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Energy Spectrum of Secondary Electrons from μ-Meson Decay

RECENT experimental results are strongly in favour of the decay of the μ-meson into more than two particles[1]. The energy spectrum of the electron emitted in the disintegration of the μ-meson at rest has been calculated on the following assumptions. The μ-meson has spin $\frac{1}{2}$; it decays spontaneously according to the scheme $\mu\pm \rightarrow \varepsilon\pm + \lambda + \nu$, where ε indicates an electron, ν a neutrino and λ a neutral particle of spin $\frac{1}{2}$ with a mass either non-vanishing (μ^0 of Powell[2]) or more probably zero, in which case it can be identified with a neutrino.

The process is treated by ordinary perturbation theory; each charged particle is described by a plane wave according to Dirac's hole theory. For the neutral particles two theories are used: (*a*) Dirac's hole theory, assuming that it is possible to distinguish the particles from the anti-particles; (*b*) Majorana's abbreviated theory[3], which identifies the particles and the anti-particles.

The Hamiltonian of interaction is the same as for the β-decay theory, with five interaction constants. All possible ways of constructing a Hamiltonian of this kind are shown, by suitable linear transformations of the five interaction constants, to be equivalent.

For the probability $P(E)dE$ of observing the electron with a total energy between E and $E + dE$

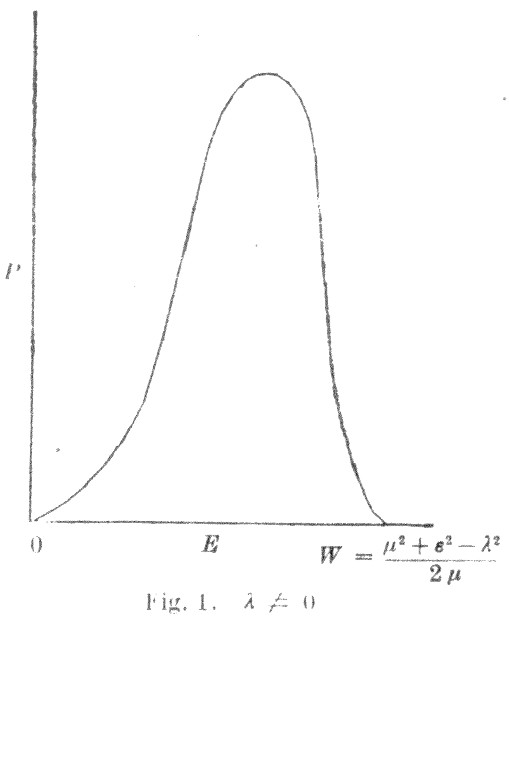

Fig. 1. $\lambda \neq 0$

($\varepsilon \leqslant E \leqslant W = \frac{\mu^2 + \varepsilon^2 - \lambda^2}{2\mu}$, where μ, ε, λ are the rest masses in energy units) we find the following results. If $\lambda \neq 0$, both descriptions a and b, chosen independently for the two neutral particles, lead to the same result ; $P(E)$ has the shape of Fig. 1, characterized by the factor $\sqrt{E^2 - \varepsilon^2}\,(W - E)^2/[2\mu(W - E) + \lambda^2]^3$.

If $\lambda = 0$ (the neutral particles are two neutrinos of zero rest mass) we have two different cases :

(1) All neutrinos are described by Dirac's hole theory, and the two emitted neutrinos are one particle and one anti-particle experimentally distinguishable (for example, by the sign of their magnetic moment) · then

$$P(E) = \frac{\sqrt{E^2 - \varepsilon^2}}{3\hbar(2\pi\hbar^2 c^2)^3}\,[3\mu E\,(W - E)\,K_1 + 2\mu\,(E^2 - \varepsilon^2)K_2 + 3\mu\varepsilon\,(W - E)\,K_3 + \varepsilon\,(E^2 - \varepsilon^2)\,K_4],$$

with

$$K_1 = g_1^2 + 2(g_2^2 + g_3^2 + g_4^2) + g_5^2,\ K_2 = g_2^2 + 2g_3^2 + g_4^2,$$
$$K_3 = g_1^2 - \tfrac{3}{2}(g_2^2 - g_4^2) + g_5^2, \qquad K_4 = -\tfrac{1}{2}\,(g_2^2 - g_4^2).$$

The terms proportional to K_3 and K_4 are very small (Fig. 2).

(2) Either all neutrinos are described by Majorana's abbreviated theory, or all neutrinos are described by Dirac's hole theory, and the two emitted neutrinos are either two particles or two anti-particles ; in each case the two emitted neutrinos are identical. The application of the exclusion principle gives the same results as above, except that now the interactions in g_2 and g_3 do not appear. (In the formula put $g_2 = g_3 = 0$) (Fig. 2). From the experimental value

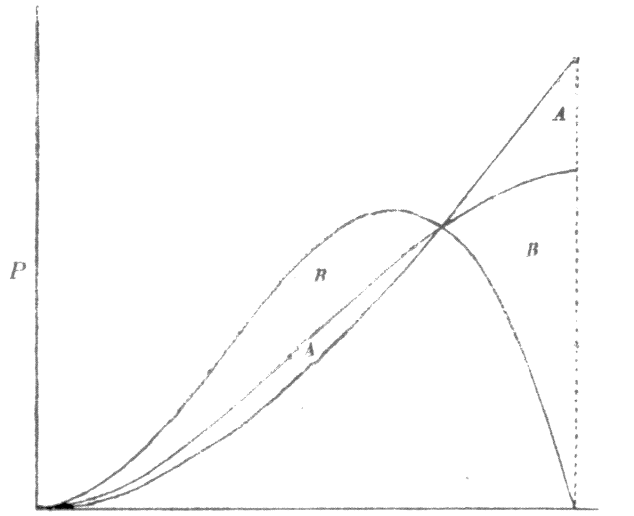

Fig. 2. $\lambda = 0$. When the g's take on all possible values, the curve sweeps the whole areas A and B in case 1, and only the area B in case 2

of the mean life of the μ-meson, the g's are found of the same order of magnitude as that of the Fermi constant[4].

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