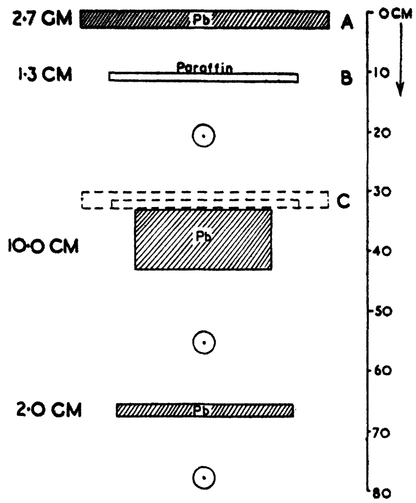

FIG. 1. Threefold coincidence set-up showing the arrangement of lead and paraffin absorbers. Drawn to scale.

increase in counting rate caused by shifting lead absorber relative to the coincidence set is not to any appreciable extent caused by the production of ionizing particles (penetrating or soft) by the non-ionizing component of cosmic radiation, but can be accounted for by spurious effects such as knock-on showers, scattering and side-showers. This holds for experiments made at low altitudes. The large increase found by Schein and Wilson at 25,000 feet seems to be real enough.

Froman and Stearns used paraffin in their experiments and found the very interesting result that paraffin, in relatively thin layers, caused a larger increase in counting rate when so shifted, than a layer of lead of approximately the same thickness.

In order to try to confirm this result a series of coincidence measurements were made in the Merensky Physics Institute at Stellenbosch, i.e., practically at sea level. The experimental set-up was as shown in Fig. 1, which has been drawn to scale. Threefold coincidences were recorded with (a) lead in position *A* and paraffin in *B* or *C* and (b) paraffin kept in position *B* and lead placed alternately in positions *A* and *C*. The results obtained are collected in Table I.

The Geiger-Müller counters used in this experiment were made according to a technique previously described,[8] and the set has now given eighteen months' continuous service without one becoming defective. The resolving time of the recording circuit was reduced to a minimum by using very small coupling condensers (50 micromicrofarads) between the tubes and their amplifiers, as well as relatively small leak resistors.

As Table I shows, shifting the lead scatterer from *A* to *C* makes very little difference to the threefold coincidence counting rate. The fact that the rates are equal must be regarded as accidental as can be seen from the probable mean error, but the results show that the effect, if any, is very small.

TABLE I. Threefold coincidence rate or various positions of lead and paraffin scatterers

Series	Lead position	Paraffin position	Counts	Time in hours	counts/hour
(a)1	*A*	*B*	25503	821.9	31.0±0.2
2	*A*	*C*	24773	821.2	30.2±0.2
(b)1	*A*	*B*	35701	1147.4	31.1±0.2
2	*C*	*B*	31103	999.4	31.1±0.2

Shifting the layer of paraffin scatterer however, causes a change in counting rate substantially greater than the probable mean error. If spurious effects were responsible for the change in counting rate between (a) 1 and (a) 2, it is to be expected that these same effects would also cause a change between (b) 1 and (b) 2, for one would expect lead to be a better scatterer and producer of knock-on showers than the far less dense paraffin. We therefore come to the same conclusion as that reached by Froman and Stearns, that the effect is real.

The fact that a light substance like paraffin is so effective in producing this effect gives ground for the hypothesis that the neutral component of cosmic radiation responsible for the phenomenon might be fast neutrons, and the penetrating secondaries might be mesotrons, or even protons. It may be remarked in this connection that Jánossy and Rochester[9] have already come to the conclusion that cosmic-ray neutrons might be responsible for an appreciable part of the penetrating showers observed at sea level. Anti-coincidence experiments are now under way at Potchefstroom to measure the penetrating power of the primary neutral radiation, and of the secondary ionizing particles.

One of us (S. J. du T.) wishes to express his sincere indebtedness to the Council of Industrial and Scientific Research of the Union of South Africa for a liberal grant.

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Successive Multiple Production of Penetrating Particles

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THE production of mesotrons by protons in successive nuclear collisions has been predicted by Hamilton, Heitler, and Peng[1] but Janossy subsequently showed[2] that one would expect a multiple process in the case of collision with a nucleus containing many protons and neutrons. Several observers[2,3] have reported some 90 penetrating particle showers in some of which mesotrons are identifiable. There has, however, been no previous direct observation of successive production centers for penetrating particles, with the possible exception of a photograph by Shutt,[3] in which heavily ionizing particles are ejected from a plate that was traversed by a penetrating particle shower.

Rochester[3] observed showers in which the penetrating particles came from different directions with no common intersection and concluded that a cascade process had probably occurred.

Evidence for the production of "mesotrons" in successive events has been obtained with a stereoscopic photograph in a counter-controlled cloud chamber. The chamber was 16 inches in diameter, nine inches deep, and contained eight ½-inch thick lead plates. The depth of the illuminated region was five inches. Slanted tracks were separated into positive and negative ion columns by a residual clearing field. The relative ages of the tracks could be accurately determined by the separation of the ion clusters in either the slanting or the vertical tracks.

Among 2100 photographs, 11 showed penetrating particle showers. All of the showers occurred among the latter two-thirds of the pictures when there was a 30-cm block of lead about 100 cm above the chamber. In each of six showers there was apparently a common origin in the lead block above the chamber; in the others, no common origin seemed possible but it should be kept in mind that the strong scattering observed for mesotrons might lead to confusion. In contrast with penetrating particle showers observed at 10,000- and 14,000-foot elevations, most of the present showers were associated with cascade radiation (electrons, etc.) to a greater or lesser extent. Two of the showers seemed to show additional production of heavily ionizing particles from new centers just as in the case of Shutt's observation.

One of the showers (Fig. 1) gives unmistakable evidence for three separate centers, which probably were in cascade, from each of which penetrating particles were emitted. Three particles from the first center (probably in the 30-cm block of lead) penetrated all eight lead plates and are similar to the "mesotron shower" particles that have often been observed. Additional nuclear collisions occurred in both the first and third lead plates. In the first plate, two heavily ionizing particles were produced that stop in the second plate. A particle that penetrated the second and third plates at an angle was also produced, as well as a particle that was projected downward through four or more plates. In the third plate, a third collision occurred with one particle ejected upward at an angle through one or more plates and two ejected downward through two or more plates and out of the illuminated region. Other diverging particles that stopped in the fourth plate were also produced. The tracks were clearly identified with a stereoscopic viewer by means of which relative depths could be observed.

The shower from the first lead plate might have been initiated by a particle that ionized strongly in the top compartment. This particle, however, was not in the same direction as the general trend of the showers and hence may have been a result rather than the cause of the shower from the top plate. Such a shower could have been produced by a neutron or ν-ray, the latter being unlikely since there was no evidence for other soft radiation in the vicinity. The shower from the third plate appears to have been initiated either by one of the penetrating particles produced in the first plate or by the same particle that produced the shower in the first plate.

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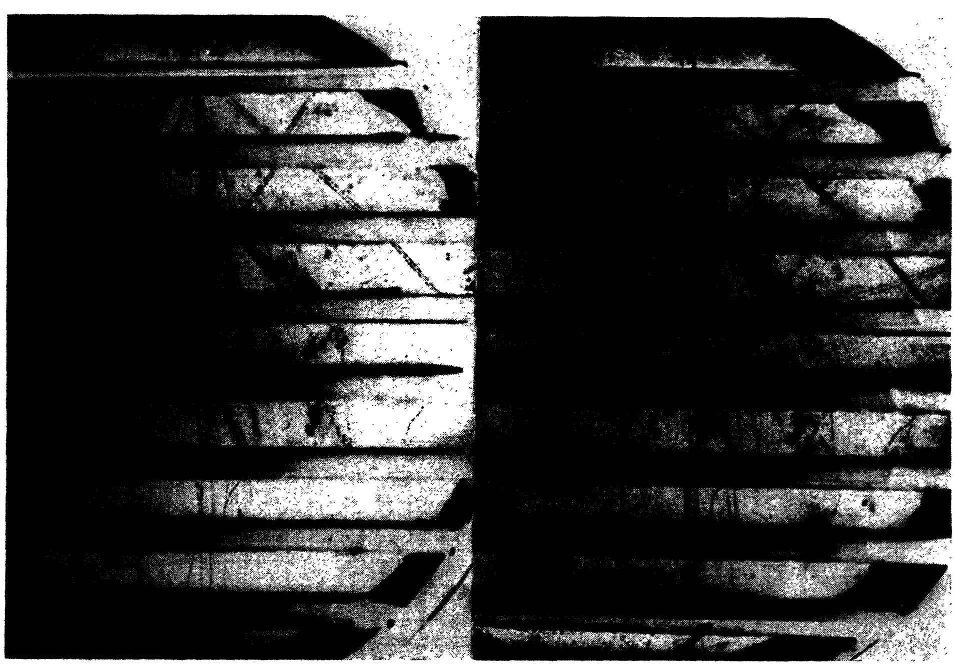
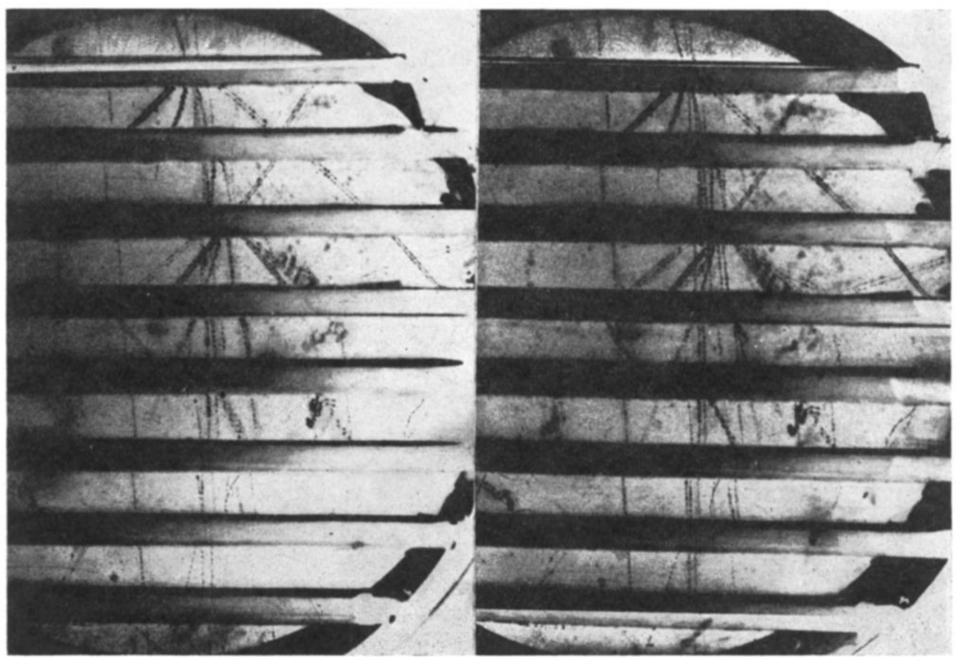


FIG. 1. Cloud-chamber photograph showing multiple production of penetrating particles in three separate successive events.



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