orbit 10^{-18} and 10^{-20} second in carbon and iron, respectively. Process (2) is likely to lead to 10 times shorter lives. This is negligible compared to the life of a negative mesotron of 2×10^{-6} second.

The experimental result[1] leads to the conclusion that the time of capture from the lowest orbit of carbon is not less than the time of natural decay, that is, about 10^{-6} second. This is in disagreement with the previous estimate by a factor of about 10^{12}. Changes in the spin of the mesotron or the interaction form may reduce this disagreement to 10^{10}.

If the experimental results are correct, they would necessitate a very drastic change in the forms of mesotron interactions. The result is significant also for the production of single mesotrons by artificial sources. Indeed the creation of a mesotron by x-rays or fast protons is the reverse of processes (1) and (2). If the interaction according to these two processes is much weaker than expected, one would conclude the same for the reverse processes. Thus one might be in doubt as to whether one can produce abundant numbers of artificial mesotrons with bombardment-energies only a little above the threshold for single-mesotron production. Predictions concerning the creation of mesotron pairs by electromagnetic radiation are, of course, not affected by these arguments.

PHYSICAL REVIEW VOLUME 71, NUMBER 5 MARCH 1, 1947

The Lateral Extension of Auger Showers

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(Received January 7, 1947)

IN 1939 P. Auger and co-workers discovered the large atmospheric showers of cosmic rays which cause the coincidences in two Geiger-Müller counters separated by a distance of several dozens of meters. They also obtained some evidence that the double coincidences C_2 can be observed at much larger separations, as much as 300 meters (the coincidence rate due to showers, being in this case, however, of the same order as that of the random coincidences).[1]

As a result of numerous theoretical investigations of the Auger showers it was concluded that the latter are of the usual cascade type but of ultra-high energy. In particular Auger's curve $C_2=f(D)$ seems on the whole to be in good accord with the assumption of the cascade nature of the showers and in agreement[2] with the predictions of the cascade theory. However the point at $D=300$ m apparently upsets somewhat this harmony.

Auger's method could not yield reliable results for much larger distances. We applied a different method of observation the essence of which will be clear from Fig. 1. In this figure 1, 2, 3, 4 are four trays of Geiger-Müller counters; I and II are circuits which record the double coincidences (1, 2) and (3, 4); III is a circuit which records coincident output pulses from I and II and thus records fourfold coincidences (1, 2 +3, 4).

The effective area of each counter tray was 1840 cm². The apparatus was placed in light veneer cabins. The pulses were sent through high frequency cables.

Auger recorded the simultaneous passage of two particles while we registered two simultaneous pairs of particles. This considerably decreased the number of random coincidences.

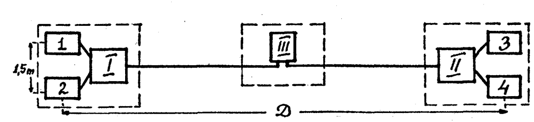

Fig. 1. The arrangement of four counter trays (1, 2, 3, 4) and the coincidence circuit.

[1] Auger, Maze, and Robley, Comptes rendus (Paris) **208**, 1641 (1939).
[2] D. V. Skobeltzyn, Comptes rendus USSR **37**, 14 (1942).

On the other hand the large effective area of our counter trays permitted us to obtain much higher counting rate (compared to those of Auger). For a resolving time in circuit III of $\tau \sim 4.10^{-6}$ sec. the number of random coincidences at $D=300$ meters was less than 0.7 percent of the number of true coincidences; at $D=600$ m the shower counting rate was 0.6 per hour while the random coincidences counting rate was 0.03 per hour.

The results of the measurements are illustrated by the curve in Fig. 2. We thus have here reliable evidence in favor of the existence of fourfold coincidences at $D=600$ m, and there is also evidence that these coincidences can be observed at $D=1000$ meters. (Because of a shortage of time we obtained only three coincidences at this distance.) The method applied by us permits one to carry out observations at even larger separations.

The mean radius of Auger showers as computed in a number of papers seems to be about 100 meters. The existence of fourfold coincidences at 600 meters (i.e., at separations exceeding by 6 times the shower radius) sharply contradicts these calculations.

The observed discrepancy may be estimated if one makes some definite assumption as to the dependence of the shower density ρ on the distance r from the shower axis, for distances $r \gg R$. If, for example, one supposes that $\rho \sim \exp[-r/R]/r^{\frac{1}{2}}$ for $r>R$* (this is practically equivalent to the assumption $\rho \sim \exp[-r/R]$ for $r \gg R$) than the ratio $C_4(D=100\text{ m})/C_4(D=600\text{ m})$ may easily be calculated and compared with the experimental values. As a matter of fact on such assumption the function $C_4(R, D)$ for *fourfold* coincidences (at $D>R$) coincides with that which one of us found for *double* coincidences assuming $\rho \sim \exp[-r/R]/r$.

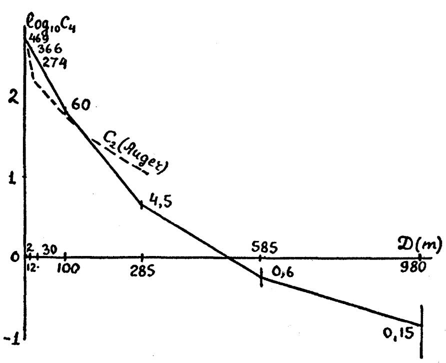

FIG. 2. The logarithm of the coincidence rate C_4 *versus* distance D in meters. The figures on the curve are the rate C_4 of fourfold coincidences per hour.

* The assumption $\rho \sim \exp[-r/R]$ probably involves an overestimation (and a very considerable one) of the density ρ at great distances r. This seems to be certainly the case for $r \leq 6R$.

The formula for C_4 can be obtained by substituting in the formula previously deduced for $C_2(R, D)$ half the shower radius, i.e.,

$$C_4(R, D) = C_2(\tfrac{1}{2}R, D)$$

or

$$\begin{aligned} C_4 &= \iint (\rho_1\sigma)^2(\rho_2\sigma)^2 F(E)dEdS \\ &= k' \int_{x=D}^{\infty} \int_{\phi=0}^{2\pi} \frac{\exp[-2x/R]}{x+D\cos\phi} dx d\phi \\ &= 2\pi k' \int_{2D/R}^{\infty} \frac{\exp[-t]dt}{[t^2-(2D/R)^2]^{\frac{1}{2}}} \\ &= k_0(2D/R), \end{aligned} \qquad (1)^{**}$$

where k' is a factor which depends on a certain integral of E.

$$\rho_1 = \rho_0 \exp(-r_1/R)/r_1^{\frac{1}{2}}; \quad \rho_2 = \rho_0 \exp(-r_2/R)/r_2^{\frac{1}{2}}$$

are the densities of the shower particles at the points at which the counter trays are located, i.e., at distances r_1 and r_2 from the element of area dS of the shower axis. $F(E)dE$ is the number of showers of primary energy E per unit area. Integral (1) is the tabulated Macdonald's function (or $\frac{1}{2}iH_0'(2Di/R)$ in which H_0' is the Bessel function of the third kind).

The observed curve and function (1) are plotted in Figs. 2 and 3 on a semi-logarithmic scale.

The curves in Fig. 3 were made to coincide at $D=100$ m.

At $D=600$ the discrepancy reaches a value of about 500 times. If $R=200$ m this discrepancy

** It is assumed that $\rho_1\sigma$ and $\rho_2\sigma \ll 1$. Such a condition is fulfilled for $D>R$ if the energy spectrum is of the form $F(E) \sim E^{-2.8}$. This conclusion may be however invalidated if the number of primary particles in the region of $E=10^{16}-10^{18}$ ev is much greater than that which can be deduced from this relation.

would be much smaller. In order to fit the part of the curve lying between $D=300$ m and $D=600$ m with the calculated curve one must assume $R=350$ m. This assumption, however, would lead to other difficulties and in particular would violate the agreement between the experimental and theoretical curve $C_2(R, D)$ for $D<100$ m (Auger's curve is in satisfactory agreement with $C_2(R, D)$ for D lying between 4 and 100 m)[2].

This result seems to raise the question as to the accuracy of the usually accepted conception concerning the production of the Auger showers.

If, for example, the shower-producing electrons are themselves produced in the atmosphere of the earth as a result of some hitherto unknown process then it may be possible that at the very birth of the shower several particles (electrons or photons) of ultra-high energy are created simultaneously in the atmosphere, their axes diverging to such an extent as to be at considerable distances from each other (of the order of several hundreds of meters) after passage through the atmosphere, even if the initial angle of divergence is of the order of one degree.† The coincidences at large distances could then be caused by different but "correlated" showers. A direct experimental check of this point is being planned at present.

This investigation was carried out in 1946 at the Pamir mountains at an altitude of 3860 m above sea level.

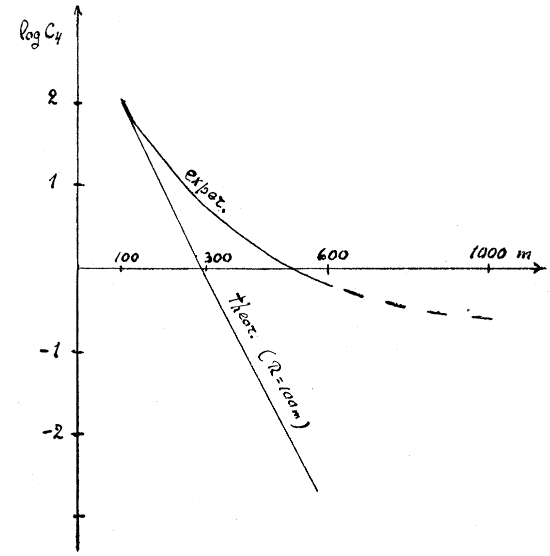

FIG. 3. Logarithm of fourfold coincidence rate C_4 *versus* distance (experimental and theoretical curves). The figures on the curve are counting rates C_4 per hour.

† This angle however is much greater than mc^2/E.