Letters to the Editor

BETA DECAY OF STRANGE PARTICLES

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Submitted to JETP editor December 7, 1958


So far no decays of hyperons into nucleons and leptons (of the type \( \Lambda^0 \rightarrow p + e^- + \bar{\nu} \)) have been observed. This contradicts the assumption that the four-fermion interaction constant \( F \), responsible for this type of processes, is the same as that of the usual \( \beta \) decay or \( \mu \) 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 \( K^\pm \) and \( K^\mp \) decays whose probability is determined by a matrix element of the same interaction that is supposed to lead to the \( \beta \) decay of hyperons. Phenomenologically we may write this matrix element as follows\(^4,5\)

\[
\langle \bar{u}_a + u_e, [if(\bar{p}_K + \bar{p}_e) + ig(\bar{p}_K - \bar{p}_e)] \times (1 + \gamma_5) u_\mu \rangle / \sqrt{4E_KE_\mu},
\]

where \( f \) and \( g \) are real functions of the invariant

\[
Q^2 = -(p_K - p_e)^2 = m_\mu^2 + m_e^2 - 2m_\mu E_\mu; \quad m_{\mu, e} \leq Q \leq m_K - m_e.
\]

Using Eq. (1) we obtain for the probabilities for \( K^\pm \) and \( K^\mp \) decays in which the \( \tau \) meson has an energy \( E_\tau \) in the \( K \) meson rest system the following formulas (in the case for \( K^\pm \) one may, of course, set \( m_e = 0 \))

\[
dW(E_\tau) = (m_\mu P_\mu dE_\tau/48m^3) (Q^2 - m_\mu^2)^2 Q^-4 / 4f^2 p_\mu^2 \times (2Q^2 + m_\mu^2) + 3 (m_{\mu, e} / m_K)^2 [f(m_K^2 - m_e^2) + gQ^2].
\]

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

So far the energy distribution of \( \tau \) mesons in \( K^\pm \) and \( K^\mp \) 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 \( K^\pm \) and \( K^\mp \) decays. We assume that the \( K^\pm \) meson lifetime is equal to \( 1.224 \times 10^{-8} \) sec and denote the branching ratios for the \( K^\pm \) and \( K^\mp \) decays relative to the total number of \( K \) decays by \( \beta_\mu \) and \( \beta_e \) respectively. Integrating (3) over \( E_\tau \) gives

\[
\bar{f} / G = 0.57 \sqrt{\bar{g}}, \quad \bar{g} / G = -2.0 \sqrt{\bar{f}} \sqrt{17.6 \bar{g} - 7.8 \bar{f}}.
\]

The dependence of \( \bar{g} / \bar{f} \) on \( \beta_\mu / \beta_e \) is shown in the figure as well as the experimental value of \( \beta_\mu / \beta_e \) taken from references 6–9. None of the experiments are in contradiction with a value of \( \beta_\mu / \beta_e \) 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 \( \bar{g} = 0 \) and \( \bar{f} = \bar{f}_0 \) const, the interaction leading to (1) is in coordinate representation given by

\[
H = \bar{f} \left[ \frac{\partial \varphi_{K-}}{\partial x_\mu} - \frac{\partial \varphi_{\bar{K}0}}{\partial x_\mu} \varphi_{K-} \right] (\bar{g} + \bar{f}_0, \gamma_0 (1 + \gamma_0) \bar{\psi}_0),
\]

where, according to Eq. (4), \( \bar{f}_0 = 0.13 G \) (here we take \( \beta_\mu = 0.051 \)).\(^9\) On the other hand, it was shown by Feynman and Gell–Mann\(^4\) that decays of the form \( \pi^- \rightarrow \pi^0 + e^- + \bar{\nu} \) should exist, analogous to the \( K^\pm \) and \( K^\mp \) decays and described by a direct interaction

\[
H' = G \left[ \frac{\partial \varphi_{\pi^-}}{\partial x_\mu} - \frac{\partial \varphi_{\bar{\pi}0}}{\partial x_\mu} \varphi_{\bar{\pi}0} \right] (\bar{f}_0, \gamma_0 (1 + \gamma_0) \bar{\psi}_0).
\]

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 \( \bar{f}_0 \) 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 \( \beta \)
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 $K_{42}$ decay.\(^6\)

<table>
<thead>
<tr>
<th>Decay mode</th>
<th>$W$</th>
<th>$10^4 \tau$</th>
<th>$W\tau$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Lambda^0 \rightarrow p + e^- + \nu$</td>
<td>5.8 \times 10^4</td>
<td>0.277</td>
<td>1.6 \times 10^{-4}</td>
</tr>
<tr>
<td>$\Lambda^0 \rightarrow p + e^- + \gamma$</td>
<td>9.4 \times 10^4</td>
<td>0.277</td>
<td>2.6 \times 10^{-4}</td>
</tr>
<tr>
<td>$\Sigma^- \rightarrow n + e^- + \gamma$</td>
<td>3.4 \times 10^4</td>
<td>0.167</td>
<td>5.7 \times 10^{-4}</td>
</tr>
<tr>
<td>$\Sigma^- \rightarrow n + e^- + \gamma$</td>
<td>1.5 \times 10^4</td>
<td>0.167</td>
<td>2.5 \times 10^{-4}</td>
</tr>
<tr>
<td>$\Sigma^- \rightarrow \Lambda^0 + e^- + \gamma$</td>
<td>1.2 \times 10^4</td>
<td>-1</td>
<td>1.2 \times 10^{-4}</td>
</tr>
<tr>
<td>$\Sigma^- \rightarrow \Lambda^0 + e^- + \gamma$</td>
<td>3.2 \times 10^4</td>
<td>-1</td>
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<td>1.4 \times 10^{-4}</td>
</tr>
<tr>
<td>$\Sigma^- \rightarrow \Sigma^0 + e^- + \gamma$</td>
<td>2.1 \times 10^4</td>
<td>-1</td>
<td>2.1 \times 10^{-4}</td>
</tr>
</tbody>
</table>

In the table are shown hyperon decay probabilities calculated on the assumption of an $A_2$–$V$ interaction only with a constant $F = 0.1 G$. The results of the calculation using the exact formula\(^\text{10}\) (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 $\Lambda^0 \rightarrow p + e^- + \nu$ one may use

$$W = \frac{F^2}{15\pi} \left( \frac{m_\Lambda - m_p}{m_\Lambda} \right)^4 \left( \frac{m_p}{m_\Lambda} \right)^{10} \Phi \left( \frac{m_n}{m_\Lambda - m_p} \right) \left( \frac{x}{1 - x} \right) \left( \frac{1 + \sqrt{1 - x}}{1 - \sqrt{1 - x}} \right)^{10} x^3 \ln \left( \frac{1 + \sqrt{1 - x}}{1 - \sqrt{1 - x}} \right)$$

(7)

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

\(^4\)Furuichi, Kodama, Sugahara, and Yonezawa, Progr. Theoret. Phys. (Japan) 18, 64 (1956).
\(^7\)Alexander, Johnston, and O'Ceallaigh, Nuovo cimento 6, 478 (1957).
\(^8\)Birge, Perkins, Peterson, Stork, and Whitehead, Nuovo cimento 4, 834 (1956).
\(^9\)Bruin, Holthuizen and Jongejans, Nuovo cimento 9, 422 (1958).

Translated by A. M. Bincer

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**LET Us Consider the Propagation of Plane Elastic Waves in a Magnetically Polarized Medium**

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Submitted to JETP editor October 20, 1958


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 $I_3$) 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., magnetostriiction and gyromagnetic effects) the non-equilibrium elastic processes are described by the relation:\(^1\)

$$\sigma_i = c_{ij}^e g_j + c_{ij}^q q_j, \quad \varepsilon_k = \left( \partial u_i / \partial x_j + \partial u_j / \partial x_i \right) / 2,$$

$$\omega_q = \left( \partial u_i / \partial x_i - \partial u_i / \partial x_i \right) / 2,$$

(1)

where $\sigma_i = \sigma_i^e + \sigma_i^q$ 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 $c_{ij}^e$ and $c_{ij}^q$ (which depend on $H_0$ or $I_3$), given in reference 1. Here $f$, $g$, and $q$ are the customary symbols for index pairs in the theory of elasticity.