G-9 - PRODUCTION OF PENETRATING PARTICLES UNDERGROUND BY COSMIC RADIATION

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The photographic plate experiment of George and Evans on the production of nuclear desintigration by μ-mesons and by cloud chamber work of Braddick and co. on the production of one penetrating secondary by μ-mesons lead us to work under rock with a cloud chamber to investigate the penetrating showers underground.

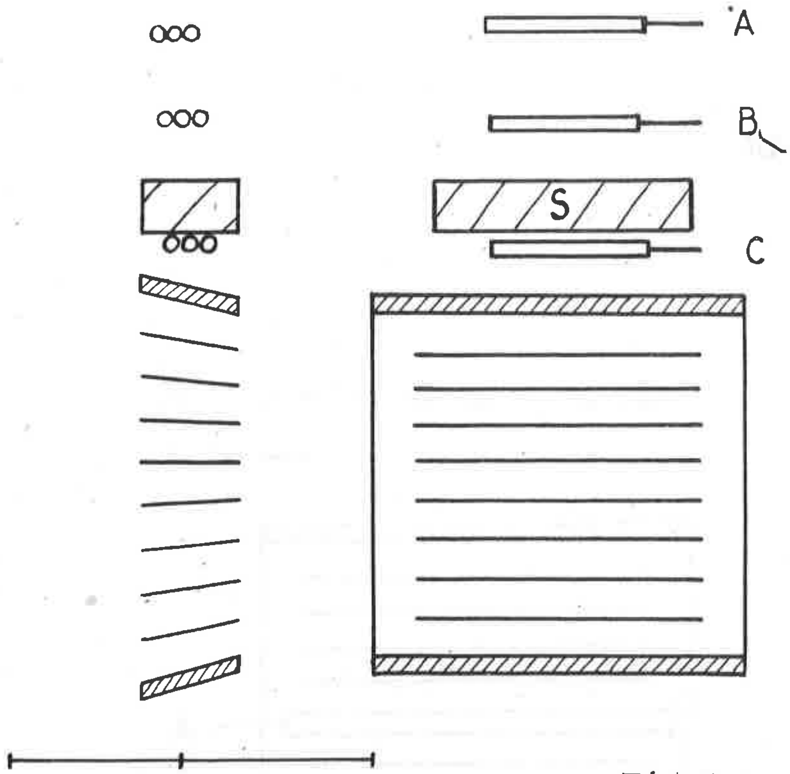

Fig. G-9, 1

Our research had two aims :

I°) To check the values of the cross-sections found by George and Braddick.
2°) To obtain some features of penetrating showers underground.

The cloud chamber was located inside a railway tunnel near Verbania, under about 55 m w.e. of granite (mean density about 2.6).

We have obtained a total of 5 000 pictures in 9 months of work, using two different experimental arrangements.

I° ARRANGEMENT (figure I). (G-9, I)

- Cloud chamber with 9 plates of lead each 1.6 cm thick.
- counter telescope above the chamber requiring a single ionising particle able to penetrate 8 cm lead.
- total number of pictures showing a single penetrating particle crossing the firsz 4 lead plates at least : 3,114.
- rate of these events : ∽ 10 per hour.

2° ARRANGEMENT (figure 2) (G-9, 2)

- Cloud chamber with 8 plates of lead each 1.6 cm thick.
- a block of aluminium above the chamber.
- coincidence between I counter inside the chamber and 2 groups of counter under the chamber.
- total number of pictures showing a single penetrating particle crossing the first 4 plates at least : 625.
- rate : ∽ 0.5 per hour.
- Some of the pictures obtained with this second arrangement show a single penetrating particle that produces electronic showers in the last plates.

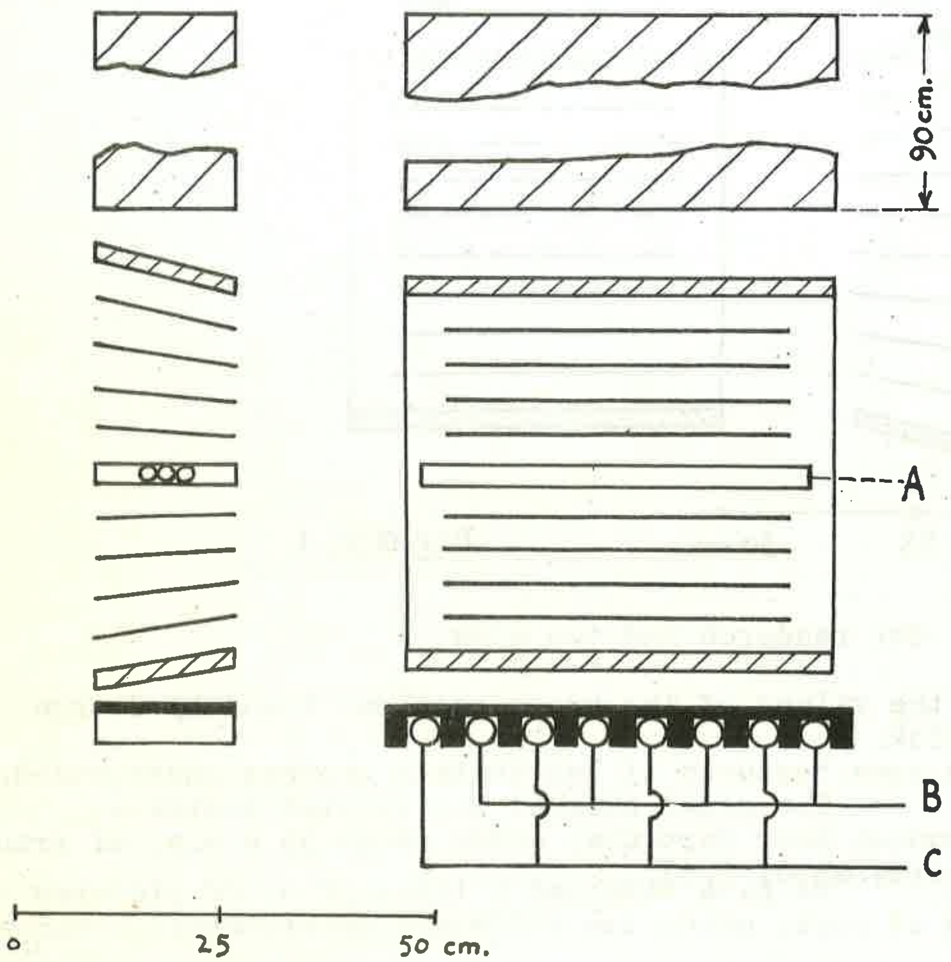

Fig. G-9, 2

I° PART;

The values reported by George and by Braddick are :

I) $\sigma > 50 \cdot 10^{-30}$ cm^2/nuclei, corresponding to a length in lead $\lambda_{Pb} > 30$ m. for showers with 2 p.p.- (a.p.p. + showers with 2 p.p.).

2) $\sigma \simeq 1.2 \cdot 10^{-30}$ cm2/nucleon ($\lambda_{Pb} \simeq 1200$m) for events with 3 or more penetrating showers (showers with ≥ 3 p.p.)

The ratio of these two cross-sections is greater than 40.

Our results are shown in this table ;

	Meters of lead	Penetrating particles in the plates 2 p.p.	3 p.p.	above 2 p.p.	3 p.p.
I° arrangement	352	I	0	I	I
Kollser	62	0	0	-	-
Deutschmann	422	0	0	-	-
George	77	3	0	-	-
2° arrangement	62	2	2	2	I

With the first arrangement we examined a total path of 352 m. Only one (figure G-9 3) example of production of one secondary particles that crosses I plate with an angle scattering less than 3 degrees was found.

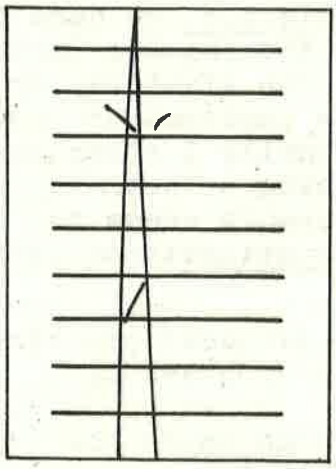

Fig. G-9, 3

Recently Walker, Deuschmann and George-Redding - Trent - reported some values (see the table above)

In all these experiments the counter control required only one penetrating particle and the events of production of showers were observed in the plates of the cloud chamber (not in the top, or above the chamber)

A large selection was - on the contrary - introduced with our 2° arrangement, where the coincidence between I counter inside the chamber and 2 counters under the chamber was required

We have examined so far a total path of 62 m of lead : 2 examples (Figure G-9, 4) of showers with 2p.p. and two examples of showers with 3 or more p.p. in the plates of the chamber, produced by single p.p. were observed.

A rather rough correction for the selection introduced by the counter control arrangement leads to the value ∽ 2 500 ∽ 5

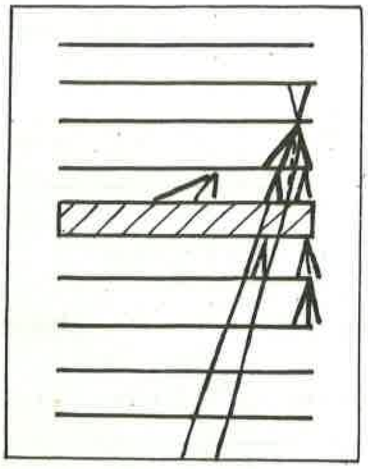

Fig G-9, 4

In this second experiment it is possible to make a direct comparison between the cases with 2p.p. and 3 or more p.p. The values are of the same order :

5 and 2

It seems to us that there is no evidence for the existence of an event with 2 p.p. - different from penetrating showers - with a cross section definitively larger than that for penetrating showers. Our results - on the contrary - are compatible with the values obtained by Amaldi and Co. Our results on the events with 3 or more p.p. are compatible with the path length of I200 m of lead first indicated by George.

2° PART -

Besides the 5 events of penetrating showers found in the lead plates inside the chamber produced by single p.p. we have found another 5 events originating immediately above the chamber (not in the rock, but in the top of the chamber, or in the Aluminium or lead blocks). We have also I shower due to one penetrating particle of a shower originated above the chamber and finally I other shower in which it is doubtful if the primary is ionising or not.

The examination of these 12 events seems to indicate two remarkable features of nuclear desintagrations underground :

I°) The penetrating particles produced are strongly interacting and therefore are not μ-mesons as proposed by Cocconi and Co.

In fact for the plates 1.6 cm thick the apparent mean free path for interaction of secondary particles produced in showers by N - component in mountain altitude is $\lambda_{a.p.p.} \simeq 750 g/cm^2$

Now in a total of 1.3 λ app. of traversal of secondary particles of our penetrating showers underground, we found I nuclear desintegration.

2^{o}) In some of the nuclear desintegrations of high energy, there is evidence of production of neutral mesons. These results show that, because of the presence of strongly interacting particles underground, we cannot attribute single events to μ-mesons with any certainty. The μ-meson component is always accompanied by an N - component underground.

G-10

PRODUCTION OF "BLACK" NEUTRONS BY PENETRATING PARTICLES UNDERGROUND

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Reported by Prof. Sard (Saint-Louis)

As time is short, I shall not show any slides. I shall simply make one general remark about the problem of determining a cross-section from a neutron yield, and then give the result of our experiment.

In our work, or in that of the Cocconis, we detect neutrons in the energy range 0.1 - 5 Mev by slowing them down in paraffin and detecting them with boron counters. One detects one or more neutrons, two or more neutrons, three or more neutrons, and like in the case of the Cocconis still higher multiplicities. Our apparatus differs from that of the Cocconis also, in requiring the presence of an unaccompanied penetrating particle to produce the neutrons, while that of the Cocconis did not distinguish between events produced by charged and uncharged particles.

A difficuilty arises in determining the cross-section for the interaction from the number of events detected, which is due to the fact that the probability of detecting the interaction depends on the number of neutrons produced. Similarly, one is more likely to notice a star in a photographic plate the more heavy prongs it has. On neutron detection the effect is even more marked. The probability of m neutrons being produced and k of them being detected is :

$$p(m) = \frac{m!}{k!(m-k)!} \varepsilon^{k} (1-\varepsilon)^{m-k}$$

where p(m) is the probability of m being emitted, and the second factor is the probability of detecting any k of these (ε being the efficiency). For a given k the second factor is a rapidly increasing function of m ; p(m). of course, decreases at large m, and the behaviour of the product depends in which factor preponderates. If p(m) has an exponential tail of the form $e^{-m/\bar{\bar{\nu}}}$, then when $\bar{\bar{\nu}} >> k$ most of the k-fold detected are due to events of much larger m. When, for example, one detects one, or two, or three, neutrons one is usually observing an event in which 20 to 40 neutrons are produced, and one