if the ions have already a nearly uniform energy, because the losses may be avoided, which always otherwise arise, if the rays hit the screen, which limits the small interval of energy.

(4) The electric field between the cylinders (*D*) and (*E*), which accelerates the positive ions of the substance, will be formed so that it works as an electron-optic lens and produces a nearly parallel beam of rays.

We have tried out such an arrangement, and found it to work most satisfactorily. The intensity is dependent on the trial-substance and was large for metals and smaller for salts. The analysis in the parabola-spectrograph shows the ions of the trial-substance and the ions of the primary canal-ray discharge, all having the same energy.

On the Spin of μ-Mesons

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THE known processes resulting from the interaction of μ-mesons with other elementary particles:

$$\pi \rightarrow \mu + \mu_0, \quad (1)$$

$$\mu \rightarrow \mu_0 + e + \nu, \quad (2)$$

$$P + \mu^- \rightarrow N + \mu_0 \quad (3)$$

give very little indication on the spin of μ-mesons. We can only say that μ and μ_0 have both integral or half-integral spin.

As in all these processes μ appears together with μ_0 we shall assume that they are two different states of charge of the same particle and thus that they have the same spin.

The possibility of a spin $\frac{1}{2}$ for these particles has been already considered[1] (in particular if μ_0 is a neutrino). Although the hypothesis of μ_0 being a neutrino is very appealing, it seems that one should not neglect the other possibilities, in particular that it has an integer spin. From the analysis of the frequency of bursts produced by cosmic-ray mesons at sea level (mostly μ-mesons), Christy and Kusaka[2] excluded the value 1 for the spin of these mesons. If we exclude values higher than 1 (which may eventually result from an extension of Christy-Kusaka's calculations) we are left only with the values 0 and $\frac{1}{2}$.

We want to show here that a zero spin for the μ-meson with a special type of coupling with electron, neutrino and nucleons is in good agreement with the experimental results.

Let us consider first the μ-decay. We describe μ and μ_0 mesons by scalar (or pseudoscalar) fields, respectively complex (Φ) and real (φ). In order that μ-decay be a first-order process we take the interaction Lagrangean bilinear[3] in the mesonic fields; the most general one that can be formed using at most first derivatives[4] of the mesonic fields *and* of the electron-neutrino wave functions (ψ)[5] is:

$$L_{\text{int}} = \psi^+ \left\{ \left[g_1 \Phi \varphi + \frac{g_2}{\kappa} \varphi \frac{\partial \Phi}{\partial x^\sigma} \gamma_\sigma + 2 \frac{g_3}{\kappa^2} \frac{\partial \varphi}{\partial x^\rho} \frac{\partial \Phi}{\partial x^\sigma} \gamma_{\rho\sigma} \right] \tau_- + c.c. \right\} \psi, \quad (4)$$

where $\kappa = \mu c/\hbar$ and $\gamma_{\rho\sigma} = i(\gamma_\rho \gamma_\sigma - \gamma_\sigma \gamma_\rho)$, τ_- being an operator that transforms an electron into a neutrino. The probability per second of μ-decay in which the electron is produced with a momentum in the interval p_e, $p_e + dp_e$ is then proportional to:

$$dp_e \left\{ |g_1|^2 f_1\left(\frac{p_e}{\mu c}\right) + |g_2|^2 f_2\left(\frac{p_e}{\mu c}\right) + |g_3|^2 f_3\left(\frac{p_e}{\mu c}\right) + \frac{i}{2}(g_1 g_2^* - g_2 g_1^*) \cdot f_{13}\left(\frac{p_e}{\mu c}\right) \right\}. \quad (5)$$

The functions f are shown, for $\mu_0 = 0$ as consistent with the experimental results,[6,7] in the upper left part of Fig. 1; the experimental points of Anderson and co-workers[7] are also plotted in an arbitrary scale. It is seen that the only one of the simple couplings which gives a spectrum in agreement with the experimental points is the one in g_2.[8] This agreement may be emphasized if one compares the integral spectrum ($\sim E_e^3[2\mu c^2 - 3E_e]$) with the experimental points, as is done in the lower part of Fig. 1.

If we consider now the capture of a μ-meson by a nucleus we calculate the nuclear excitation as in case of spin $\frac{1}{2}$,[1] using for the interaction of μ, μ_0-mesons with nucleons an expression similar to (4); we then obtain a spectrum of nuclear excitation very similar to that of the case of spin $\frac{1}{2}$ and, then, also the result that the probability for star production is very small.[9]

One then concludes that the possibility of spin zero for μ_0-mesons is in good agreement with the experimental results and should not be disregarded for the moment.

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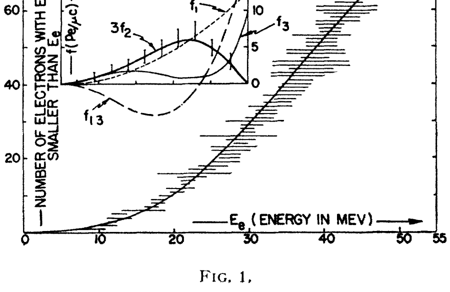

Fig. 1.

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[1] J. Tiomno and J. A. Wheeler, Rev. Mod. Phys. **21**, 144, 153 (1949).
[2] R. F. Christy and S. Kusaka, Phys. Rev. **59**, 414 (1941).
[3] The possibility of a coupling of μ, μ_0 with the electron-neutrino field, linear in each mesonic field is easily excluded in view of the impossibility of making the process (2) significantly more probable, then:

$$\mu \rightarrow e + \nu \rightarrow e + \nu + h\nu.$$

[4] We exclude terms with two time derivatives of ϕ, φ and ψ as they lead to difficulties in the application of the usual Hamiltonian formalism.
[5] Terms with derivatives of ψ are, to first order, equivalent to terms of the kind considered in (4).
[6] C. M. G. Lattes, Phys. Rev. **75**, 1468 (1949).
[7] Leighton, Anderson, and Seriff, Phys. Rev. **75**, 1432 (1949).
[8] A rough agreement can also be obtained with $g_3 = 0$, $g_1 = ig_3$.
[9] It should be pointed out that assuming that the interaction of spinless μ-mesons with nucleons is through an intermediate κ-meson we obtain a lifetime for the $\pi - \mu$-decay of the order of 10^{-8} sec. as shown by A. S. Lodge (Nature **161**, 809 (1948)), R. Latter and R. F. Christy (Phys. Rev. **75**, 1459 (1948)) and others.

Analysis of Delayed Coincidence Counting Experiments

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THE use of the delayed coincidence method for measuring short half-lives by several investigators[1-4] makes a reexamination of the basis of the experiment desirable. The coincidence counting rate *versus* delay curves exhibit two regions. The first is affected by the random delays in the counter itself, and the second is a pure exponential decrease determined by the radioactive decay. Van Name[3,5] analyzed the combination of these effects by assuming a triangular distribution for the delays in the counter but found it necessary to divide the range of artificial delays into six regions. A Gaussian distribution will be used here, and a fairly simple relation will result.