Cosmic Ray Experiments Before Accelerators. Jack Steinberger. November 5, 2012.

There were three means for particle detection:

- Cloud Chambers:

  Discovery of positron, 1935, Anderson & Neddermeier.

  Discovery of muon (mesotron), 1936, Anderson and Neddermeier.

  Discovery of strange particles, Rochester and Butler, 1948

- Photographic Emulsions:

  Discovery of pion, π^-, Perkins, 1947,

  π^+, Powell, 1947.

  Discovery of K^+, ??, 1948.

- Geiger Counters:

  Two examples I will talk about:

  Conversi, Panchini and Piccioni, 1947. The experiment showed that muons (mesotrons) are not the particles proposed by Yukawa to be responsible for nuclear forces.

  My thesis, 1948, showed that the electron spectrum in muon decay is continuous, that therefore 2 neutrinos are emitted, pointing the way to the "Universal Fermi interaction".

$$n \rightarrow p + e^- + \bar{\nu}$$
$$p + \mu^- \rightarrow n + \nu$$
$$\mu \rightarrow e + \nu + \bar{\nu}$$

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Letters to the Editor

On the Disintegration of Negative Mesons

M. CONVERSI, E. PANCINI, AND O. PICCIONI*
Centro di Fisica Nucleare del C. N. R. Istituto di Fisica dell'Università di Roma, Italia

December 21, 1946

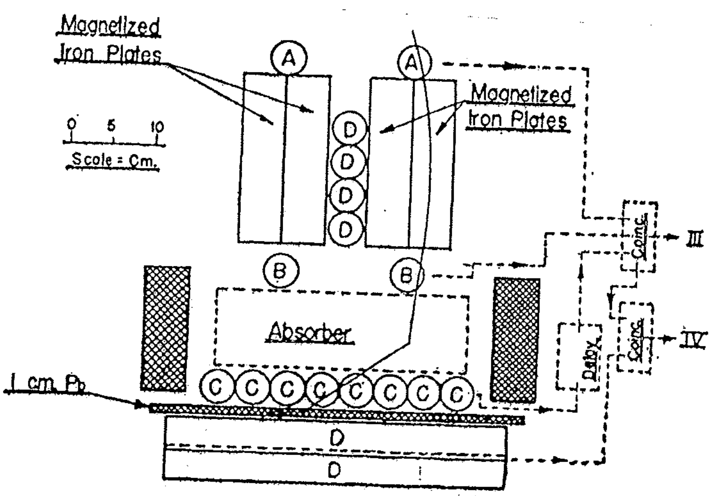

FIG. 1. Disposition of counters, absorber, and magnetized iron plates. All counters "D" are connected in parallel.

TABLE I. Results of measurements on β-decay rates for positive and negative mesons.

Sign	Absorber	III	IV	Hours	M/100 hours
(a) +	5 cm Fe	213	106	155.00′	67±6.5
(b) −	5 cm Fe	172	158	206.00′	3
(c) −	none	71	69	107.45′	−1
(d) +	4 cm C	170	101	179.20′	36±4.5
(e) −	4 cm C+5 cm Fe	218	146	243.00′	27±3.5
(f) −	6.2 cm Fe	128	120	240.00′	0

	+	−
Fe	67	3
C	36	27

Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is, for the issue of the 1st of the month, the 8th of the preceding month and for the issue of the 15th, the 23rd of the preceding month. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length.

On the Disintegration of Negative Mesons

M. CONVERSI, E. PANCINI, AND O. PICCIONI*
Centro di Fisica Nucleare del C. N. R. Istituto di Fisica dell'Università di Roma, Italia

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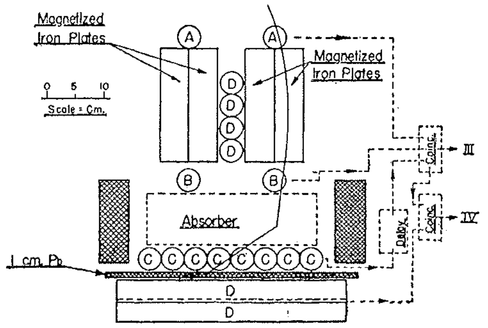
IN a previous Letter to the Editor,[1] we gave a first account of an investigation of the difference in behavior between positive and negative mesons stopped in dense materials. Tomonaga and Araki[2] showed that, becuase of the Coulomb field of the nucleus, the capture probability for negative mesons at rest would be much greater than their decay probability, while for positive mesons the opposite should be the case. If this is true, then practically all the decay processes which one observes should be owing to positive mesons.

Several workers[3] have measured the ratio η between the number of the disintegration electrons and the number of mesons stopped in dense materials. Using aluminum, brass, and iron, these workers found values of η close to 0.5 which, if one assumes that the primary radiation consists of approximately equal numbers of positive and negative mesons, support the above theoretical prediction. Auger, Maze, and Chaminade,[4] on the contrary, found η to be close to 1.0, using aluminum as absorber.

Last year we succeeded in obtaining evidence of different behavior of positive and negative mesons stopped in 3 cm of iron as an absorber by using magnetized iron plates to concentrate mesons of the same sign while keeping away mesons of the opposite sign (at least for mesons of such energy that would be stopped in 3 cm of iron). We obtained results in agreement with the prediction of Tomonaga and Araki. After some improvements intended to increase the counting rate and improve our discrimination against the "mesons of the opposite sign," we continued the measurements using, successively, iron and carbon as absorbers. The recording equipment was one which two of us had previously used in a measurement of the meson's mean life.[5] It gave threefold (III) and fourfold (IV) delayed coincidences. The difference (III)−(IV) (after applying a slight correction for the lack of efficiency of the fourfold coincidences) was owing to mesons stopped in the absorber and ejecting a disintegration electron which produced a delayed coincidence. The minimum detected delay was about 1 μsec. and the maximum about 4.5 μsec. Our calculations of the focusing properties of the magnetized plates (20 cm high; $\beta=15{,}000$ gauss) and including roughly the effects of scattering, showed that we should expect almost complete cut-off for the "mesons of the opposite sign." This is confirmed by our results, since otherwise it would be very hard to explain the almost complete dependence on the sign of the meson observed in the case of iron.



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The results of our last measurements with two different absorbers are given in Table I. In this table "Sign" refers to the sign of the meson concentrated by the magnetic field. $M=(\mathrm{III})-(\mathrm{IV})-P(\mathrm{IV})$, the number of decay electrons, is corrected for the lack of efficiency (p) in our fourfold coincidences ($\sim$0.046).

The value M_- (5 cm Fe) is but slightly greater than the correction for the lack of efficiency in our counting, so that we can say that perhaps no negative mesons and, at most, only a few ($\sim$5) percent undergo β-decay with the accepted half-life.

The results with carbon as absorber turn out to be quite inconsistent with Tomonaga and Araki's prediction. We used cylindrical graphite rods having a mean effective thickness of 4 cm because we were unable to procure a graphite plate. In addition, when concentrating negative mesons, we placed above the graphite a 5-cm thick plate of iron to guard against the scattering of very low energy mesons which might destroy the concentrating effect of our magnets. We alternated the following three measurements:

A. Negative mesons with 4 cm C and 5 cm Fe,
B. Negative mesons with 6.2 cm Fe (6.2 cm Fe is approximately equivalent to 4 cm C+5 cm Fe as far as energy loss is concerned.
C. Positive mesons with 4 cm C.

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On the Range of the Electrons in Meson Decay

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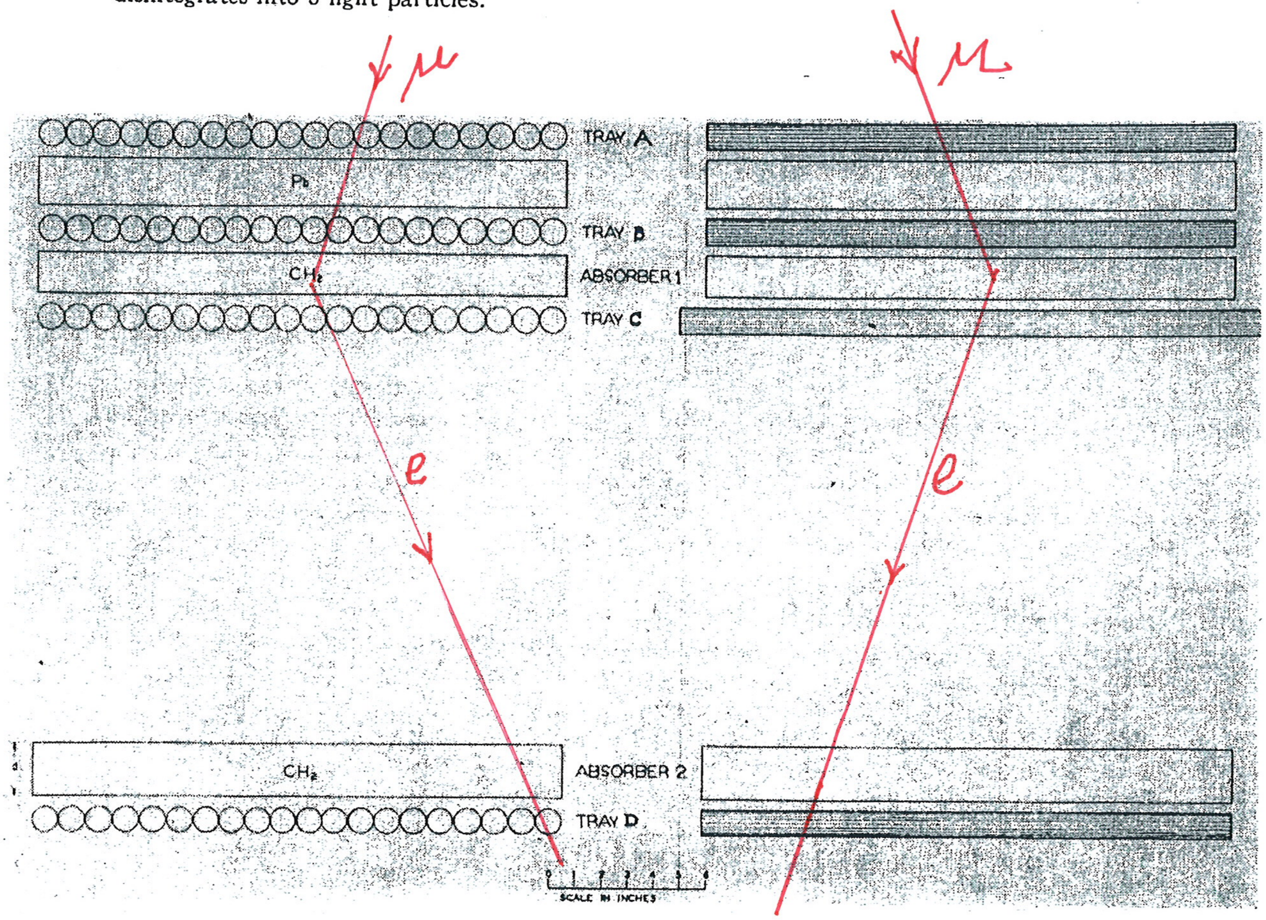
(Received January 10, 1949)

An experiment has been carried out both at Chicago and on Mt. Evans, Colorado, to determine the absorption of the electrons emitted in the decay of cosmic-ray mesons. Approximately 8000 counts have been obtained, using a hydrocarbon as the absorbing material. These data are used to deduce some features of the energy spectrum of the decay electrons. The resolution of the apparatus is calculated, taking the geometry, scattering, and radiation into account. The results indicate that the spectrum is either continuous, from 0 to about 55 Mev with an average energy ~32 Mev or consists of three or more discrete energies. No variation of the lifetime with the thickness of the absorber is observed. The experiment, therefore, offers some evidence in favor of the hypothesis that the μ-meson disintegrates into 3 light particles.



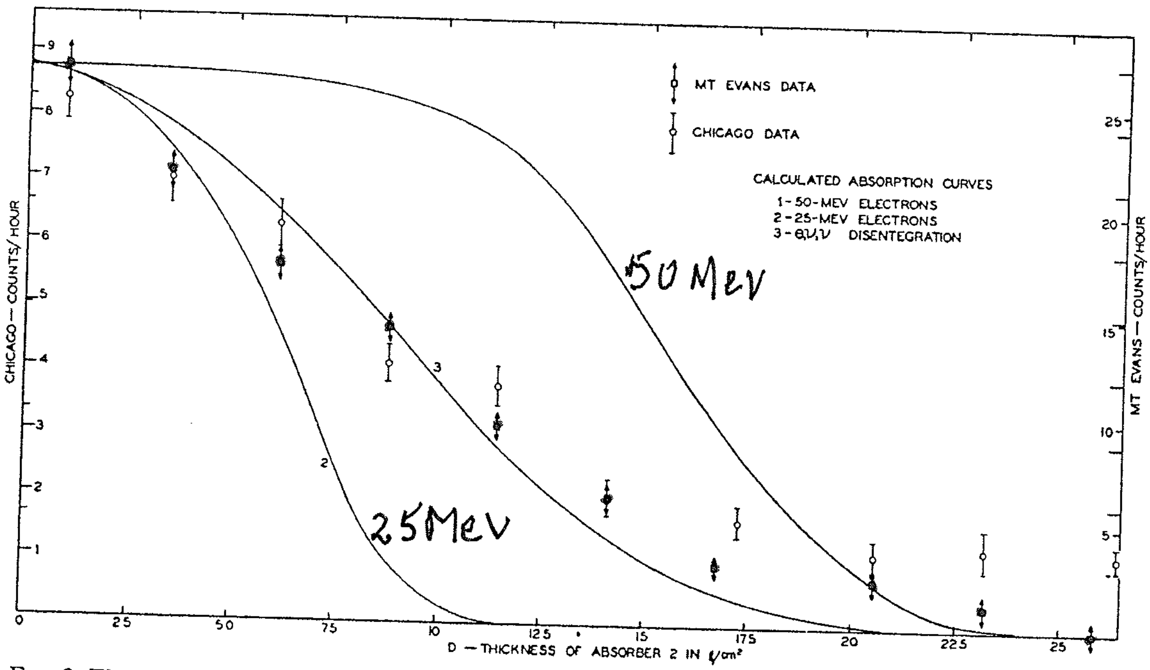


FIG. 8. The experimental points represent the data obtained in Chicago and on Mt. Evans. The indicated error is the standard deviation. The full curves 1 and 2 represent the calculated absorption curves for 50 and 25 Mev, respectively. Curve 3 is the absorption curve calculated for electrons emitted in a continuous spectrum. The spectrum is calculated from Eq. (2), taking $\mu c^2 = 100$ Mev.

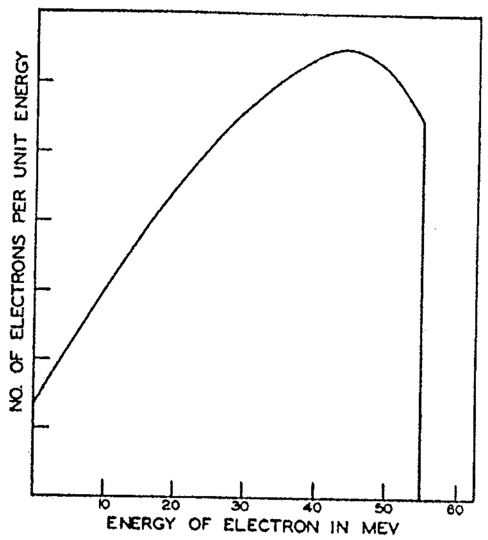


FIG. 9. The decay electron spectrum in this figure has been calculated to give as good a fit as possible with the data, at the same time excluding energies greater than 55 Mev. The limits of error of this spectrum are unknown, but large.

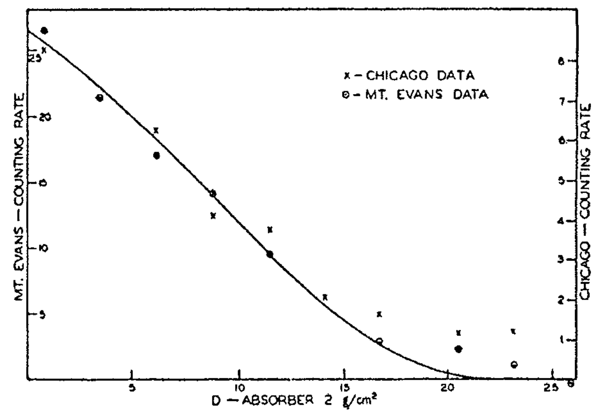


FIG. 10. The absorption curve calculated for the spectrum in Fig. 9.