fact, close to the vertical in the appropriate plane.

This conclusion was checked by two further experiments. 146 showers triggering the array with the telescopes vertical and separated by 15 cm were photographed using the two cloud chambers. In 83 cases it was possible to obtain the direction of the shower through the hut with an accuracy of $\pm 4°$ (standard deviation). Table II gives the distribution of the projected angles to the vertical in the plane of the cloud chamber whose axis was parallel to that of the counters. This distribution is not noticeably an improvement upon that obtained with a normal unshielded array. 45% of the showers were at angles to the vertical greater than 12° which is the maximum allowed if the pairs of counters are triggered by only one particle each.

The second experiment checked the electron density of the showers triggering this arrangement. A tray of 12 counters each of the same size as those used in the telescopes was placed with its center 6.5 meters from the center of the array. Each counter was connected to a small neon lamp via a hodoscope circuit and thus it was possible to determine how many of these counters were hit whenever the telescope array was discharged. The results of this experiment are shown in Table III. It will be seen that the most common type of event is that in which all 12 counters of this tray are discharged corresponding to a shower of high electron density.

Finally the absolute rate of the horizontal array was checked by measuring the rate of a similar array but with only 3 counters in coincidence. The ratio of these two rates can be calculated easily using the well-known integrals.[2] The calculated ratio was 2.44:1, in good agreement with the experimentally observed value of $2.51 \pm 0.14:1$.

IV. DISCUSSION

It will be seen that there is no serious disagreement between the experimental results reported above and those of Shen and Singer. However, the rate observed with the horizontal array, the angular distribution of the events seen in the cloud chamber, and the high average electron density of the showers require us to place quite a different interpretation upon these results. The great majority of the showers observed (86%) with the vertical array are just those that are observed with a similar array placed with all counters in one horizontal plane. Thus there is no great improvement in the angular resolution of the apparatus; the vertical arrangement leading at the best to a 14% "enrichment" of showers coming from the near vertical direction.

TABLE III. The number of events discharging from 0 to 12 counters in an unshielded tray of 12 counters placed 6.5 meters from the center of the main array.

No. of counters discharged	0	1	2	3	4	5	6	7	8	9	10	11	12
No. of events	3	6	6	7	13	10	6	15	10	21	19	25	47

It seems possible that the angular resolution might be improved in either of two ways. The first method would be to use a tray of counters in anticoincidence with the telescopes in order to reject the high density showers coming from all directions. This would considerably reduce the counting rate but, if the size of the anticoincidence tray was suitably chosen, might lead to a set detecting rather low density showers coming from near the vertical.

The second method would be to encase the telescopes at both sides and ends in lead. If the walls were made thicker than 20 cm it is possible that side showers might be rejected. This second method has the advantage that high-density showers arriving from near the vertical would not be rejected. Experiments along these lines are in progress.

ACKNOWLEDGMENTS

We are greatly indebted to the Air Research and Development Command of the U. S. Air Force for their support for this work.

[2] D. Broadbent and L. Janossy, Proc. Roy. Soc. (London) **A192**, 364 (1948).