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The Decay of Negative Mesotrons in Matter

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IN a recent experiment Conversi, Pancini, and Piccioni[1] observed separately the behavior of positive and negative mesotrons coming to rest in iron or in graphite. They find that in iron the disintegration electrons are observed only for positive mesotrons. This was indeed to be expected[2] because negative mesotrons after being slowed down can approach the nuclei and disappear by nuclear interactions. If, on the other hand, graphite is used for stopping the mesotrons, delayed disintegration electrons are observed to be about equally abundant for positive and negative mesotrons. This is in sharp disagreement with current expectations and seems to indicate that the interaction of mesotrons with nucleons according to the conventional schemes is many orders of magnitude weaker than usually assumed. The disappearance of a negative mesotron can be analyzed into a process of approach of the mesotron to the nucleus and the process of capture by short range interaction of the mesotron and the nucleons.

The slowing down of mesotrons to an energy of about 2000 ev takes place according to the conventional theory. In estimating the energy loss for lower energies we have considered energy exchange with electrons and radiation. We consider the electrons as a degenerate gas with a maximum velocity v_0 and assume that the velocity V of the mesotron is small compared to v_0. Then the energy loss to the electrons per unit time is of the order of magnitude $e^4m^2T/(\hbar^3\mu)$. Here m and μ are the masses of the electrons and the mesotrons, respectively, and T is the kinetic energy of the mesotron. This formula allows losses of energy even when the total energy is negative (mesotron bound to an atom), and is valid as long as the mesotron moves outside the K orbit. At closer distances the formula will be somewhat modified and at the lowest energies loss by radiation will predominate. The mesotron reaches its lowest orbit around the nucleus in most solids in not more than 10^{-12} second. This orbit is 200 times smaller than the radius for the K shell, which is for carbon about 10 times the nuclear radius and for iron about twice the nuclear radius. After reaching this orbit the mesotron can be found within the nucleus with a probability of 1/1000 in the case of carbon and a probability $\frac{1}{10}$ in the case of iron.

According to the conventional mesotron theories, one will have to assume that the capture now proceeds according to one of the following schemes:

$$P+\mu^-=N+h\nu \tag{1}$$

$$X+\mu^-=N+Y. \tag{2}$$

Here P and N stand for proton and neutron, μ signifies the mass of the mesotron, $h\nu$ is a light quantum, and X and Y stand for initial and residual nuclei in the capture process. The first calculation of these processes for a special form of mesotron interaction is due to Kobayasi and Okayama, and Sakata and Tanikawa.[3] The results depend to some extent upon the spin of the mesotron and the form of the interaction assumed. For example, in the case of pseudoscalar mesotrons with an interaction energy given by $\Sigma_i(\hbar/\mu c)(4\pi)^{\frac{1}{2}}g\tau_i\int(\psi^*\sigma\psi)$ grad ϕ_i (ψ is the wave function of the nucleons, ϕ_i of the mesotrons, μ is the mesotron mass, the index i refers to the charge, and τ is the isotopic spin operator), one obtains for the time of capture by process (1) for a mesotron already captured in its lowest

[1] M. Conversi, E. Pancini, and O. Piccioni, Phys. Rev. **71**, 209 (1947).
[2] S. Tomonaga and G. Araki, Phys. Rev. **58**, 90 (1940).
[3] Kobayasi and Okayama, Proc. Phys.-Math. Soc. Japan **21**, 1 (1939); Sakata and Tanikawa, Proc. Phys.-Math. Soc. Japan **21**, 58 (1939).

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.

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The Lateral Extension of Auger Showers

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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.

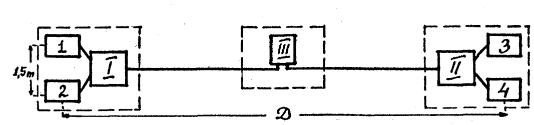

Fig. 1. The arrangement of four counter trays (1, 2, 3, 4) and the coincidence circuit.

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