On Symmteries Shared by Strong and Weak Interactions

ABRAHAM PAIS

Institute for Advanced Study, Princeton, New Jersey

IT is a general characteristic of weak interactions that they violate parity. It is a general characteristic of all known weak leptonic transitions that they violate parity maximally. This maximal violation is accounted for by the so-called two-component neutrino structure of the weak leptonic interactions.

In the first investigations of nonleptonic decays, where

$$\Lambda \to p+\pi^- \tag{1}$$

was studied, this maximal trend seemed to persist.[1] However, the Σ decays

$$\Sigma^+ \to n+\pi^+ \tag{2}$$

$$\Sigma^+ \to p+\pi^0 \tag{3}$$

$$\Sigma^- \to n+\pi^- \tag{4}$$

showed something new in this respect. In reactions (2) and (4), the degree of parity violation is quite small.[2] Thus, optimal parity violation is certainly no general rule for nonleptonic processes. The mode of $\Sigma_0{}^+$, on the other hand,[3] shows, like the Λ decay, again nearly maximal s, p interference.

We can say something more than just that $\Sigma_+{}^+$ and $\Sigma_-{}^-$ are nearly conserving if we invoke the $\Delta T=\frac{1}{2}$ rule. In what follows, the apparently good approximation is made that this rule is strictly valid for nonleptonic processes, without regard as to whether deviations from the rule are of purely electromagnetic origin or not. The question of whether this rule also applies to leptonic processes does not concern us here; experimental information on this last point is quite limited.

The amplitudes for reactions (2)–(4) each have generally an s and a p component. If we assume invariance under time reversal and neglect small final state interactions, the A's can be considered as vectors in a real (s,p) plane. The $\Delta T=\frac{1}{2}$ rule implies that A^+, A^-, and $A^0\sqrt{2}$ form a triangle in this plane.[4] Experimental results are not only compatible with this condition but, more specifically, they imply the following. The parity properties of $\Sigma_+{}^+$ and $\Sigma_-{}^-$ mean that A^+ and A^- are nearly aligned along the p or s axes. The $\Delta T=\frac{1}{2}$ rule now says that if A^+ is aligned along the p axis, then A^- is aligned along the s axis or vice versa. In other words, with respect to the reactions (2) and (4), the particles Σ^+ and Σ^- do not only behave as if they each have "almost" a well-defined parity with respect to π-nucleon systems, but moreover these two respective parities are opposite to each other.[5]

The truly remarkable nature of these parity phenomena comes only then fully to light if we consider the influence of the strong interactions on these weak processes. As an example, consider the following virtual transitions by which Σ^- may proceed:

$$\Sigma^- \xrightarrow{S} \Lambda+\pi^- \xrightarrow{W} p+2\pi^- \xrightarrow{S} n+\pi^-, \tag{5}$$

$$\Sigma^- \xrightarrow{S} \Sigma^+ +2\pi^- \xrightarrow{W} n+\pi^+ +2\pi^- \xrightarrow{S} n+\pi^-. \tag{6}$$

Here S or W above an arrow means that the transition in question is a strong or a weak one.[6] S transitions conserve parity. In Eq. (5) the W link is known to be strongly parity violating (at least on the mass shell), yet the net result of the sequence (5) must be parity conserving—unless there are cancellations with other sequences. In Eq. (6) the W link is nearly parity conserving. To fix ideas, let us suppose that $\Sigma_+{}^+$ is a p-wave decay. Then, with respect to this channel, Σ^+ has even parity relative to nucleons. As Σ^+ also has even parity relative to Σ^-, it follows that the sequence (6) produces a p-wave contribution to A^-. Yet, as we have seen, A^- should be almost purely an s-wave amplitude if, as was assumed for a moment, A^+ is a p-wave amplitude. Thus, we would like to cancel or inhibit the sequence (6). And so on.

Thus, this Σ puzzle has the following features: (a) we meet somewhat unexpectedly with near parity conservation in certain weak interactions; (b) the channels $\Sigma_+{}^+$ and $\Sigma_-{}^-$ have opposite relative parity; (c) the strong interactions seem effectively to avoid, as it were, to use many opportunities to mix up strongly parity violating with nearly parity conserving channels, or to mix up weak parity conserving channels of opposite parity. Clearly then, this puzzle can be solved only if in some sense the weak *and* the strong interactions cooperate to maintain certain orderly patterns.

---

[1] *Proceedings of the International Conference on High Energy Physics* (Interscience Publishers, Inc., New York, 1959), p. 265.

[2] B. Cork, L. Kerth, W. Wenzel, J. Cronin and R. Cool, Phys. Rev. **120**, 1000 (1960).

[3] Reactions (2)–(4) will be denoted as $\Sigma_+{}^+$, $\Sigma_0{}^+$, and $\Sigma_-{}^-$, respectively. The amplitudes for reaction (1)–(4) will be called A_Λ, A^+, A^0, and A^-.

[4] M. Gell-Mann and A. Rosenfeld, Ann. Rev. Nuclear Sci. **7**, 454 (1957).

[5] At the time of writing it is not known which of the two channels $\Sigma_+{}^+$, $\Sigma_-{}^-$ is s wave, which is p wave.

[6] Here a weak link need not be taken in the sense of perturbation theory but may itself be considered as properly modified by the presence of strong interactions.

Various authors[7] have approached this parity problem essentially by assuming that there exist highly specific strong virtual transitions which are dominant over all others in these reactions. According to this view, the parity properties of the nonleptonic decays are two more or less related accidents. Owing to our present inability to handle the detailed dynamics of strong interactions, it can neither be denied nor definitely be asserted that this is the correct approach. However this may be, it should be emphasized that the more qualitative line of thought which is about to follow is by no means orthogonal to the dynamical considerations just mentioned. These ideas are contained in recent publications,[8,9] their content is now briefly paraphrased. This work builds further on contributions by d'Espagnat and Prentki[10] and by Treiman.[11]

The main idea is to consider the possibility that the Λ and Σ decays give us perhaps a first qualitative indication for the need of a refinement of the current description in terms of isotopic spin T and strangeness S only. Expressed differently, it is explored if these processes could be understood better in terms of new approximate selection rules which are in accord with but more specific than $\Delta T=0$, $\Delta S=0$ for strong, $\Delta T=\frac{1}{2}$, $|\Delta S|=1$ for weak nonleptonic processes.

At this point we digress for a moment to note that experiment has revealed[2] a further interesting property of the Σ triangle, namely, that $|A^+|\simeq|A^-|$. According to the foregoing this implies an approximate equality of rates of an s-wave compared to a p-wave reaction. This is an important clue which cannot have anything to do with symmetry arguments, however.[8,9] In fact, a simple example shows[12] that this approximate equality of rates must be somewhat of an accidental consequence of the particular value of the Σ-nucleon mass difference. It would seem that the near-one magnitude of the Λ-asymmetry parameter is a similar accident.[12] It should further be noted that the two main predictions of the theory to be developed [see Eqs. (15) and (16)] are independent of the magnitude ratio $|A^+|/|A^-|$. Thus, there is at least no logical objection to proceed in two stages: to consider the parity questions first and separate and thereupon to inquire how more specific arguments may lead to the understanding of the near equality of the various Σ rates. Here only the first stage is discussed.

Let us now return to the question of approximate selection rules. The strong conservation law $\Delta T=0$ is the expression of the symmetry property called charge independence. Thus, more refined rules would have to be the expression of symmetries stronger than charge independence, but compatible with $\Delta T=0$. The weak violation law[13] $\Delta T=\frac{1}{2}$ states that the nonconservation of T comes about in a quite specific manner. Likewise, we seek for a specific violation law of the stronger symmetry in weak processes in a specific manner, but compatible with $\Delta T=\frac{1}{2}$.

It is known that the weakest symmetry[14] stronger than charge independence is the so-called doublet approximation or restricted symmetry, which is sketched in a moment. It should directly be stated, however, that this doublet symmetry has been shown[15] to be not at all useful for a wide class of strong reactions, at least in the energy regime explored by recent experiments. These reactions are associated hyperon K production, K scattering, and K production in hyperon absorption. It must therefore be asked if the reconsideration in the present context of the doublet picture amounts to letting a dead skeleton out of a closet. This may in fact very well be true, but it is not necessarily true. For, first of all, the fact that the doublet language is not useful in the mentioned reactions does not necessarily prove that this symmetry does not exist anywhere.[16] Secondly, the doublet approximation turns out to be a possibly useful starting point for the considerations to follow. Now, reactions (1)–(4) are distinct from the reactions just mentioned in that they do involve hyperons explicitly but K particles only virtually. While we have for the present no definite answer, we would nevertheless like to raise the question: Could it be that strong symmetries become more manifest whenever one has to integrate over all (virtual) K- particle effects? This by no means implies that all K-baryon forces are weak compared to π-baryon forces. There is ample evidence that this is not the case, and it may therefore generally be considered as well established that no arguments of approximate symmetry may rest on the assumption of relative weakness of K vs π

---

[7] G. Feldman, P. Matthews and A. Salam, Phys. Rev. **121**, 302 (1961); L. Wolfenstein, *ibid* **121**, 1245 (1961).

[8] A. Pais, Nuovo cimento **18**, 1003 (1960).

[9] A. Pais, University of California Rept. UCRL 9460 and Phys. Rev. **122**, 317 (1961). In this paper the relations of the present considerations with those of reference 7 are also studied.

[10] B. d'Espagnat and J. Prentki, Phys. Rev. **114**, 1366 (1959).

[11] S. Treiman, Nuovo cimento **15**, 916 (1960).

[12] Consider a particle Y_1 (mass M) which decays into a nucleon (mass m) and a π (mass μ) via $C_A\bar{Y}_1\gamma_\lambda\gamma_5N\partial\pi/\partial x_\lambda$, and a particle Y_2 (mass M) which decays likewise via $C_V\bar{Y}_2\gamma_\lambda N\partial\pi/\partial x_\lambda$ ($M \geq m+\mu$). If M is such that the nucleon is nonrelativistic, the ratio of decay rates is

$$\frac{1}{16}\left(\frac{C_A}{C_V}\right)^2\frac{(M+m)^2[M^2-(m+\mu)^2][M^2-(m-\mu)^2]}{m^2M^2(M-m)^2}.$$

If M corresponds to the Σ mass, this ratio is unity for $C_A\cong 1$, $2C_V$ (an interesting ratio in itself!). If, by way of illustration, M is taken to be the Λ mass, then for the same C_A/C_V, the ratio of rates becomes $\cong\frac{1}{2}$. It is in this sense that one may be led to consider $|A^+|\cong|A^-|$ as somewhat accidental. Similarly, if one considers the asymmetry parameter α for the decay induced by $\bar{Y}\gamma_\lambda(C_A\gamma_5+C_V)N\partial\pi/\partial x_\lambda$, one finds again a very sensitive dependence of α on the mass M of Y.

[13] I believe that it is not just a matter of semantics to say that expressions "an invariance law is violated" are no more than temporary expedients which actually mean that the law in question is not properly stated. From this view, it is the major task of theoretical particle physics to interpret all particle phenomena in terms of exact laws.

[14] A. Pais, Phys. Rev. **110**, 1480 (1958).

[15] A. Pais, Phys. Rev. **110**, 574 (1958).

[16] By way of analogy, the existence of irreversible processes does not prove that the basic laws are noninvariant with respect to time reversal.

couplings. It is at least gratifying that the considerations to follow have been shown[9] to be independent of such assumptions.

Let us now discuss the doublet approximation by making an analogy. Consider nonrelativistically the ^3S and ^1S state of the deuteron. In the absence of all spin-dependent interactions, these states would be degenerate. While in the split situation only the total spin is a good quantum number, the proton and neutron spins separately are conserved in the degenerate situation. Let us now look similarly upon the (triplet +singlet) $\Sigma\Lambda$ system with $T=1, 0$. Put

$$T=I+K, \tag{7}$$

where I and K each are spin $\frac{1}{2}$ operators. The doublet approximation amounts to the neglect of the $\Sigma\Lambda$ mass difference or, more generally, precisely to assuming that I and K are separately conserved. The $\Sigma\Lambda$ states are now rearranged to simultaneous eigenstates of I and K as follows:

$$N_2=\begin{pmatrix}\Sigma_+\\ Y_0\end{pmatrix},\quad N_3=\begin{pmatrix}Z^0\\ \Sigma^-\end{pmatrix} \tag{8}$$

$$Y^0=(\Lambda-\Sigma^0)/\sqrt{2},\quad Z^0=(\Lambda+\Sigma^0)/\sqrt{2}. \tag{9}$$

Again invoking the deuteron analogy, it is clear and it can be shown in more detail[15] that this procedure is then meaningful only if the parity of Σ relative to Λ is even. This $\Sigma\Lambda$ parity has so far not been determined. If it would turn out to be odd, all that follows would be irrelevant.

The upper (lower) components of N_2 and N_3 have $I_3=+\frac{1}{2}(-\frac{1}{2})$, while $N_2(N_3)$ have $K_3=+\frac{1}{2}(-\frac{1}{2})$. The remaining baryons

$$N_1=\begin{pmatrix}p\\ n\end{pmatrix},\quad N_4=\begin{pmatrix}\Xi^0\\ \Xi^-\end{pmatrix} \tag{10}$$

are doublets to begin with. We wish Eq. (7) to be true also for those doublets. Hence, we put one of the two spin operators on the right-hand side of Eq. (7), say K, equal to zero for those doublets.[17] Then $T=I=\frac{1}{2}$ for N_1 and N_4. The spin I is called the doublet spin.

Each doublet interacts with the π field. From our assignments for the nucleons, it follows that

$$T=I=1,\quad K=0 \text{ for } \pi \text{ mesons.}$$

Of course, this assignment, once made, is also to hold for the interaction of the other doublets with π mesons. The dynamical condition for the π couplings to respect the doublet approximation is[15] that the coupling of π to N_2 has the same strength as the coupling of π to N_3.

The K field couples N_1 to (N_2,N_3) and N_4 to (N_2,N_3). As (N_1,N_2) have $K=0$, it follows that

$$T=K=\tfrac{1}{2},\quad I=0 \text{ for } K \text{ mesons.}$$

[17] From the structure of the K interactions, one can conclude that it is not possible to put $K=0$ for nucleons, $I=0$ for cascades.

The dynamical condition for the K couplings to respect the doublet approximation is[15] that the K couplings of Λ and Σ to nucleons have equal strength. Likewise for the couplings to cascades.

Thus, T breaks up into two spins, the doublet spin which governs the π couplings, and the "K spin" which governs the K couplings. To the extent that all strong interactions participate in the doublet approximation, it is true that $\Delta T=0$ for strong interactions is refined to $\Delta I=0$, $\Delta K=0$. This statement is independent of the relative strengths of π and K couplings.

Let us now return to the sequences (5) and (6). In Eq. (6) we meet the strong link $\Sigma^-\to\Sigma^++2\pi^-$. By virtue of our (I,K) assignments, this is a $\Delta K_3=1$ transition and therefore incompatible with the requirement $\Delta K=0$ which we just laid down. This demonstrates how the doublet approximation prohibits a mixup of the weak parity conserving channels of opposite parity.

Consider next the strong link $\Sigma^-\to\Lambda+\pi^-$ in Eq. (5). According to Eq. (9), Λ has the ambiguous position of riding on two different doublets. $\Delta K=0$ implies that only the Z^0 part of Λ can combine with Σ^-: $\Sigma^-\to Z^0+\pi^-$. Let us now suppose that "Z^0 decay" is parity conserving. Then the sequence (5) gives a parity conserving contribution to Σ_-^-, as desired. Parity conserving Z^0 decay is not in conflict with strong parity violation in Λ decay. Indeed, $A\sqrt{2}$ is the coherent sum of the amplitudes for $Z^0\to p+\pi^-$, $Y^0\to p+\pi^-$. Suppose that each of these two processes separately are parity conserving, one giving a p-wave, the other an s-wave π meson. Then Λ is precisely strongly parity violating—always in the doublet approximation.

These few examples may elucidate what is the essence of the present attempt: to try and use parity properties of weak (nonleptonic) processes as probes for possible symmetries of strong interactions in the sense that "near parity conservation" in Σ_+^+ and Σ_-^- becomes strict parity conservation to the extent that a symmetry stronger than charge independence is true. The more precise tool for this is a more detailed version of the $\Delta T=\frac{1}{2}$ rule.

Just as we have considered the refinement $\Delta I=\Delta K=0$ of $\Delta T=0$, we now wish to consider a refinement of the weak $\Delta T=\frac{1}{2}$ rule in terms of a $(\Delta I,\Delta K)$ rule. With regard to ΔK, we have trivially $\Delta K=\frac{1}{2}$ for all reactions (1)–(4) and incidentally also for

$$\Xi^-\to\Lambda+\pi^-, \tag{11}$$

as follows from the fact that in all these decays only one particle figures with $K=\frac{1}{2}$. By the vector addition, $\Delta\mathbf{T}=\Delta\mathbf{I}+\Delta\mathbf{K}$, it follows that $\Delta I=0$ or 1. Thus, in the doublet approximation, the most general form of the complete nonleptonic interaction is[18]

$$S^{(0)}+W^{(0)}+W^{(1)}, \tag{12}$$

[18] Deviations from the doublet approximation can be obtained by adding a term $S^{(1)}$ ($\Delta I=\pm1, 0$; $\Delta K=\pm1, 0$) and such that $\Delta T=0$.

where S is the strong part ($\Delta I=\Delta K=0$) while $W^{(0)}$ and $W^{(1)}$ are the weak parts with $\Delta I=0$, 1, respectively, and both with $\Delta K=\frac{1}{2}$. Now observe the following properties of reactions (2)–(4):

$$\Sigma^+ \text{ decays: } \Delta I_3=0;\quad \Sigma^- \text{ decay};\quad \Delta I_3=1. \tag{13}$$

Hence, Σ^- decay proceeds via the part $S^{(0)}+W^{(1)}$ of the dynamics. Thus, if $W^{(1)}$ conserves parity, then Σ^- decay is parity conserving *modulo* the doublet symmetry, without any further ado.

The situation is more complex for Σ^+ decays for which $\Delta I_3=0$, and hence both $\Delta I=0$ and 1 may contribute. Consider first $\Sigma^+\rightarrow p+\pi^0$ which is strongly parity violating. Its contribution from $W^{(1)}$ alone conserves parity in virtue of our condition just imposed in the discussion of Σ^- decay. Let us now assume that also $W^{(0)}$ gives a parity conserving contribution, but such that if $W^{(1)}$ gives a pure p (or s) amplitude, then $W^{(0)}$ gives a pure s (or p) amplitude. Then $\Sigma_0{}^+$ is indeed strongly parity violating. Moreover, $W^{(0)}$ gives now a parity conserving amplitude for $\Sigma_+{}^+$ and, as is desired, $\Sigma_+{}^+$ and $\Sigma_-{}^-$ have opposite parity.

It may be noted that any parity violating interaction can be written as the sum of two separately parity conserving interactions. What is particular to the structure (12) is that these two separate parts are at the same time labeled by distinct doublet spin properties. Thus, in the present line of thought, a link is envisaged between spatial reflection and isotopic properties of interactions. One is here reminded of the link between P and C, which is presumed valid for all weak interactions.

How far have we now come? Only $W^{(1)}$, not $W^{(0)}$, contributes to $\Sigma_-{}^-$ and in a parity conserving way. $W^{(1)}$ and $W^{(0)}$ both contribute to $\Sigma_0{}^+$ which violates parity because $W^{(1)}$ and $W^{(0)}$ give opposite parity contributions. $W^{(0)}$ gives a contribution to $\Sigma_+{}^+$ which conserves parity and gives an opposite parity in $\Sigma_+{}^+$ as compared to $\Sigma_-{}^-$. There remains one problem. $W^{(1)}$ can in general also contribute to $\Sigma_+{}^+$, but clearly this contribution should be negligible in order to keep $\Sigma_+{}^+$ pure. Thus, we have to impose an additional condition on $W^{(1)}$.

The nature of this additional condition has been investigated.[9] Let us call $A_{(1)}{}^+$ that part of the amplitude A^+ of reaction (2) which is due to the effect of $W^{(1)}$ (in the presence of strong interactions). $A_{(1)}{}^+$ is a function of the masses m_N and m_Σ and of the decay momentum transfer Δ. It has been shown[19] that under suitable conditions an additional invariance argument may be applied to $W^{(1)}$ which has the consequence that

$$A_{(1)}{}^+(m_N,m_\Sigma,\Delta)=0 \quad \text{for} \quad m_N=m_\Sigma \text{ and fixed } \Delta. \tag{14}$$

This limit property would then especially be of great help if it could further be shown that the amplitudes depend only weakly on the Σ-nucleon mass difference (for fixed Δ). In addition, it has been shown[20] that there exist classes of diagrams for which $A_{(1)}{}^+$ vanishes without any further restriction of the type $m_N\rightarrow m_\Sigma$. It should be noted that both for the validity of Eq. (14) and in the discussion of diagrams just mentioned, the global condition[21] need be satisfied that the absolute value of the π-nucleon strength equals the strength of the $\pi-N_2$ (and thus the $\pi-N_3$) coupling. A further study of the minimal conditions to be imposed on $W^{(1)}$ is in progress.

Just as the $\Delta T=\frac{1}{2}$ rule establishes relations between certain decay amplitudes, so the "$\Delta I=0$, 1" rule establishes stronger relations which tie the Σ and Λ decays together. The following two results are valid with no further assumption than the structure (12) of the interaction provided only that the additional condition on $W^{(1)}$ which we referred to a moment ago is indeed satisfied:

(a) upon correction for the difference in phase volume in Σ compared to Λ decay, the following rate relation holds,

$$R(\Sigma^+\rightarrow p+\pi^0)\simeq 2R(\Lambda\rightarrow p+\pi^-), \tag{15}$$

in qualitative agreement with experiment;

(b) if the asymmetry parameters in reactions (1) and (3) are denoted by α_Λ and α_0, then

$$\alpha_\Lambda=-\alpha_0. \tag{16}$$

We also mention a result on cascade decay. Again because the Λ in Eq. (11) is a member of two doublets, it follows from the $\Delta I=0$, 1 rule that cascade decay is parity violating in the same approximation that $\Sigma_+{}^+$ and $\Sigma_-{}^-$ are parity conserving. To relate the helicity α_Ξ of reaction (11) to α_Λ is possible only if global symmetry conditions obtain, in which case one shows that[22]

$$|\alpha_\Xi|=|\alpha_\Lambda|. \tag{17}$$

The reason for the remaining ambiguity in sign is the following. The Ξ-decay amplitude is additively composed of the contribution from $W^{(0)}$ and that of $W^{(1)}$ (in either case in the presence of $S^{(0)}$). Suppose that we have a definite expression for $W^{(0)}$ and $W^{(1)}$ which satisfies all invariance requirements. This gives a definite relative sign for α_Ξ and α_Λ. If we now change by -1 the phase of Ξ relative to nucleon to nucleon either only in $W^{(0)}$ or only in $W^{(1)}$, then the invariance conditions turn out[22] to be still valid. But this change of phase changes also the relative sign of α_Ξ and α_Λ. Thus, the sign ambiguity in Eq. (17) can be resolved

[19] See reference 9, Sec. II.C. In Eq. (14), m_N and m_Σ are the nucleon and Σ mass, respectively.

[20] See reference 9, Sec. VI.

[21] J. Schwinger, Phys. Rev. **104**, 1164 (1956); M. Gell-Mann, *ibid.* **106**, 1296 (1957).

[22] See reference 9, Sec. IV. In the earlier papers (see references 8, 10, and 11), the stronger relation $\alpha_\Xi=\alpha_\Lambda$ was obtained. In reference 11 the weak interaction was supposed to be purely of the form $W^{(1)}$, and it was shown in reference 8 that this implies $\alpha_\Xi=\alpha_\Lambda=0$ if global invariance arguments are brought to bear. In reference 8 it had not yet been appreciated that the sign ambiguity in Eq. (17) is compatible with all invariance requirements.

only by further dynamical arguments concerning the structure of the strangeness changing weak interactions.[23]

Thus far we have assumed that the nonleptonic decay rule $\Delta T=\frac{1}{2}$ is strict. There are relatively small electromagnetic deviations from this rule which lead to $\Delta T=\frac{3}{2}$ (and higher) transitions. The most important known experimental deviation from $\Delta T=\frac{1}{2}$ is the very existence of the decay

$$K^+ \rightarrow \pi^+ + \pi^0, \tag{18}$$

which has been found to be inhibited by a factor $\sim 1/200$ compared to $K_{\pi 2}{}^0$ decay. It is not clear whether this ratio can be accounted for merely by electromagnetic connections to $\Delta T=\frac{1}{2}$. In this connection it is perhaps of some interest to note that the doublet picture provides us with a nonelectromagnetic way to inhibit $\Delta T=\frac{3}{2}$ (and higher transitions).

This is seen as follows. The reaction (18) has $\Delta K=\frac{1}{2}$, $\Delta I=2$. As $\mathbf{\Delta T}=\mathbf{\Delta I}+\mathbf{\Delta K}$, we can, for example, consider a vector composition to $\Delta T=\frac{3}{2}$. Consider now a decay interaction with $\Delta K=\frac{3}{2}$, $\Delta I=1$, $\Delta T=\frac{3}{2}$. Even though this is a $\Delta T=\frac{3}{2}$ coupling, reaction (18) remains forbidden in the doublet approximation as the ΔK and ΔI of the interaction do not match the ΔK and ΔI of the decay $K_{\pi 2}{}^+$. However, if we now consider the deviations from the doublet symmetry,[18] the $\Delta T=\frac{3}{2}$ nature of the coupling remains intact but its $(\Delta I,\Delta K)$ properties no longer survive. Hence, the decay $K_{\pi 2}{}^+$ can take place due to the breakdown of the doublet approximation. It remains to be seen, however, if it is more than an amusing coincidence that the square of the dimensionless parameter $(m_\Sigma - m_\Lambda)/m_\Lambda$ which characterizes this breakdown is just $\sim 1/200$.

[23] After the completion of the paper mentioned in reference 9, it was learned that Ξ decay is indeed strongly parity violating and that α_Ξ and α_Λ have opposite sign. See W. Fowler, R. Birge, Ph. Eberhard, R. Ely, M. Good, W. Powell, and H. Ticho, Phys. Rev. Letters **6**, 134 (1961).

Finally, a few remarks on the consequences of the present ideas, if correct, with respect to leptonic processes. There seem to exist tensions, as it were, between two qualitative ideas. One is the $\Delta T=\frac{1}{2}$ rule, the other the (over-all current)$\times$(over-all current) structure of the totality of weak interactions. For example, when these ideas are synthesized, the question of the neutral lepton currents arises.[24] This tension is aggravated only if the structure (12) of the nonleptonic decay interactions is correct. It is very easy to see[24] that it is impossible to have at the same time a nonleptonic decay coupling consisting of two separately parity conserving but clashing parts, $W^{(0)}$ and $W^{(1)}$, and also retain the (over-all current)$\times$(over-all current) picture in its present form; one idea is fatal to the other.

In conclusion, there is the following important question. Let us suppose for a moment that the considerations which have been presented are not totally wrong, and that there does indeed exist some underlying doublet symmetry in the strong and weak interactions. What then is the dynamical mechanism that effectively breaks this symmetry when K particles appear explicitly? What is the influence of this mechanism on the nonleptonic hyperon decays? We have no definite answers to these questions, but we do want to say that the new resonance or particles of which we have heard so much in the past few days give one new food for thought also about these problems. In particular, it may be recalled[15] that one of the assumptions under which doublet symmetries have been discussed was the completeness of the particle spectra. Moreover, if the object K^* has $T=\frac{1}{2}$, a coupling $\bar{K}^*\boldsymbol{\tau}K\boldsymbol{\pi}+\text{c.c.}$ is just of a kind which effectively breaks down the doublet approximation. But we have not yet digested the new findings from this point of view.

[24] For a survey see, e.g., reference 8, discussion subsequent to Eq. (16).