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FACULDADE DE FILOSOFIA, CIÊNCIAS E LETRAS
CAIXA POSTAL, 2926

São Paulo (Brasil), ... de .....

LETTER TO THE EDITORS OF "PHYSICAL REVIEW"

COSMIC RAYS SHOWERS AT GREAT DEPTHS

By G. Wataghin and M. Damy de Souza Santos

Arrangements for fourfold coincidences measurements with G. M. counters wers employed experiment conditions. Measurements were made in the mine of Morro Velho (Brasil) at depths of 200 and 600 m. water equivalent below the surface.

we used 8G. M. counters of 33 cm effective length and 3.5 cm diameter, efficiency higher than 95% , counting plateau of about 1000 volts. The counters were arrange in order to tegistrate fourfold coincidences of 2 or more particles in a first arrangement, and of ar least 3 particles in a second arrangement. The circuit os coincidences was of the Rossi type with the arrangements of Neher and Harper. The resolving power of the apparatus was measured in the mine and found to be $=3.\ 10^{-5}$ min approximately. The individual conting in the mine for each counter was of about N=60 min^{-1} and the random fourfold coincidences was espectes to be one in every 35 days. ( )
An analogous computation for random coincidences between the systematic triple and individual countrs, shows one coincidence in every 4 days.

The measurements in depth were made in a gold mine in two stations under thicknesses of 85 m of rock (240 m water equivalent) and of 140 m of rock (400 m water equivalent). The arrangements of counters are indicated in figure 1 and results are given in table 2. Notwithstanding the preliminary caracter of these measurements which were interrupted for reasons independent from our will, we think they show in an unmistakable manner the existence of nom-ionizing particles at great depths as can be concluded from the following discussion.

The most striking result of measurements in tehe 2 stations lies in the fact that in arrangements 4) and IV) no coincidences are recorded during a time of 900 minutes, and thus, there probably is a notable diminution in the intensity of

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showers in comparison with the average values observed in 7 other experiments, values which are several times greater than the errors of measurements.

A better understanding of results can be obtained from examintion of measurements at depths of 50 m in S. Paulo (Table 2). From the comparison of experiments a) b) and c) we can see that the supporting wood table in c) is responsible for part of showers having secondaries of small range as much the paraffin layer in experiment b). The non-ionizing particles which produce this kind of showers were subject of further studios, which will be published elsewhere in collaboration with G.Occhialini.

From experiments f) g) h) there follows that this shower producing radiations is stopped by a block of 17 cm Pb and below this block there is some shower-producing radiation, probably of the cascade type. The comparisons of e) and f) shows that at this depth we have penitrating ionizing particles which can produce showeers. No effect similar to the results IV of Morro-Velho ha been observed. The three experiments A) B) and C) with arrangements of counters identical to that of station 1 may be used for comparison of intensities.

A t the stations 1 and 2 the number of coincidences reportid is so reduced that only a roughe evoluation of intensites is allowed. So, in experiment 1) of first station, showers produced in the rock are recorded, the effect of the supporting table being negligible. The increment of intensity in cases 2) and 3) if there really is one, can be ascribed to secondaries produced in the lead plates.

The comparison between 4) and 5) shows that the shower particles coming from the rock above the counters are stopped by a block of 17 cm Pb, and in this block new showers are produced which are responsible for the coincidences of experiment 5). The radiation producing these showers must be of non-ionizing type as follows from 4).

Similar results can be derived from measurements at the second station. If follows from experiments I) II) and III) that the arrangement of 17 cm Pb in A) does not sensibly make the intensity to vary, so as does not the interposition of 1.5 cm Pb in B).

We deduce from III) and IV) that the range of secondaries is less than 17 cm Pb and that the showers produced in the block of 17 cm Pb are due to non-ionizing particles.

Another indirect test o wxistence of non-ionizing radiation can be obtained

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from comparison of shower intensities with the intensity corresponding to an arrangement of fourfold coincidences in a "telescope". Our measurements and those of Wilson and Ehmert give a ratio between "telescope" and shower intensities if the order of 5 or 20. The absorption coefficient of the shower producing radiations is of the order of 2.10^{-5} at the depth of 200-400 m water equivalent, whereas the secondaries of showers have a range les than 1.5 m H^2O.

Thus the number of shower producing particles crossing the area of counters must be several hundred times greater than the number of showers. Should these particles be of ionizing type, than the intensity in a "telescope" arrangement would be much great than the observed value.

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We used 8 G.M. counters of 33 cm effective length and 3.5 cm diameter , efficiency higher than 95 % , counting plateau of about 1000 volts . The counters were arranged in order to registrate fourfold coincidences of 2 or more particles in a first arrangement , and of at least 3 particles in a second arrangement . The circuit of coincidences was of the Rossi type with the arrangements of Neher and Harper[1] . The resolving power of the apparatus was measured in the mine and found to be $\alpha = 3\ 10^{-5}$ min approximately . The individual counting in the mine for each counter was of about $n = 60$ min^{-1} and the random fourfold coincidences was expected to be one in every 35 days . [ ]

An analogous computation for random coincidences betwsen the systematic triple and individual counts , shows one coincidence in every 4 days .

The measurements in depth were made in a gold mine in two stations under thicknesses of 85 m of rock (240 m water equivqlent) and of 140 m of rock (400 m water equivqlent) . The arrangements of counters are indicated in figure 1 and results are given in table 2 . Notwithstanding the preliminary caracter of these measurements which were interrupted for reasons independent from our will , we think they show in an unmistakable manner the existence of non-ionizing particles at great depths as can be concluded from the following discussion .

The most striking result of measurements in the 2 stations lies in the fact that in arrangements 4) and IV) no coincidences are recorded during a time of 900 minutes , and thus , there probably is a notable diminution in the intensity of showers in comparison with the average values observed in 7 other experiments , values which are several times greater than the errors of measurements .

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A better understanding of results can be obtained from examination of measurements at depths of 50 m in S.Paulo (Table 2) . From the comparison of experiments a) b) and c) we can see that the supporting wood table in c) is responsible for part of showers having secondaries of small range as much as the paraffin layer in experiment b) . The non-ionizing particles which produce this kind of showers were subject of further studies , which will be published elsewhere in collaboration with G. Occhialini .

From experiments f) g) h) there follows that this shower producing radiation is stopped by a block of 17 cm Pb and below this block there is some shower-producing radiation , probably of the cascade type . The comparisons of e) and f) shows that at this depth we have penetrating ionizing particles which can produce showeers. No effect similar to the results of IV) Morro-Velho has been observed).

Three experiments A) B) and C) with arrangements of counters identical to that of station 1 may be used for comparison of intensities. At the stations 1 and 2 the number of coincidences reported is so reduced that only a rough evaluation of intensities is allowed. So , in the experiment 1) of first station , showers produced in the rock are recorded , the effect of the supporting table being negligible . The increment of intensity in the cases 2) and 3) , if there really is one can be ascribed to secondaries produced in the lead plates .

The comparison between 4) and 5) shows that the shower particles coming from the rock above the counters are stopped by a block of 17 cm Pb , and in this block new showers are produced which are responsible for the coincidences of experiment 5). The radiation producing these showers must be of non-ionizing type as follows from 4)-. Similar results can be derived from measurements at the second station .

If follows from experiments 1) 2) and 3) that the arrangement of 17 cm Pb in A) does not sensibly make the intensity to vary , so as does not the interposition of 1.5 cm Pb in B) .

We deduce from III) and IV) that the range of secondaries is less than 17 cm Pb and that the showers produced in the block of 17 cm Pb are due to non-ionizing particles .

Another indirect test of existence of non-ionizing radiation can be obtained from comparison of shower intensities with the intensity corresponding to an arrangement of fourfold coincidences in a "telescope" . Our measurements and those of Wilson and Ehmert give a ratio between "telescope" and shower intensities in the order of 5 or 20 . The absorption coefficient of the shower producing radiation

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is of the order of $2 \cdot 10^{-5}$ at the depth of 200-400 m water equivalent , whereas the secondaries of showers have a range less than 1.5 m H^2O .

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