ASYMMETRY PARAMETER OF Λ DECAY AND THE INTERMEDIATE BOSON OF WEAK INTERACTIONS*

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The magnitude of the pion asymmetry parameter α^- of the $\Lambda \to p+\pi^-$ decay has been determined[1] to be greater than or equal to (0.73 ± 0.14). The sign of this parameter, however, is rather hard to find. The results of Boldt et al.[2] and the preliminary results of Birge and Fowler[3] indicated a positive sign for α^-. Recently, however, Birge and Fowler[4] have reported a negative sign for α^-, contrary to their own preliminary[3] results.

In this Letter we wish to point out that the negative sign of α^-, provides a favorable argument for the conjecture that the V-A four-fermion interaction may be mediated by a vector boson.

A related problem has already been discussed in our previous work,[5] which is referred to as I in the Letter. There, however, we have developed the arguments under the assumption that the sign of α^- is positive, which was believed to be true at that time. The purpose of this note is to stress the implications of the negative sign. Let us adopt,[6] as in I, more or less in the spirit of the Sakata model, the tetrahedron scheme of four-fermion interactions, mediated by the charged vector bosons $B^\pm$. The weak interaction is thus assumed to be

$$H_{\text{weak}} = J_\alpha B_\alpha + \text{H.c.}, \tag{1}$$

where[7]

$$J_\alpha = F[\bar{e}\gamma_\alpha(1+\gamma_5)\nu + \bar{\mu}\gamma_\alpha(1+\gamma_5)\omega + \bar{n}\gamma_\alpha(1+\gamma_5)p + (F'/F)\bar{\Lambda}\gamma_\alpha(1+\gamma_5)p]. \tag{2}$$

The results of the local four-fermion interaction are obtained by taking the limit $m_B \to \infty$ and $F^2/m_B^2 \to G/\sqrt{2}$, where G denotes the usual Fermi coupling constant and m_B, the mass of the vector boson.

Starting with the above interaction, it was indicated in I that Fig. 1(b) may be the dominant diagram for $\Lambda \to N+\pi$ decays, instead of Fig. 1(a) (which had previously been considered[8] as the dominant diagram) for the following four reasons.

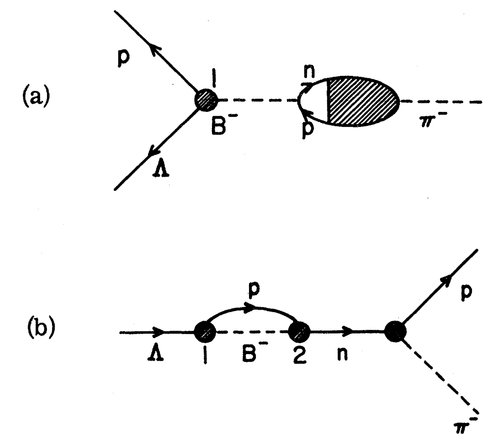

FIG. 1. Typical diagrams for $\Lambda \to p+\pi^-$ decay.

(i) From the point of view of dispersion relation calculations, taking the mass of Λ as a variable of the dispersion integral, the single-neutron state [Fig. 1(b)] is the lowest mass intermediate state contributing to the imaginary part of the matrix element.

(ii) While Fig. 1(a) contains an appreciable amount of $|\Delta\vec{I}| = 3/2$ transitions, Fig. 1(b) satisfies the strict $|\Delta\vec{I}| = \frac{1}{2}$ rule. Thus the dominance of Fig. 1(b) may be at the root of the approximate validity of the $|\Delta\vec{I}| = \frac{1}{2}$ rule.

(iii) If Fig. 1(a) is the main mechanism of $\Lambda \to N+\pi$ decays, it can explain the observed rate of Λ decay for a choice of $F' \approx (2.5)^{1/2} F$, while the slow leptonic modes of Λ and K-meson decays seem to require $F' \approx F/(10)^{1/2}$. If, however, Fig. 1(b) dominates over Fig. 1(a) [say, by a factor $\approx (20)^{1/2}$ in the matrix elements], one can hope to explain the rates of both leptonic and nonleptonic modes of strange particle decays with a single choice of F' [i.e., $F' \approx F/(10)^{1/2}$].

(iv) An actual perturbation-theoretic calculation[9] reveals the following:

(a) For reasonably finite values of m_B ($m_K < m_B < 2m_p$, say), the contribution of Fig. 1(b) is considerably bigger than that of Fig. 1(a).[10] For instance, one obtains [without any renormalization effects at vertices 1 and 2 in Fig. 1(b)] the following values for the absolute square of the ratio of the matrix elements:

$$|M[\text{Fig. 1(b)}]/M[\text{Fig. 1(a)}]|^2 \approx 8.8 \text{ for } \lambda \approx m_\Lambda,\ m_B \approx m_p,$$
$$\approx 73.6 \text{ for } \lambda \approx 1.5 m_p,\ m_B \approx m_p, \tag{3}$$

where λ denotes the Feynman cutoff parameter introduced to evaluate M [Fig. 1(b)].

(b) In the local limit ($m_B \to \infty$), the contribution of Fig. 1(b) vanishes for bare $V-A$ interaction. However, as shown in I, introduction of renormalization effects[11] at vertices 1 and 2 leads to significant contribution from Fig. 1(b). The introduction of such effects for finite values of m_B does not alter the qualitative aspects of the situation mentioned above in (a).

Thus we will proceed by assuming[12] that Fig. 1(b) is indeed the dominant diagram for Λ decay, even compared to diagrams other than Fig. 1(a). An important fact to be noticed now is the sign of the asymmetry parameter α^- given by Fig. 1(b), as a function of m_B. The following remarks are pertinent in this connection.

(1) Introducing the renormalization effects at vertices 1 and 2, as mentioned in reference 11, the matrix elements of Figs. 1(a) and 1(b) are found[9] to be proportional to

$$M[\text{Fig. 1(a)}] \propto \bar{u}_p(\gamma\cdot p_\pi)(1+A\gamma_5)u_\Lambda, \tag{4}$$

$$M[\text{Fig. 1(b)}] \propto \bar{u}_p(\gamma\cdot p_\pi)(\alpha+\beta\gamma_5)u_\Lambda, \tag{5}$$

where

$$\alpha = (A-B)O_1 - (A+B)(m_\Lambda/m_p)O_2,$$
$$\beta = (1-AB)O_1 + (1+AB)(m_\Lambda/m_p)O_2. \tag{6}$$

O_1 and O_2 are known[9] functions of m_Λ, m_p, m_B, and the cutoff parameter λ. The variations of O_1 and O_2 as a function of m_B are given in Table I for $\lambda = m_\Lambda$. The same qualitative behavior is obtained for other choices of λ.

(2) For positive values of A,[13] it is clear from Eq. (4) that Fig. 1(a) leads to a positive[14] sign for α^-, independent of the value of m_B.

(3) For finite values of m_B, and with no renormalization effects at vertices 1 and 2 in Fig. 1(b) (i.e., with $A=B=+1$), it is clear from Eq. (6) that $\beta/\alpha = -1$ for all values of the cutoff λ. This leads to negative values of the asymmetry parameter α^-.

(4) The above conclusion regarding the sign of α^- holds, even if we introduce renormalization effects at vertices 1 and 2, as long as A and B are positive. Thus the conclusion for finite values of m_B is not so sensitive to the choice of the renormalization effects.

(5) In the local limit ($m_B \to \infty$), $O_2 \to 0$ (see Table I). In this case the conclusion depends rather strongly on the choice of the renormalization effects, since without any renormalization effect, i.e., for $A=B=+1$, α and $\beta \to 0$ as $m_B \to \infty$. For a choice of A and $B>1$, with $B>A$, however, α^- is positive (see Table I, last column).

Thus we find that the negative sign of α^- may

Table I. Asymmetry parameter of $\Lambda \to p+\pi^-$ decay.[a]

m_B (Mev)	$O_1 \times 10^2$	$O_2 \times 10^2$	α^- ($A=B=+1$)	α^- ($A=+1$, $B=+1.25$)
500	4.29	-5.71	-0.90	-0.948
938	5.55	-5.20	-0.90	-0.95
1876	7.43	-4.05	-0.90	-1.0
4690	17.40	-1.09	-0.90	+0.573
∞	40.48	0	Zero amplitude	+0.90

[a]The values listed in this table are for a choice of the cutoff $\lambda = m_\Lambda$. Column 4 gives the asymmetry parameter α^- for Fig. 1(b) without any renormalization effect at vertices 1 and 2 ($A=B=+1$). Column 5 gives α^- for a particular choice of the renormalization effects ($A=+1$, $B=+1.25$).

indeed favor the intermediate-boson hypothesis. Since we have little knowledge of the true nature of the renomalization effects at vertices 1 and 2, we cannot, however, conclude that the negative sign of α^- would totally exclude the local four-fermion interaction, while the positive sign would exclude the nonlocal one. The purpose of this Letter is, however, to stress that, if future experiments confirm a negative sign for α^-, there is a more straightforward way to understand this result simply (even without any renormalization effects) within the intermediate-boson framework (m_B finite) than without it ($m_B \to \infty$). On the other hand, if experiments confirm a positive sign for α^-, the same picture will favor a local four-fermion interaction rather than a nonlocal one.

With our present experimental limitations, we have to infer the existence of the B meson from processes where its role as a virtual intermediate particle may be important. In this connection, it is important to recall that the introduction of a B meson with mass nearly equal to the mass of the K meson gives rise to a nonlocal effect,[15] which could explain[16] the observed lifetimes of O^{14} and μ decay on the hypotheses of strictly universal couplings and conserved vector current.[17] It also accounts for the recently observed[18] value of the Michel parameter, $\rho = 0.78 \pm 0.025$, which is slightly higher than the normally expected value 0.75. The implication[19] from the slowness of $\mu \to e + \gamma$ decay is an unsettled[16] question, until one determines[20] the nature of the neutrinos associated with the muon and the electron. On the basis of the picture presented in this Letter, the sign of the asymmetry parameter α^- could favor or disfavor the intermediate-boson hypothesis.

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[4] R. W. Birge and W. B. Fowler, Phys. Rev. Letters 5, 254 (1960).

[5] S. Oneda, J. C. Pati, and B. Sakita, Phys. Rev. 119, 482 (1960). Other references are cited here.

[6] The extension of our arguments to other intermediate-boson models, such as proposed by T. D. Lee and C. N. Yang, Phys. Rev. 119, 1410 (1960), is straightforward and leads to similar conclusions to those discussed here.

[7] It is pertinent to notice that the arguments in this Letter will rest heavily on the belief that all currents in J_α, including the (Λp) current, have the same chiral form, i.e., positive chiral form as in β decay.

[8] See for instance, S. Okubo, R. E. Marshak, and E. C. G. Sudarshan, Phys. Rev. 113, 944 (1959).

[9] See reference 5. For details, see J. C. Pati, thesis, University of Maryland, 1960, Physics Department Technical Report No. 193 (unpublished).

[10] The contribution of Fig. 1(a) is calculated from the observed rate of $\pi \to \mu + \nu$ decay.

[11] This was done phenomenologically in I by replacing vertices 1 and 2 in Fig. 1(b) by $f'\gamma_\alpha(1+A\gamma_5)$ and $f\gamma_\alpha(1+B\gamma_5)$, respectively. A and B denote the renormalization effects and were treated as positive constants. For the purpose of orientation, we had adopted $A \approx 1$, $B \approx +1.25$. The exact choice of A and B, however, does not affect our arguments in the present Letter regarding the sign of α^- for finite values of m_B, as long as A and B are considered as positive.

[12] The application of such a picture to K-meson decays seems to be consistent with the relative rates of all the decay modes of the K meson. See J. C. Pati, S. Oneda, and B. Sakita, Nuclear Phys. 18, 318 (1960).

[13] Starting from bare positive chiral currents, it is reasonable to assume that the strong virtual effects are perhaps not so drastic as to lead to negative values for either A or B or both.

[14] Thus, if α^- turns out to be negative, Fig. 1(a) can clearly be excluded from being the dominant mechanism of Λ decay.

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