Texto completo do trabalho
apresentado no Simpósio de
Física de julho de 1952.

PROPERTIES OF MIXED SHOWERS

G. SCHWACHHEIM AND A. WATAGHIN

Departamento de Física da Faculdade
de Filosofia, Ciências e Letras da
Universidade de São Paulo.
São Paulo - Brasil.

Measurements with counter arrangements were made in Peru(4500mt. altitude) and in São Paulo(700mt. altitude).

The principal problems investigated were:

a) the density spectrum of atmospheric showers;

b) the percentage of penetrating particles present in the showers, in several density regions;

c) altitude effect.

The master arrangement cosisted of four trays of counters located along the sides of a square and shielded by 20 cm. Pb.

The length of the sides of the square was 1.6 mt.

Fourfold coincidences among these trays were the master counting rate.

The resolving power of the coincidence set was 5 microseconds.

Fivefold coincidences C_5^H and C_5 between the master arrangement and additional trays, one shielded by 20 cm. Pb and the other unshielded, located in the center of wquare, were also registered.

We shall first briefly describe what methods were used.

The counting rate C_4 of non-screened trays of counter in coincidence can be written as

$$C_4(s) = \int_0^\infty F(\delta)\,(1-e^{-\delta s})^4\,d\delta$$

where S is the area of each tray, δ is the density and $F(\delta)\,d\delta$ is the number of incident showers with density between δ and $\delta + d\delta$

The coincidence counting rate C_4^H of 4 trays, each of area S_H shielded by 20 cm of lead will be

$$C_4^H(S_H) = \int_0^\infty F(\delta)\,(1 - e^{-\delta_H S_H})^4\,d\delta$$

If a surface S_H is found by trial such that $C_4^H(S_H) = C_4(S)$ we shall have $\delta_H S_H = \delta S$ and therefore $\frac{\delta_H}{\delta} = \frac{S}{S_H}$

The ratio $\frac{\delta_H}{\delta}$, which we call K, is the percentage of penetrating particles present in the showers. This we shall call briefly method of equal counting rates. This method was employed by Ise e Fretter[1] who worked at 3000 m. and by us in this work. They found 2,5% and we found 2% at both altitudes investigated. These results are in agreement if we take into account statistical errors and differences in the geometry of the experimental arrangement. The hypothesis that the density spectrum $F(\delta)$ is described by a power law of the type $\delta^{-\gamma}$ has been already checked, for electron showers by Cocconi et al[2], Ise and Fretter[1] and by ourselves in this work. The method used for this check is to vary simultaneously the areas of all counter trays.

The value of γ we obtained for penetrating showers by this method was 1.46 ± 0.03 in Morococha and 1.50 ± 0.11 in S.Paulo. Fretter found at 3000 m. 1.6 but his arrangement was geometrically somewhat different.

A second method of determining k is to have an extra tray of counters not screened in coincidence whith the screened master. The ratio $\frac{C_5}{C_4^H}$ and γ allow us to calculate k in the hypothesis that k does not depend on the density of the showers. We shall call this method for brevity the fifth counter method. This method has the utility of showing whether penetrating atmospheric showers exist with much greater k than 2%. This second method was employed by us in the experiment now reported. McCusker and Millar[3] used recently a similar arrangement but the analysis was made by then on a somewhat different basis. A third method, similar to the one just described, but which depends less on the form of the density spectrum, is to measure also the five-fold coincidences C_5^H between the master and a screened extra tray. The comparison of C_5^H and C_5 allows us to calculate K. This method, which we employed simultaneously with the method of the fifth counter confirmed its results. Our measurements in different density regions did not show any appreciable variation in the percentage of penetrating particles. This percentage was found to be (3.6 ± 0,4) in S. Paulo and (2,05 ± 0,14) % in Peru.

We call the attention to the fact that at low altitude (S.Paulo) there is a difference outside statistical errors between the values obtained by the methods of equal counting rates and of the fifth counter.

At mountains altutude, Morococha, no such difference is found.

This indicates that at low altitude, one of the hypothesis needed for the application of the methods given above to penetrating showers, namely the constancy of K, is not valid. In order to explain the discrepancy one has to suppose that besides the showers having K= 2% there is at low altitude, a certain number of penetrating showers with very few electrons. This conclusion is in agreement whith the results obtained by McCusker and Millar(3) on somewhat different grounds.

These extra showers present at low altitude, could be, as suggested by McCusker and Millar, tail ends of normal extensive showers, having the electrons been absorbed during the development of the showers in the atmosphere.

We want to notice that from the registered density of electrons, which varied from 1000 to 6000 part. m^{-2} one can estimate roughly that the mean energy of the showers was very great, of the order of 10^{15} e.v.

Another result of the experiments is that the apparent mean range obtained from the altitude variation of the penetrating showers, is 103,1±2,0 gr. cm^{-2}.
But the real mean range must be much less, perhaps of the order of the geometrical one, becuse the showers must be produced at high altitude above the arrangement.

We thank UNESCO and Instituto de Biologia Andina de la Universidad Mayor de S. Marcos de Lima for providing the laboratory and many facilities during the experiments in Peru.

We thank Cerro de Pasco Corporation for providing part of the lead used in the experiments in Peru, and for many facilities.

We thank Conselho Nacional de Pesquisas for having provided the transportation to Peru.

We acknowledge our gratitude to H.A.Meyer who participated in the preparation of the experiments.

We thank Professors J.Tiomno and D.Bohm for stimulating discussions.

References:

(1) Ise and Fretter, Phys. Rev., 76, 933, 1949.
(2) Cocconi, Cocconi and Greisen, Phys. Rev., 75, 1058, 1949
(3) McCusker and Millar, Proc. Phys. Soc., A, 64, 915, 1951.