-71

JOINT INSTITUTE FOR NUCLEAR RESEARCH

Laboratory of Theoretical Physics

P-394

Ho Tso-hsiu

FORM FACTOR AND THE PROBABILITY OF THE β AND μ - DECAY OF THE Λ -PARTICLE

ЖЭТФ, 1959, т37, в6, с1825-1826.

Dubna 1959

Р-394

Ho Tso-hsiu

454/5

FORM FACTOR AND THE PROBABILITY OF THE β AND μ - DECAY OF THE Λ -PARTICLE

Preliminary experimental results about the transition probabilities of the β decay and the μ - meson decay of the Λ hyperon[1] seem small in comparison with the theoretical value obtained from the elementary theory of the (V - A) type universal Fermi weak interaction by considering the Λ as a point particle[2,3]. It will be interesting to estimate to what extent the form factor influences the value of the transition probability of these decay modes.

The matrix element of the leptonic decay of the Λ particle

$$\Lambda \longrightarrow p + L + \nu \tag{1}$$

can be written in the following form[4]

$$\begin{aligned} M &= \frac{G}{\sqrt{2}} \langle p | V_\alpha + A_\alpha | \Lambda \rangle \langle L | \gamma_\alpha (1+\gamma_5) | \nu \rangle \\ V_\alpha &= f_1 \gamma_\alpha + \frac{f_2}{m_\Lambda} \sigma_{\alpha\beta} k_\beta + \frac{i f_3}{m_\Lambda} k_\alpha \\ A_\alpha &= g_1 \gamma_\alpha \gamma_5 + \frac{g_2}{m_\Lambda} \sigma_{\alpha\beta} k_\beta \gamma_5 + \frac{i g_3}{m_\Lambda} k_\alpha \gamma_5 \end{aligned} \tag{2}$$

where L represents the μ - meson or the electron; $k = p_\Lambda - p_p$ - the 4 - momentum transfer, $\sigma_{\alpha\beta} = \frac{1}{2i}(\gamma_\alpha \gamma_\beta - \gamma_\beta \gamma_\alpha)$, f_i and g_i are invariant functions of the 4 - momentum transfer. If the time reversal is valid, all the $f's$ and $g's$ will be real.

The probability of the β - decay of the Λ - particle is

$$W_e = \frac{G^2 \epsilon_e^5}{60 \pi^3} \left[(f_1^2 + 3g_1^2)\left(1 + \frac{\epsilon_e}{m_\Lambda}\right) - 4 g_1 g_2 \frac{\epsilon_e}{m_\Lambda} \right] \tag{3}$$

and the probability of the μ meson decay of the Λ particle is

$$\begin{aligned} W_\mu = 0.03 \frac{G^2 m_\mu^5}{2\pi^3} \Big[& f_1^2 + 3g_1^2 + [f_1^2 + 9g_1^2 + f_1(f_1 + 2f_3) - g_1(g_1 + 2g_2)] \frac{m_\mu}{m_\Lambda} \\ & - [2g_1(f_1 + 2f_2) + 2g_1(g_1 + 2g_2)] \frac{\epsilon_\mu - m_\mu}{m_\Lambda} \Big] \end{aligned} \tag{4}$$

where ϵ represent the maximum energy of an electron or μ - meson. In expressions (3) and (4), the terms of order of magnitude $\frac{\epsilon_e^2}{m_\Lambda^2} \sim \frac{\epsilon_\mu^2}{m_\Lambda^2} \sim 0.02$ are neglected, and all the f and g are assumed to be constant in the interval of integration, since $\langle r^2 \rangle k^2 \ll 1$; where $\langle r^2 \rangle$ is the square of the radius of the Λ particle. It is easy to note, that in the case of β decay of the Λ particle only terms related to g_2 give large corrections to the transition probability. The terms of f_3 and g_3 can be neglected, since they are always proportional to the mass of the electron. In the case of μ meson decay, terms related to f_2, g_2, f_3 give large corrections, the pseudoscalar term g_3 is neglected here, because it has order of magnitude of $\left(\frac{m_\mu}{m_\Lambda}\right)^2$.

Although the present experimental situation seems unfavorable to the theoretical prediction on the rate of the β and μ decay of the Λ particle, but still it cannot be regarded as a serious discrepancy, because the experiment carried out does not accumulate enough statistics. Next, though both the signs and the order of magnitude of the form factor are unknown, we can hardly say more about the influence of the form factor on the probability of the β decay and the μ decay of the particle. It is to be noted, if we substitute experimental value in the above formula, put $Gm_N^2 = 1.01\times 10^{-5}$, $\frac{\epsilon_\mu}{m_\Lambda} \sim \frac{\epsilon_e}{m_\Lambda} \sim \frac{1}{7}$ and the experimental results of $W_e = \frac{1}{\tau_\Lambda}\cdot\frac{2}{1529} \sim 5\times 10^6$, we obtain

$$W_e = 5\times 10^6 = \frac{8}{7}\times 10^6\left[f_1^2 + 3g_1^2 - \frac{1}{2}g_1 g_2\right] \tag{5}$$

or

$$0.42 = f_1^2 + 3g_1^2 - \frac{1}{2}g_1 g_2. \tag{6}$$

For μ - decay

$$W_\mu = \frac{1}{6}\times 10^6\Big[f_1^2 + 3g_1^2 + \left[f_1^2 + 9g_1^2 + f_1(f_1+2f_3) - g_1(g_1+2g_2)\right]\frac{1}{10} - 2\left[g_1(f_1+2f_2) + g_1(g_1+2g_2)\right]\left(\frac{1}{7}-\frac{1}{10}\right)\Big]. \tag{7}$$

If we assume all the f and g are to be the same, i.e. they have the same order of magnitude, then we can estimate the probability of β - decay, roughly equal to

$$W_\mu \cong \frac{1}{6}W_e = 0.8\times 10^6. \tag{8}$$

It seems the ratio of $\frac{W_\mu}{W_e} \cong \frac{1}{6}$ is not sharply in contradiction with present experimental data (up to now only two cases of β - decay of the Λ particle, have been discovered in experiments but still we have no case of μ - decay of the Λ particle)[1].

In order to determine the effect of the form factors, if "total experiments", must be carried out the such as measuriment of the spectrum, angular correlation,up-down asymmetry, etc. We have already obtained all these formulas.

The author is grateful to Professor J.A. Smorodinsky for suggesting this problem and for many helpful discussions. We also wish to thank S.M. Bilenky and R.M. Ryndin for advice and discussion of the results.

R e f e r e n c e s

1. Frank S., Crawford, J. et al, Phys.Rev. Letters 1, 377, 1958,Paul Nordin, et al, Phys. Rev. Letters 1, 380, 1958.

2. R.P. Feynmann, M. Gell-Mann, Phys.Rev. 109, 193, 1958. E.C.G. Sudarshan, R.E. Marshak. Proc. of the Padua-Venice Conference(1957), Phys.Rev. 109, 1860, 1958.

3. V.M. Shekhter JETP, 35, 458, 1958.

4. J.A. Smorodinsky. Report at IX All-Union Conference on Nuclear Spectroscopy (in print).

Received by Publishing Department
on August 17, 1959.