Phenomenological Analysis of Hyperon Decay*†

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(Received February 16, 1959)

The $\Delta I=\frac{1}{2}$ rule is incorporated into a previously discussed universal weak Yukawa interaction by assuming the simplest relation between chirality and charge operators. Expressing the $\Delta I=\frac{1}{2}$ rule by forming the N and Ξ isospinors into an isovector $\mathbf{B}$ and an isoscalar B_0, we assume $\mathbf{B}$ occurs (as in β decay) with $g\gamma_\mu\frac{1}{2}(1+r\gamma_5)$ and B_0 (which has no β-decay counterpart) with $g\gamma_\mu\frac{1}{2}(1-r\gamma_5)$. Here g is the constant previously fitted to the π decay rate, and r the ratio of Gamow-Teller and Fermi coupling constants. Depending on the sign taken between the $\mathbf{B}$ and B_0 interaction terms, Σ decays into $n+\pi^+$ in pure S and into $n+\pi^-$ in pure P channels, or vice versa. In either case, $\Sigma^+\rightarrow p+\pi^0$ involves maximal S-P interference and $\alpha^0=0.98$. Decay into $I=\frac{1}{2}$ proceeds via $\gamma_\mu(\frac{1}{2}+\frac{3}{2}r\gamma_5)$ or $\gamma_\mu(\frac{3}{2}+\frac{1}{2}r\gamma_5)$, depending on whether Σ^- decay is pure S or pure P. The second case, but not the first, leads to a Λ-decay rate in agreement with experiment. In this case $\alpha_\Lambda=0.54$, and in Ξ^- decay, $\alpha_\Xi=0.64$ and the calculated decay rate is 2.4×10^{-10} sec^{-1}.

I. INTRODUCTION

In a recent paper,[1] we discussed the consequences of assuming a phenomenological weak Yukawa interaction

$$(g/M\sqrt{2})\partial_\mu\phi\bar{\psi}\gamma_\mu(1+\gamma_5)\psi \tag{1}$$

between a meson field ϕ, with mass M, and various fermion pairs ψ. This interaction, with

$$g^2/4\pi=3.67\times10^{-15} \tag{2}$$

fitted to the experimental charged pion lifetime, was proposed tentatively as an alternative to calculating decays involving mesons through the strong couplings $\pi(NN)$, $K(NY)$ and the Fermi interactions (NY) (NN), (NN) $(\mu\nu)$, and (NN) $(e\nu)$. The possibility of attributing all weak processes to a more or less universal Fermi interaction involving only one weak coupling constant is certainly attractive in principle, provided the outstanding discrepancy between the predicted and observed rates of hyperon β decay can be explained. In practice, however, the number of virtual states possible is so large and the difficulties of strong-coupling calculations so severe, that we preferred—tentatively at least—to calculate with the simple phenomenological interaction (1).

If virtual baryon pairs are responsible for the observed meson and hyperon decays, then g, instead of being a universal constant, will be a form factor function $g(p,m)$ of the momentum transfer and intermediate states (each of mass m) involved. Because of the variety of intermediate states possible and the apparent damping[2] of the strong meson-baryon coupling constants g_π and g_K, it is conceivable that $g(p,m)$ actually turn out to be effectively constant for a variety of processes.

In the earlier paper no attempt was made to calculate branching ratios that would follow, for example, from rules for strangeness change, like the $\Delta I=\frac{1}{2}$ rule. In this paper, motivated by the recent experiments on Σ decay,[3] we attempt to include the $\Delta I=\frac{1}{2}$ rule by making a simple assumption about the relation of charge operators and chirality. The $\Delta I=\frac{1}{2}$ rule, like the interactions we discuss, is a phenomenological rule that is so far consistent with all information on hyperon and K-meson decays, with the possible exception of the $\theta_1^0\rightarrow 2\pi^0/(\pi^++\pi^-)$ ratio. Recently, attempts have been made[4] to derive some of the consequences of the $\Delta I=\frac{1}{2}$ rule from more basic theoretical ideas about the relation of strangeness-changing and strangeness-preserving baryon pairs. These attempts are also frustrated by the practical impossibility of including all virtual strong processes we know to be important. For that reason, we believe that the predictions of the simple but phenomenological weak Yukawa interaction and $\Delta I=\frac{1}{2}$ rule are worth comparing with experiment. Even if the basic process is the weak Fermi interaction, useful physical orientation may be gained in this way.

II. CHARGE-INDEPENDENT DESCRIPTION OF DECAYS INVOLVING UNSTRANGE PARTICLES

Our purpose is now to write the π-decay and hyperon-decay interactions in a charge-independent form. In doing this we actually generalize somewhat from the empirical charge-exchange character of $\pi^\pm\rightarrow\mu^\pm+\nu$ and $n\rightarrow p+e^-+\nu$. Such a generalization is necessary because in the strange decays charge retention, $\Lambda\rightarrow n+\pi^0$, $\Sigma^+\rightarrow p+\pi^0$, occurs along with charge exchange, $\Lambda\rightarrow p+\pi^-$, $\Sigma^\pm\rightarrow n+\pi^\pm$. Such a generalization is also suggested theoretically[1] if the Fermi interactions are to be derived from a continuous symmetry group, since the charge-exchange interactions involving τ^+ and τ^- form a group only when τ_3 is also included.

* Presented at the Conference on Weak Interactions, Gatlinburg, Tennessee [Bull. Am. Phys. Soc. Ser. II, 4, 77 (1959)].
† Work done under the auspices of the U. S. Atomic Energy Commission.
[1] S. A. Bludman, Nuovo cimento **9**, 433 (1958).
[2] M. L. Goldberger and S. B. Treiman, Phys. Rev. **110**, 1178 (1958).
[3] Cool, Cork, Cronin, and Wenzel, Phys. Rev. **114**, 912 (1959). I am indebted to Dr. R. L. Cool for access to his results before publication.
[4] R. H. Dalitz, Revs. Modern Phys. (to be published), reviews these attempts, which are originally due to Gell-Mann, Okun, and Marshak and collaborators.

The generalization of the β-decay and π-decay interactions to a charge-independent form leads to the prediction of specific weak processes, $e^-+p\to e^-+p$ and $\pi^0\to e^++e^-$, with the same coupling constant as in $e^-+p\to\nu+n$ and $\pi^+\to e^++\nu$. Both these weak charge-retention interactions are, unfortunately, completely masked by identical processes proceeding through the electromagnetic interactions. Specifically, if μ and ν (and also e and ν) are regarded as members of a charge doublet Ψ, so that $\bar{\Psi}\boldsymbol{\tau}\gamma_\mu(1+\gamma_5)\Psi$ is the lepton covariant involved in π decay, then the interaction (1) assumes the charge-independent form

$$H_\pi=(g/M)\partial_\mu\boldsymbol{\phi}\cdot\bar{\Psi}\boldsymbol{\tau}\gamma_\mu\tfrac{1}{2}(1+\gamma_5)\Psi. \qquad (1')$$

This interaction leads to $\pi^0\to e^++e^-$ at the rate 1.0×10^4 sec^{-1}. However, π^0 decays into 2γ (presumably electromagnetically) at a rate $>10^{15}$ sec^{-1} and hence[5] into e^++e^- at a rate faster than $2[\alpha(m_e/M_\pi)\ln(M_\pi/m_e)]^2\times10^{15}=10^7$ sec^{-1}. The charge-retaining part of Eq. (1′) is thus completely hidden by the electromagnetic interactions, which also lead to $\pi^0\to e^++e^-$.

III. CHARGE-INDEPENDENT DESCRIPTION OF HYPERON DECAY

1. Spurion Formulation of $\Delta I=\frac{1}{2}$ Rule

We now write the hyperon-decay interactions in charge-independent form by the device of introducing a "spurion" S that transforms as an isotopic spinor, but carries no other physical attributes.[6] With S the nucleon isospinor $N=\begin{pmatrix}n\\p\end{pmatrix}$ can form an isovector $\bar{N}\boldsymbol{\tau}S$ or an isoscalar $\bar{N}S$. Then, taking $S=\begin{pmatrix}1\\0\end{pmatrix}$ so that the fictitious spurion carries no charge, we have

$$\mathbf{B}=\bar{N}\boldsymbol{\tau}S=(\bar{p},i\bar{p},\bar{n}),\qquad B_0=\bar{N}S=\bar{n}. \qquad (3)$$

With this isovector and this isoscalar, the Σ-decay interaction

$$H_\Sigma=\{B_0\mathcal{O}'\boldsymbol{\Sigma}+i\mathbf{B}\times\mathcal{O}\boldsymbol{\Sigma}\}\cdot\boldsymbol{\pi} \qquad (4)$$

involves only two different interactions $\mathcal{O}$ and $\mathcal{O}'$. When Eq. (3) is substituted into Eq. (4), we have

$$H_\Sigma=\bar{n}(\mathcal{O}'+\mathcal{O})\pi^-\Sigma^-+[\bar{n}(\mathcal{O}'-\mathcal{O})\pi^++\sqrt{2}\bar{p}\mathcal{O}\pi^0]\Sigma^+ +[\bar{n}\mathcal{O}'\pi^0+\sqrt{2}\bar{p}\mathcal{O}\pi^-]\Sigma^0, \qquad (5)$$

where $\pi^\pm$ emits $\pi^\pm$ and $\Sigma^\pm$ absorbs $\Sigma^\pm$. The Σ^0 decay interaction in Eq. (5) is weak compared with the electromagnetic interaction $\Sigma^0\to\Lambda+\gamma$ and will be dropped hereafter. $\mathcal{O}^0$, $\mathcal{O}^+$, and $\mathcal{O}^-$ will be used to designate the amplitudes for $\Sigma^+\to p+\pi^0$, $\Sigma^+\to n+\pi^+$, and $\Sigma^-\to n+\pi^-$, respectively.

[5] S. D. Drell, Nuovo cimento (to be published).
[6] G. Wentzel, *Proceedings of the Sixth Annual Rochester Conference* (Interscience Publishers, Inc., New York, 1956); B. d'Espagnat and J. Prentki, Nuovo cimento **3**, 1045 (1956); and others.

TABLE I. Dimensionless phase-space and matrix elements of γ_μ and $\gamma_\mu\gamma_5$ for hyperon decay according to the interaction (8). The V and A matrix elements squared, with $r^2=1.42$, are given in the last two columns. These lead to partial decay rates and decay asymmetries given, once a and b are chosen, by Eqs. (9) and (10), respectively.

	$q/(M_Yc)$	$\langle\gamma_\mu\rangle$	$\langle\gamma_\mu\gamma_5\rangle$	$\langle\gamma_\mu\rangle^2$	$\langle r\gamma_\mu\gamma_5\rangle^2$
$\Sigma^-\to n+\pi^-$	0.160	1.83	1.55	3.36	3.42
$\Sigma^+\to p+\pi^0$	0.159	1.86	1.57	3.46	3.49
$\Sigma^+\to n+\pi^+$	0.156	1.79	1.48	3.22	3.12
$\Xi^-\to\Lambda+\pi^-$	0.104	1.50	1.14	2.25	1.85
$\Lambda\to p+\pi^-$	0.0896	1.27	0.780	1.60	0.87

Since, from Eq. (5), we have $\mathcal{O}^0=\sqrt{2}\mathcal{O}$, $\mathcal{O}^+=(\mathcal{O}'-\mathcal{O})$, $\mathcal{O}^-=(\mathcal{O}'+\mathcal{O})$, the constraint $\sqrt{2}\mathcal{O}^0=\mathcal{O}^--\mathcal{O}^+$, which is also imposed by the usual $\Delta I=\frac{1}{2}$ rule, is immediately recognized here. The amplitudes for decay into isospin $\frac{3}{2}$ and $\frac{1}{2}$ are

$$\mathcal{O}^3=\mathcal{O}^-,\qquad \mathcal{O}^1=\tfrac{1}{2}(3\mathcal{O}^+-\mathcal{O}^-). \qquad (6)$$

The interactions responsible for Λ and Ξ decay involve only the isovector $\bar{N}\boldsymbol{\tau}S$ formed through the spurion device:

$$H_\Lambda=\{(\bar{N}\boldsymbol{\tau}S)\mathcal{O}''\Lambda\}\cdot\boldsymbol{\pi}=(\sqrt{2}\bar{p}\pi^-+\bar{n}\pi^0)\mathcal{O}''\Lambda,$$
$$H_\Xi=\{\bar{\Lambda}\mathcal{O}'''(\bar{S}\boldsymbol{\tau}\Xi)\}\cdot\boldsymbol{\pi}=\bar{\Lambda}\mathcal{O}'''(\sqrt{2}\Xi^-\pi^--\Xi^0\pi^0). \qquad (7)$$

The $\sqrt{2}$:1 ratio predicted by the $\Delta I=\frac{1}{2}$ rule for the ratio of the amplitudes $(\Lambda\to p+\pi^-)/(\Lambda\to n+\pi^0)$ and for $(\Xi^-\to\Lambda+\pi^-)/(\Xi^0\to\Lambda+\pi^0)$ is apparent here also.

2. Dynamical Assumption About the Interaction Forms $\mathcal{O}$ and $\mathcal{O}'$ in Σ Decay

So far the spurion formulation (which is identical to the assumption $\Delta I=\frac{1}{2}$) has been introduced only to express the dependence of the decay interaction on the ordinary charge operators $\boldsymbol{\tau}$ and 1. A specific assumption (made in the next paragraph) concerning the spin and momentum dependence contained in $\mathcal{O}$ and $\mathcal{O}'$ leads to a generalization of the heretofore used interaction (1) to the new form

$$H_Y=(g/M)2^{-\frac{1}{2}}\partial_\mu\pi\bar{\psi}(a+b\gamma_5)\psi, \qquad (8)$$

in which a and b are parameters depending on the baryon charge states in such a way that the $\Delta I=\frac{1}{2}$ rule will now be satisfied. With the neglect of final-state interaction, Eq. (8) leads to a decay rate

$$W=(g^2/4\pi)\frac{(M_N+E_N)c^2}{2\hbar}\times(a^2\langle\gamma_\mu\rangle^2+b^2\langle\gamma_\mu\gamma_5\rangle^2)(q/M_Yc), \qquad (9)$$

and a pion asymmetry

$$\alpha=2ab\langle\gamma_\mu\rangle\langle\gamma_\mu\gamma_5\rangle/[a^2\langle\gamma_\mu\rangle+b^2\langle\gamma_\mu\gamma_5\rangle]. \qquad (10)$$

Here E_N, M_N, E, M are the energies and masses of the decay nucleon and pion; q is the final-state momentum

TABLE II. Partial decay rates and pion asymmetries for the three modes of charged Σ decay calculated from the effective interaction (13) of the V-A form. Solutions (1) and (2) correspond to choosing + or − for the relative sign between the isoscalar and isovector terms in Eq. (13). The observed decay ratio and asymmetries are taken from Glaser[a] and Cool *et al.*,[b] respectively.

	Decay rate (in 10^{10} sec^{-1})			Asymmetry		
	Solution (1)	Solution (2)	Observed	Solution (1)	Solution (2)	Observed
$\Sigma^+ \rightarrow p+\pi^0$	0.59	0.59	0.65	0.98	0.98	$\geqslant 0.70\pm0.30$
$\Sigma^+ \rightarrow n+\pi^+$	0.52	0.53	0.68	0	0	$\leqslant 0.03\pm0.11$
$\Sigma^- \rightarrow n+\pi^-$	0.57	0.58	0.58	0	0	?

[a] See reference 8.
[b] See reference 3.

and M_Y the parent hyperon mass, so that (q/M_Yc) is a dimensionless measure of the phase space available. The matrix elements

$$\langle\gamma_\mu\rangle = \left(1+\beta^2\frac{E}{E+M}\right)\frac{E}{Mc^2},$$

$$\langle\gamma_\mu\gamma_5\rangle = \left(1+\frac{E}{E+M}\right)\frac{q}{Mc},$$

where βc is the decay pion's velocity, are given in Table I for the momentum transfers obtaining in hyperon decay. The quantities $\langle\gamma_\mu\rangle$ and $\langle\gamma_\mu\gamma_5\rangle$ are, within 10%, the total energy and momentum of the decay pion, in units of its mass. With $g^2/4\pi = 3.67 \times 10^{-15}$, the numerical formula

$$W = (0.53\times10^{10}\ \text{sec}^{-1})(a^2\langle\gamma_\mu\rangle^2 + b^2\langle\gamma_\mu\gamma_5\rangle^2)q/M_Yc \quad (11)$$

is obtained. From Eqs. (11) and (10), together with the entries in Table I, the rate of any hyperon decay and the asymmetry α can be read off immediately once the amounts a and b of V and A are decided upon.

Now, the $\boldsymbol{\tau}$ operator has appeared before in π decay and in β decay: there the spinor form of the interaction is known to be $\mathcal{O} = g\gamma_\mu\frac{1}{2}(1+r\gamma_5)$, where $r = -g_A/g_V$ is the ratio of Gamow-Teller and Fermi coupling constants. We assume that the $\boldsymbol{\tau}$ operator *always* occurs in combination with

$$\mathcal{O} = g\gamma_\mu\tfrac{1}{2}(1+r\gamma_5), \quad (12a)$$

and the 1 operator always with

$$\mathcal{O}' = g'\gamma_\mu\tfrac{1}{2}(1-r\gamma_5), \quad (12b)$$

with $g^2/4\pi = g'^2/4\pi$ equal to the same universal coupling constant, Eq. (2), chosen to fit the $\pi^\pm$ decay rate.

Phenomenologically we have no way for choosing r, the ratio of A to V strengths. In μ decay we have $r\approx 1$, and in neutron decay[7] $r = 1.19\pm0.03$. There is the feeling that in the absence of strong interactions r should be precisely 1, and that the departure from unity in β decay is a strong-coupling renormalization effect. In any case, r has so far been neither observed nor calculated for hyperon decay. In the numerical results to be presented we assume simply that the renormalization effects operating in hyperon decay are similar to those in β decay, and insert $r = 1.19$. This choice of r makes the matrix elements of $\langle r\gamma_\mu\gamma_5\rangle$ approximately equal to those of $\langle\gamma_\mu\rangle$ at the energies characteristic of Σ decay.

3. Σ Decay

The two possibilities for the relative sign between the B_0 and $\mathbf{B}$ terms lead to two possible Yukawa theories for Σ decay,

$$g/M\{B_0\gamma_\mu\tfrac{1}{2}(1-r\gamma_5)\boldsymbol{\Sigma}\pm i\mathbf{B}\times\gamma_\mu\tfrac{1}{2}(1+r\gamma_5)\boldsymbol{\Sigma}\}\cdot\partial_\mu\boldsymbol{\pi}. \quad (13)$$

Solution (1), for $g = +g'$, is

$$(g/M\sqrt{2})\{\bar{p}\gamma_\mu(1+r\gamma_5)\Sigma^+\partial_\mu\pi^0 + \bar{n}(\sqrt{2}r\gamma_\mu\gamma_5)\Sigma^+\partial_\mu\pi^+ + \bar{n}(\sqrt{2}\gamma_\mu)\Sigma^-\partial_\mu\pi^-\}. \quad (14)$$

Solution (2), for $g = -g'$, is

$$(g/M\sqrt{2})\{\bar{p}\gamma_\mu(1+r\gamma_5)\Sigma^+\partial_\mu\pi^0 + \bar{n}(\sqrt{2}\gamma_\mu)\Sigma^+\partial_\mu\pi^+ + \bar{n}(\sqrt{2}r\gamma_\mu\gamma_5)\Sigma^-\partial_\mu\pi^-\}. \quad (15)$$

In Solution (1), $\Sigma^+\rightarrow n+\pi^+$ through the pure A interaction (with $b=\sqrt{2}r$), and $\Sigma^-\rightarrow n+\pi^-$ through the pure V interaction (with $a=\sqrt{2}$). In Solution (2), the reverse is the case. In both cases $\Sigma^+\rightarrow p+\pi^0$ through the V-A mixture (with $a=1, b=r$). As a consequence, $\alpha^0=\alpha^-=0$ and $\alpha^+\sim 1$. The Σ-decay rates calculated from Eq. (11) in this way are given in Table II along with the observed rates,[8] with which they agree within about 30%.

4. Λ and Ξ Decay

1. If the principle enunciated in the preceding subsection—that $\boldsymbol{\tau}$ always occurs in combination with $\gamma_\mu\frac{1}{2}(1+r\gamma_5)$—is adhered to, then in Λ and Ξ decay $\mathcal{O}''$ and $\mathcal{O}'''$ are given by Eq. (12a) and the interaction forms responsible for Λ and Ξ decay are

$$H_\Lambda = (g/M)(\sqrt{2}\bar{p}\partial_\mu\pi^- + \bar{n}\partial_\mu\pi^0)\gamma_\mu\tfrac{1}{2}(1+r\gamma_5)\Lambda,$$

and (16)

$$H_\Xi = (g/M)\bar{\Lambda}\gamma_\mu\tfrac{1}{2}(1+r\gamma_5)(\sqrt{2}\Xi^-\partial_\mu\pi^- + \Xi^0\partial_\mu\pi^0).$$

[7] Burgy, Krohn, Novey, Ringo, and Telegdi, Phys. Rev. Letters **1**, 324 (1958); Sosnowski, Spivak, *et al.*, quoted by M. Goldhaber in *Proceedings of the Annual International Conference on High-Energy Physics, CERN, 1958*, edited by B. Ferretti (CERN, Geneva, 1958).

[8] Summary talk by D. Glaser, *Proceedings of the Annual International Conference on High-Energy Physics, CERN, 1958*, edited by B. Ferretti (CERN, Geneva, 1958).

TABLE III. Partial decay rates and pion asymmetries for $\Lambda \to p+\pi^-$ and $\Xi^- \to \Lambda+\pi^-$ calculated from the effective interaction (7) of the V-A form. Solutions (1) and (2) are obtained by assuming that the interactions forms responsible for Λ and Ξ decay are the same as those leading to isospin $\frac{1}{2}$ in Σ decay. Solution (3) is obtained by assuming that the interaction (12a) is associated with the $\boldsymbol{\tau}$ operator. The observed decay rates and asymmetries are taken from Glaser.[a]

	Decay rate (in 10^{10} sec^{-1})				Asymmetry			
	Solution (1)	Solution (2)	Solution (3)	Observed	Solution (1)	Solution (2)	Solution (3)	Observed
$\Xi^- \to \Lambda+\pi^-$	0.37	0.42	0.23	0.005–0.2	0.55	0.64	0.95	?
$\Lambda \to p+\pi^-$	0.14	0.24	0.12	0.25	0.66	0.54	0.89	$\geqslant 0.7\pm0.1$

[a] See reference 8.

For Λ decay this interaction gives an asymmetry $\alpha_\Lambda=0.89$, which is in good agreement with the experimental value $\alpha_\Lambda=0.7\pm0.1$, but also gives a transition rate into $p+\pi^-$ of 0.12×10^{10} sec^{-1}, which is in poor agreement with the value 0.25×10^{10} sec^{-1} observed. For $\Xi^- \to \Lambda+\pi^-$ this interaction gives $\alpha_\Xi=0.95$ and $W_\Xi=0.23\times10^{10}$ sec^{-1}. These values are listed as Solution (3) in Table III.

2. According to Eq. (6), in Σ decay into all of the isospin-$\frac{1}{2}$ channel the interaction operator is

$$\mathcal{O}^1=\begin{cases} -g\gamma_\mu\frac{1}{2}(1+3r\gamma_5) & [\text{Solution (1)}], \\ g\gamma_\mu\frac{1}{2}(3+r\gamma_5) & [\text{Solution (2)}]. \end{cases} \quad (17)$$

Now Λ and Ξ decay only into the isospin-$\frac{1}{2}$ final state (of which $\Lambda \to p+\pi$ and $\Xi^- \to \Lambda+\pi^-$ constitute in each case two-thirds). If this $I=\frac{1}{2}$ final state, rather than the association of the $\boldsymbol{\tau}$ operator with $\gamma_\mu\frac{1}{2}(1+r\gamma_5)$, is determining, then the asymmetries and rates listed in the first two columns of Table III are obtained.

Between these two solutions, Solution (2) gives a P- to S-wave decay amplitude $(P/S)_\Lambda=0.29$, consistent with the evidence $(P/S)_\Lambda<1$ from the analysis[9] of light hyperfragments. [Solutions (1) and (3) give $(P/S)_\Lambda=2.61$ and 0.87 respectively.] Solution (2) leads to a Λ-decay rate agreeing with experiment but a decay asymmetry barely in agreement with the lower of the two measured values $\alpha\geqslant0.67\pm0.13$ (by the Columbia group) and $\alpha\geqslant0.73\pm0.14$ (by the Berkeley group).

[9] R. H. Dalitz, Phys. Rev. **112**, 605 (1958).

Solution (2) predicts a Ξ^- lifetime of 2.4×10^{-1} second.

The observed rates quoted in Tables II and III are each subject to about 10% uncertainty. Even within the framework of our Yukawa model, the neglect of strong couplings (final-state interaction corrections are $\leqslant10\%$), departures from charge independence (the Σ and π masses each differ among themselves by a few percent), and uncertainty about the V-A ratio r must lead to a theoretical uncertainty that is also at least 10%.

IV. CONCLUSIONS

We have found that Σ-decay rates and asymmetries in fairly good agreement with present experimental data can be calculated from the universal weak Yukawa interaction (8) by making the simplest assumption relating the chirality operators $\gamma_\mu\frac{1}{2}(1+\gamma_5)$ or $\gamma_\mu\frac{1}{2}(1+r\gamma_5)$ and $\gamma_\mu\frac{1}{2}(1-r\gamma_5)$ to charge operators $\boldsymbol{\tau}$ and 1.

The same simple assumption unfortunately leads to too slow a decay rate when applied to Λ decay [Solution (3) in Table III]. If, on the other hand, the isospin-$\frac{1}{2}$ interaction (17) found in Σ decay is also applied to Λ decay, then in one case, corresponding to a P/S ratio 0.29, a reasonable Λ-decay rate is obtained, along with a rather low asymmetry.

The approach relating Λ decay to Σ decay through the isospin-$\frac{1}{2}$ channel has already been employed by Cool *et al.*,[3] who from the observed Σ-decay rates, obtain Λ-decay rates and asymmetries similar to our Solutions (1) and (2). By assuming the phenomenological Yukawa interaction we have, on the other hand, obtained *absolute* rates for Ξ, Σ, and Λ decay separately.