Secondary Particles from the Penetrating Component of the Cosmic Radiation

WILLIAM H. PICKERING
Norman Bridge Laboratory of Physics, California Institute of Technology, Pasadena, California

(Received February 24, 1937)

Experiments are described that show that some of the coincidences between three Geiger counters in a vertical line separated by a considerable thickness of lead are not due to the passage of a single ionizing particle through the three counters but rather to secondary particles released in the lead near the counters. The experiments enable an estimate of the magnitude of this effect to be made.

EXPERIMENTS with coincidences between Geiger counters separated by considerable thicknesses of lead have shown the presence of a very penetrating component of the cosmic radiation that can apparently traverse as much as a meter of lead without suffering appreciable deviation from its straight path. The original experiments of Rossi[1] show that such an undeflected radiation is responsible for most of the coincidences, but new experiments that he reported at the London Conference in 1934[2] demonstrate that not all the coincidences are of this type. This paper is concerned with further experiments dealing with coincidences resulting from secondary particles.

The counters used in this work were of the usual copper-sealed-in-glass type, and were filled to a pressure of about 5 cm of mercury with a mixture of 80 percent argon and 20 percent air. Coincidences were selected by a circuit similar to those of Johnson and Rossi.

Three counters were first arranged as shown in Fig. 1. The lead between the counters totalled 15 cm and above the top counter was a lead plate 2.5 cm thick. The number of coincidences per hour was obtained with the lead blocks $a-a'$ in the position shown, and then with these blocks removed. It was found that removing the blocks decreased the counting rate about 7 percent. Obviously the extra coincidences caused by the blocks $a-a'$ must arise either from a bending of the path of the primary ionizing particle, or from a secondary particle generated in the extra lead. From the geometry of the arrangement it is clear that a deflection of a primary particle that had passed through the two top counters would have to be through a large angle and hence this possibility can be excluded as too rare to be significant. This means that the 7 percent more coincidences must be due to secondaries or showers produced in the extra lead beside the bottom counter.

The next experiment is a verification of the fact that secondaries may be formed at intervals along the path of the primary and not just near the end of its range. The same arrangement as Fig. 1 was used but the lead blocks $a-a'$ were removed. The counting rate was then measured with and without the 2.5 cm lead plate above the top counter. It was found that the presence of this lead increased the counting rate about 5.5 percent. This increase can only be ascribed to secondaries produced in the topmost lead.

There are two possible mechanisms by which such secondaries released in the top lead plate could increase the counting rate. First, if the primary is an ionizing particle then secondaries released in this lead could operate the top counter while the primary itself did not pass through this

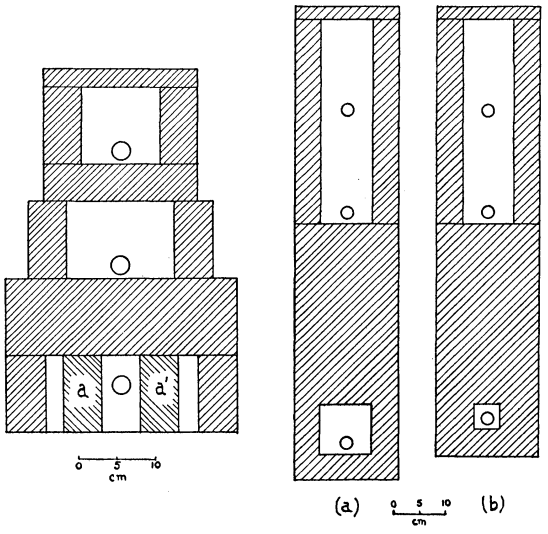

Fig. 1 (left) and Fig. 2 (right). Arrangements of lead about counters.

[1] Rossi, Zeits. f. Physik 82, 151 (1933).
[2] Rossi, Report at London Conference, 1934.

counter but did operate the other counters. Primaries that passed through the top counter would not be affected by the top lead plate except insofar as the slight additional thickness of lead would cause a slight decrease in the number that reached the bottom counter. Second, if the primary did not ionize then the presence of the lead above the top counter would increase the probability that the primary would be accompanied by an ionizing secondary when it passed through this counter. Hence in this case the lead would cause an increase in the counting rate even with primaries that passed through the top counter.

These two possibilities may be investigated by a simple experiment, namely that of placing a lead block just the size of the geometrical beam defined by the counters, above the top counter. If all the coincidences are due to ionizing primaries then this lead should cause no increase in the counting rate, but rather a slight decrease, provided that there is sufficient lead between the counters to prevent secondaries from reaching the bottom counter. On the other hand, if the coincidences are due to radiation which does not ionize then this lead should cause an appreciable increase in the counting rate, provided that the radiation is not already accompanied by secondaries produced in the air or the roof above the apparatus. This experiment was performed with three counters separated by a total thickness of 20 cm of lead. A lead bar 3.0 cm thick and having a cross section equal to that of the top counter could be placed immediately above this counter. It was found that the lead above the counter increased the counting rate from 30.1 to 30.9 counts per hour with a probable error in each case of about 0.44 count per hour. Thus the effect of the additional lead is small, but these data seem to indicate that there may be a slight increase with the lead above the counters.

A further experiment shows that the secondaries responsible for additional coincidences are not able to penetrate more than a centimeter or two of lead. For this the counters were arranged as shown in Fig. 2, with 36 cm of lead between them and a 2.5 cm lead plate above the top counter. It will be noted that the difference between the two parts of this experiment lies in the arrangement of the lead around the bottom counter. The following results were obtained. In part (a) the lead plate above the top counter increased the counting rate 9 percent with a probable error of about 2 percent. In part (b) no increase could be observed within the limits of error, about 5 percent. The interpretation of the difference between the two cases is as follows: In part (a) secondaries generated in the top plate operate the top two counters while the primary continues through, or more probably, near the bottom counter. Occasionally this primary generates a secondary in the lead a short distance above the bottom counter and the secondary operates this counter and registers a coincidence. In part (b) the only difference is that for secondaries to operate the bottom counter they must be formed in a more restricted area than in part (a), and hence the path of the primary to register a coincidence is restricted to a smaller solid angle and fewer coincidences are observed. It is to be expected that if the experiment had been more accurate a small increase would have been found with arrangement (b). If the range of the secondaries had been more than 5 cm of lead then secondaries formed in the lead near the bottom counter in case (b) would have been able to reach this counter as well in this case as in case (a), and hence there would have been no difference in the two experiments. Since there is a difference the experiment offers good evidence that only secondaries formed within a very few centimeters of the bottom counter are effective in scoring extra coincidences.

The results of these experiments may be summed up as follows: When three Geiger counters are placed in a vertical line with a considerable thickness of lead between them, not all the observed coincidences result from the passage of single ionizing particles through the three counters, but a number which varies with the arrangement of the lead outside the geometrical beam formed by the counters, and which may be as much as 10 percent of the total number of coincidences, result from secondary particles that operate one or more of the counters. The secondaries that are effective in registering coincidences are those that make a large angle with the path of the primary, and accordingly their range is only a centimeter or two of lead.

I wish to thank Dr. R. A. Millikan for many helpful suggestions and discussions during the course of this work.