Letters to the Editor

BETA DECAY OF STRANGE PARTICLES

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So far no decays of hyperons into nucleons and leptons (of the type $\Lambda^0 \rightarrow p + e^- + \tilde{\nu}$) have been observed. This contradicts the assumption that the four-fermion interaction constant F, responcible for this type of processes, is the same as that of the usual β decay or μ meson decay ($G = 1.41 \times 10^{-49}$ erg-cm^3).[1] The decrease in the magnitude of F may be due to either renormalization effects due to strong interactions which must exist in hyperon decay[2,3] or to a difference in the nonrenormalized constants. In either case an estimate of the order of magnitude of F is of interest. One way to obtain such an estimate is to study the K_{e3} and $K_{\mu 3}$ decays whose probability is determined by a matrix element of the same interaction that is supposed to lead to the β decay of hyperons. Phenomenologically we may write this matrix element as follows[4,2,5]

$$(\bar{u}_\mu + \bar{u}_e, [if(\hat{p}_K + \hat{p}_\pi) + ig(\hat{p}_K - \hat{p}_\pi)] \times (1 + \gamma_5) u_\nu) / \sqrt{4E_K E_\pi}, \quad (1)$$

where f and g are real functions of the invariant

$$Q^2 = -(p_K - p_\pi)^2 = m_K^2 + m_\pi^2 - 2m_K E_\pi; \quad m_{\mu,e} \leqslant Q \leqslant m_K - m_\pi. \quad (2)$$

Using Eq. (1) we obtain for the probabilities for K_{e3} and $K_{\mu 3}$ decays in which the π meson has an energy E_π in the K meson rest system the following formulas (in the case of K_{e3} one may, of course, set $m_e = 0$)

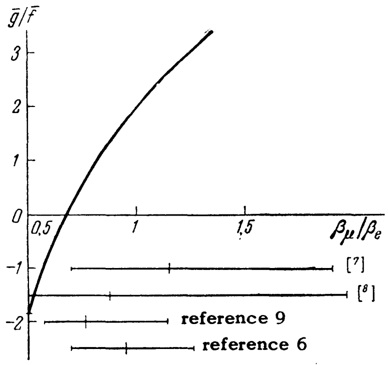
$$dW(E_\pi) = (m_K P_\pi dE_\pi / 48\pi^3)(Q^2 - m_{\mu,e}^2)^2 Q^{-6} \{4f^2 P_\pi^2 \times (2Q^2 + m_{\mu,e}^2) + 3(m_{\mu,e}/m_K)^2 [f(m_K^2 - m_\pi^2) + gQ^2]^2\}. \quad (3)$$

To obtain the total decay probability one must integrate (3) over E_π from $m_{\mu,e}$ to $(m_K^2 - m_\pi^2 - m_{\mu,e}^2)/2m_K$.

So far the energy distribution of π mesons in K_{e3} and $K_{\mu 3}$ decays has not been studied so that the dependence of f and g on Q^2 is not known. One may assume that within the range of Eq. (2) this dependence is weak. Then f and g may be replaced by some average values $\bar{f}$ and $\bar{g}$ and these quantities may be obtained from the total probabilities of K_{e3} and $K_{\mu 3}$ decays. We assume that the $K^\pm$ meson lifetime is equal to[6] 1.224×10^{-8} sec and denote the branching ratios for the $K_{\mu 3}$ and K_{e3} decays relative to the total number of K decays by β_μ and β_e respectively. Integrating (3) over E_π gives

$$\bar{f}/G = 0{,}57\sqrt{\beta_e}; \quad \bar{g}/G = -2.0\sqrt{\beta_e} + \sqrt{17.6\beta_\mu - 7.8\beta_e}. \quad (4)$$

The dependence of $\bar{g}/\bar{f}$ on β_μ/β_e is shown in the figure as well as the experimental value of β_μ/β_e taken from references 6 – 9. None of the



The dependence of the ratio of the constants $\bar{g}/\bar{f}$ on the ratio of the probabilities of $K_{\mu 3}$ and K_{e3} decays.

experiments are in contradiction with a value of β_μ/β_e between 0.7 and 1, i.e., $\bar{g}/\bar{f}$ between 0 and 2 and, in particular, $\bar{g} = 0$ (in which case $\beta_\mu/\beta_e = 0.7$). With $g = 0$ and $f = \bar{f} =$ const, the interaction leading to (1) is in coordinate representation given by

$$H = \bar{f}\left(\varphi_{\pi^0}^* \frac{\partial \varphi_{K^-}}{\partial x_\lambda} - \frac{\partial \varphi_{\pi^0}^*}{\partial x_\lambda} \varphi_{K^-}\right)(\bar{\psi}_\mu + \bar{\psi}_e, \gamma_\lambda (1 + \gamma_5)\psi_\nu), \quad (5)$$

where, according to Eq. (4), $\bar{f} = 0.13\,G$ (here we take $\beta_e = 0.051$).[9] On the other hand, it was shown by Feynman and Gell-Mann[1] that decays of the form $\pi^- \rightarrow \pi^0 + e^- + \tilde{\nu}$ should exist, analogous to the K_{e3} decays and described by a direct interaction

$$H' = G\left(\varphi_{\pi^0}^* \frac{\partial \varphi_{\pi^-}}{\partial x_\lambda} - \frac{\partial \varphi_{\pi^0}^*}{\partial x_\lambda} \varphi_{\pi^-}\right)(\bar{\psi}_e, \gamma_\lambda (1 + \gamma_5)\psi_\nu). \quad (6)$$

A comparison of the constants shows that $\bar{f}$ is eight times smaller than the G appearing in Eq. (6). If one assumes, in analogy with Eq. (6), that $\bar{f}$ is of the same order as F, where F is the constant (more correctly, some sort of an average form factor) giving the strength of the four fermion interaction responsible for hyperon β

decay, then one would expect F to be an order of magnitude smaller than G. An analogous quenching takes place in the form factor responsible for the $K_{\mu 2}$ decay.[6]

Probabilities of hyperon decays

Decay mode	W	$10^9 \tau$ [6]	$W\tau$
$\Lambda^0 \longrightarrow p + e^- + \tilde{\nu}$	$5.8 \cdot 10^5$	0.277	$1.6 \cdot 10^{-4}$
$\Lambda^0 \longrightarrow p + \mu^- + \tilde{\nu}$	$9.4 \cdot 10^4$	0.277	$2.6 \cdot 10^{-5}$
$\Sigma^- \longrightarrow n + e^- + \tilde{\nu}$	$3.4 \cdot 10^6$	0.167	$5.7 \cdot 10^{-4}$
$\Sigma^- \longrightarrow n + \mu^- + \tilde{\nu}$	$1.5 \cdot 10^6$	0.167	$2.5 \cdot 10^{-4}$
$\Xi^- \longrightarrow \Lambda^0 + e^- + \tilde{\nu}$	$1.2 \cdot 10^6$	~1	$1.2 \cdot 10^{-3}$
$\Xi^- \longrightarrow \Lambda^0 + \mu^- + \tilde{\nu}$	$3.2 \cdot 10^5$	~1	$3.2 \cdot 10^{-4}$
$\Xi^- \longrightarrow \Sigma^0 + e^- + \tilde{\nu}$	$1.4 \cdot 10^5$	~1	$1.4 \cdot 10^{-4}$
$\Xi^- \longrightarrow \Sigma^0 + \mu^- + \tilde{\nu}$	$2.1 \cdot 10^3$	~1	$2.1 \cdot 10^{-6}$

In the table are shown hyperon decay probabilities calculated on the assumption of an A-V interaction only with a constant $F = 0.1\,G$. The results of the calculation using the exact formula[10] (the decay probabilities given in reference 10 for $F = G$ are somewhat high due to a mistake in the coefficient) are for all practical purposes the same as those obtained from an approximate formula; for example for the decay $\Lambda^0 \rightarrow p + \mu^- + \tilde{\nu}$ one may use

$$W = \frac{F^2}{15\pi^3}(m_\Lambda - m_p)^5 \left(\frac{m_p}{m_\Lambda}\right)^{3/2} \Phi\left[\left(\frac{m_\mu}{m_\Lambda - m_p}\right)^2\right],$$

$$\Phi(x) = (1 - 4.5x - 4x^2)\sqrt{1-x} + \frac{15}{4}x^2 \ln\left|\frac{1+\sqrt{1-x}}{1-\sqrt{1-x}}\right| \quad (7)$$

(for the electron modes $x \ll 1$ and $\Phi \approx 1$). It is seen from the table that the product $W\tau$ (τ = experimental hyperon lifetime), which gives the fraction of leptonic decays relative to the total number of decays, for $F = 0.1\,G$ is of the order of 2×10^{-4} for Λ^0 and 10^{-3} for Σ^- and Ξ^- (in the last case the estimate is complicated by the absence of exact data on Ξ^- lifetime). In view of the fact that the number of Λ and Σ decays investigated so far is much less than $1/W\tau$, the absence of leptonic modes among them is not surprising.

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ON THE ROTATION OF THE PLANE OF POLARIZATION OF ELASTIC WAVES IN A MAGNETICALLY POLARIZED MEDIUM

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Let us consider the propagation of plane elastic waves in a magnetically polarized medium (i.e., one located in a constant, uniformly polarized magnetic field H_0, or one which contains a constant, uniform magnetization polarization I_0) with uniaxial symmetry. Let us study the case in which a constant polarizing field H_0 is oriented along the axis of symmetry, which we shall take to be the axis x_3. Neglecting magneto-mechanical effects (i.e., magnetostriction and gyromagnetic effects) the non-equilibrium elastic processes are described by the relation:[1]

$$\sigma_f = c_{fg}\varepsilon_g + c^*_{fq}\omega_q, \qquad \varepsilon_g = (\partial u_i / \partial x_j + \partial u_j / \partial x_i)/2,$$

$$\omega_q = (\partial u_i / \partial x_j - \partial u_j / \partial x_i)/2, \quad (1)$$

where $\sigma_f = \sigma^*_{ij} = \sigma^*_{ji}$ are the components of the mechanical stress tensor, u_i are the components of the displacement vector, and the non-zero components of the dynamic elastic modulus tensor, under the given conditions, are c_{fg} and c^*_{fq} (which depend on H_0 or I_0), given in reference 1. Here f, g, and q are the customary symbols for index pairs in the theory of elasticity.