[17]W. H. Marlow, private communication. It appears that this is the most general form for π. In the Dirac representation, $\Gamma_0 \to \frac{1}{2}\gamma_0$, (11) reproduces the well-known result $\pi^{\mathrm{Dirac}} = \eta e^{i\pi\gamma_0/2} = \eta\gamma_0$.

[18]We remark that there is a representation of $\mathfrak{S}$ very similar to the present representation (with the same eigenvalues of the Casimir operators) but containing only half-integer spins. This representation offers itself for the description of baryons, in particular since the lowest Poincaré group representations that it contains are the same as are contained in $\mathfrak{S}^{(\mathrm{Dirac})}$. This would then be able to describe fine structure in the baryon spectrum as, e.g., given by the $\frac{5}{2}^+$ $N(1688)$ and $\frac{5}{2}^-$ $N(1680)$.

DUALITY, ABSENCE OF EXOTIC RESONANCES, AND THE $\Delta I = \frac{1}{2}$ RULE IN NONLEPTONIC DECAYS

Ken Kawarabayashi and Shinsaku Kitakado
Research Institute for Fundamental Physics, Kyoto University, Kyoto, Japan
(Received 14 July 1969)

Based on the current-current theory of weak interactions the $\Delta I = \frac{1}{2}$ rule for nonleptonic decays is derived from a dynamical mechanism that satisfies duality and absence of resonances in exotic channels.

It has been argued,[1] based on universal current-current theory of weak interactions, that the $\Delta I = \frac{1}{2}$ rule in nonleptonic decays may be accounted for either by adding an extra current-current term so as to cancel the $\underline{27}$ portion of the interactions or by a dynamical mechanism that selectively enhances the octet component. The usual mechanism for the octet enhancement, often referred to in terms of "tadpoles,"[2] has been discussed in a variety of ways.[3] None of them, however, appears convincing enough.

In this note we wish to point out that the $\Delta I = \frac{1}{2}$ rule or more precisely, the absence of $\Delta I = \frac{3}{2}$ transitions may be understood as a dynamical mechanism that satisfies duality[4] and the hypothesis of no exotic resonances.[5]

The nonleptonic decays are described as a quasihadronic scattering process in which the weak interaction acts like a scalar and a pseudoscalar spurion carrying zero energy and momentum. We assume, as in the case of ordinary hadron scattering, that they are governed by a dynamics that satisfies duality and the hypothesis of absence of exotic resonances.[6]

Let us first consider octet baryon decays in the SU(3)-symmetric limit. It is then easy to show, under the foregoing assumptions, that

$$S(\underline{27}) + B(\underline{8}) \to M(\underline{8}) + B(\underline{8}) \tag{1}$$

is forbidden. Here $S(\underline{27})$ stands for scalar or pseudoscalar 27-plet spurion with $I = \frac{3}{2}$ and $|Y| = 1$. The argument that leads to the above conclusion is quite simple: There are six independent amplitudes, corresponding to the SU(3) representations of $\underline{8}$, $\underline{8}'$, $\underline{10}$, $\underline{10}^*$, $\underline{27}$, and $\underline{27}'$ for each parity-nonconserving (pv) and parity-conserving (pc) decay. The same representations arise in all s, t, and u channels. Absence of exotic resonances implies that there be no $\underline{10}^*$, $\underline{27}$, and $\underline{27}'$ in both s and u channels and no $\underline{10}$, $\underline{10}^*$, $\underline{27}$, and $\underline{27}'$ in the t channel. For each pv and pc amplitude, $s(u)$- and t-channel duality then requires seven linearly independent SU(3) amplitudes to vanish and therefore requires that they all vanish. Similarly, s- and u-channel duality gives six independent conditions on six amplitudes, which again requires that all amplitudes must vanish. Thus $\Delta I = \frac{3}{2}$ transitions for baryon decays are forbidden.[7]

It is straightforward to apply the present arguments to $K \to 2\pi$ (3π)[8] and $\Omega^- \to \Xi\pi$ decays. One then obtains the result that $\Delta I = \frac{3}{2}$ transitions for the above processes are again forbidden and therefore these decays should obey the $\Delta I = \frac{1}{2}$ rule.

We have so far assumed, besides our basic assumptions of duality and absence of exotic resonances, the exact SU(3) symmetry. Let us next consider the case of broken SU(3).[9] In that case, it is not difficult to show that similar arguments can still be applied to $\Omega^- \to \Xi\pi$, $\Sigma^- \to n\pi^-$, and $K \to 2\pi$ (3π) decays. As a result, the $\Delta I = \frac{1}{2}$ rule is still valid for these decays. An interesting fact is that absence of a $\Delta I = \frac{3}{2}$ transition for $\Sigma^- \to n\pi^-$ implies the well-known triangle relation $\sqrt{2}\Sigma_0^+ + \Sigma_+^+ = \Sigma_-^-$ and thus effectively the $\Delta I = \frac{1}{2}$ rule for Σ decays.[10]

At this point, let us recall[11] that for pv decays, soft-pion calculations based on SU(2)$\otimes$SU(2) demand the $\Delta I = \frac{1}{2}$ rule for Λ and Ξ decays but not for Σ decays. It is then an interesting observation that if we combine our results with current-algebra predictions, we are led to the conclusion that all pv decay amplitudes, including Ω^- and K decays, satisfy the $\Delta I = \frac{1}{2}$ rule in broken SU(3), with the additional restrictions $S(\Sigma_+^+) = 0$ and

$2S(\Xi_-^{\ -})+S(\Lambda_-^{\ 0})-\sqrt{3}S(\Sigma_0^{\ +})=0$. For pc decays, on the other hand, the $\Delta I=\frac{1}{2}$ rule remains valid for $\Omega^-\to\Xi\pi$, $\Sigma\to N\pi$, and $K\to 3\pi$, but we have not been able to derive the same rule for Λ and Ξ decays in the presence of SU(3) breaking.

We close this note with a few remarks: (a) As stated before, the amplitude corresponding to (1) was assumed to satisfy the duality principle that governs hadronic processes. This assumption, though not yet verified, may not be unreasonable since for such quasihadronic processes there is so far no evidence for a fixed pole singularity usually present in nonhadronic amplitudes. Furthermore, we note that the Pomeranchuk singularity is not involved in our case. (b) It is known that for baryon-antibaryon scattering,[5] such as $\Delta\overline{\Delta}\to\Delta\overline{\Delta}$, arguments similar to that which we employed here lead to the problem that the relevant amplitude should vanish. Frankly, we have no clear-cut solution to this problem.[12] We note, however, that our case rather corresponds to meson-baryon scattering, for which we have met no such difficulty.

We would like to express our appreciation to Professor H. Yukawa for his interest in this work and to Professor Z. Maki and Professor M. Konuma for discussions.

---

[1]R. F. Dashen, S. C. Frautschi, M. Gell-Mann, and Y. Hara, in Eightfold Way, edited by M. Gell-Mann and Y. Ne'eman (W. A. Benjamin, Inc., New York, 1964).

[2]A. Salam and J. C. Ward, Phys. Rev. Letters 5, 390 (1960); S. Coleman and S. Glashow, Phys. Rev. 134, B671 (1964).

[3]E. R. McCliment and K. Nishijima, Phys. Rev. 128, 1970 (1962); R. E. Cutkosky and P. Tarjanne, Phys. Rev. 132, 1355 (1963); R. Dashen and S. Frautschi, Phys. Rev. 137, B1331 (1965), and Phys. Rev. 140, B698 (1965).

[4]R. Dolen, D. Horn, and C. Schmid, Phys. Rev. 166, 1768 (1968).

[5]J. L. Rosner, Phys. Rev. Letters 21, 950 (1968); D. P. Roy and M. Suzuki, Phys. Letters 28B, 558 (1969); H. J. Lipkin, Nucl. Phys. B9, 349 (1969); J. Mandula, C. Rebbi, R. Slansky, J. Weyers, and G. Zweig, Phys. Rev. Letters 22, 1147 (1969).

[6]In a recent paper Suzuki attempted, from a similar point of view, to explain some properties of pc baryon decays [M. Suzuki, Phys. Rev. Letters 22, 1217, 1413(E) (1969)].

[7]For reactions involving octet spurions we do not meet such situations. The number of conditions that prohibit exotic resonances in certain channels is always smaller than the number of nonexotic amplitudes in its dual channels.

[8]For $K\to 3\pi$ decays we require, as an additional assumption, the factorization property of five-point amplitudes.

[9]We consider, in place of (1), the scattering involving spurions with $I=\frac{3}{2}$, $|Y|=1$, and $|I_Z|=\frac{1}{2}$.

[10]In the present case, there are three independent amplitudes to describe Σ decays since the $\Delta I=\frac{3}{2}$ transition is still effective in Σ^+ decays. However, it can be shown by explicit calculations that the triangle relation is satisfied.

[11]H. Sugawara, Phys. Rev. Letters 15, 870 (1965); M. Suzuki, Phys. Rev. Letters 15, 986 (1965).

[12]It is our feeling that the difficulty associated with baryon-antibaryon scattering should be settled on quite different grounds. Several possibilities have so far been suggested to solve this problem. See S. Pinsky, Phys. Rev. Letters 22, 677 (1969); J. E. Mandula, J. Weyers, and G. Zweig, ibid. 23, 266 (1969).

PHOTON-PHOTON SCATTERING CONTRIBUTION TO THE SIXTH-ORDER MAGNETIC MOMENT OF THE MUON*

Janis Aldins† and Toichiro Kinoshita
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York 14850

and

Stanley J. Brodsky and Andrew J. Dufner
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305
(Received 25 July 1969)

We report a calculation of the three-photon—exchange (electron-loop) contribution to the sixth-order anomalous magnetic moment of the muon. Our result, which contains a logarithmic dependence on the muon-to-electron mass ratio, brings the theoretical prediction into agreement with the CERN measurements, within the 1—standard-deviation experimental accuracy.

In the last few years increasingly accurate measurements of the magnetic moment of the muon have been performed at CERN. The most recent value of the anomalous part of the muon g factor is[1] $[a=\frac{1}{2}(g-2)]$

$$a_{\exp}=(116\,616\pm 31)\times 10^{-8}. \tag{1}$$