[5] J. J. Sakurai, Phys. Rev. Letters 9, 472 (1962).

[6] Strictly speaking, we need to neglect the Y-B mass differences.

[7] This is really a statement of the form factors at zero momentum transfer. B. Sakita and K. C. Wali, to be published.

CONFIRMATION OF AN $SU(6)_W$ SCATTERING RELATION[*]

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The $SU(6)_W$ scheme[1] provides an unambiguous method of relativizing $SU(6)$[2] for colinear processes. For electromagnetic and weak processes the predictions of $SU(6)_W$ are similar to those of other relativistic $SU(6)$ procedures.[3] In meson-baryon scattering reactions, as was the case with $SU(6)$,[4] there are many possible relations,[3] of which most have no clear interpretation due to mass differences among the external particles. It would seem, therefore, that the most desirable scattering equalities are those relating different charge states of the same set of isospin multiplets. Furthermore, if the particles in the final state are in s waves, the predictions of $SU(6)_W$ should apply to the whole amplitude, and not just in the forward and backward directions.

A relation of this type has been given by Carter et al.[3] These authors find that under $SU(6)_W$ the cross sections for all the charge states in the reaction

$$\pi + N \rightarrow \pi + \Delta,$$

where Δ is the $N^*(1238)$, are proportional to a single quantity. Since in general there are two isotopic-spin amplitudes which enter (i.e., the $T=\frac{1}{2}$ and $T=\frac{3}{2}$ isospin amplitudes A_1 and A_3), this implies a relation between these amplitudes. An elementary calculation gives

$$A_1/A_3 = +\sqrt{10}. \tag{1}$$

Olsson and Yodh[5] have performed a phenomenological study of the single-pion-production process at low energies and have found that s-wave isobar production is dominant near isobar production threshold. In this region (near isobar threshold) it was found that the s-wave isobar production amplitude could be represented by two energy-independent scattering lengths (for production through $T=\frac{1}{2}$ or $\frac{3}{2}$ isotopic-spin channels). The values of these scattering lengths have been found to be

$$A_3 = 0.0175 \pm 0.0008\ \mathrm{F},$$

$$A_1 = 0.059 \pm 0.005\ \mathrm{F}.$$

The ratio of scattering lengths is then

$$A_1/A_3 = +3.4 \pm 0.3, \tag{2}$$

showing good agreement with the $SU(6)_W$ prediction given in (1). This test is significant for two reasons: (i) The relation involves no large mass splitting. (ii) Both the magnitude and the sign are in agreement with the prediction. It is of interest to compare what various simple mechanisms would predict for this ratio. Nucleon and Δ exchange imply that

$$A_1/A_3 = +(8/5)^{1/2},$$

while ρ exchange gives

$$A_1/A_3 = -(\tfrac{2}{5})^{1/2},$$

both of these ratios being well outside the experimental error. The nucleon pole in the direct channel only contributes to A_1, but since this singularity is much more distant than the exchanged nucleon pole,[6] its contribution would not seem to be large.[7]

In conclusion, we have found that the isospin ratio for s-wave isobar production is accurately predicted by $SU(6)_W$, and that this ratio is not accounted for by the simplest dynamical models.

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[1] H. Lipkin and S. Meshkov, Phys. Rev. Letters 14, 670 (1965).

[2] M. Bég and A. Pais, Phys. Rev. 137, B1514 (1965), contains a review of the subject.

[3] J. Carter, J. Coyne, S. Meshkov, D. Horn, M. Kugler, and H. Lipkin, Phys. Rev. Letters 15, 373 (1965).

[4] K. Johnson and S. Treiman, Phys. Rev. Letters 14, 189 (1965); R. Good and Nguyen-huu Xuong, Phys. Rev. Letters 14, 191 (1965); V. Barger and M. Rubin, Phys. Rev. Letters 14, 713 (1965); J. Carter, J. Coyne, and S. Meshkov, Phys. Rev. Letters 14, 523 (1965); T. Bin-

ford, D. Cline, and M. Olsson, Phys. Rev. Letters 14, 715 (1965).

[5] M. Olsson and G. Yodh, Phys. Rev. Letters 10, 353 (1963); M. Olsson, University of Maryland Report No. 379, May 1964 (unpublished); M. Olsson and G. B. Yodh, to be published.

[6] F. Selleri, Lectures In Theoretical Physics (The University of Colorado Press, Boulder, Colorado, 1965), Vol. 7B.

[7] At isobar threshold the ratio $(s-m^2)/(u-m^2) = -3.5$, this being the relative importance of the exchanged pole and the direct pole.

FURTHER DISCUSSION OF PARTICLE-MIXTURE THEORIES OF $K^0 \rightarrow 2\pi$ DECAY

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Fitch, Roth, Russ, and Vernon[1] have recently reported an important additional result on the apparent CP invariance violation in K_2^0 decays.[2-4] We discuss below the implications of their result, with particular reference to particle-mixture theories of long-lived $K^0 \rightarrow 2\pi$ decays.[5]

As described more fully in reference 5, the experimental results cited in references 2-4 (which we call the LLD effect) could be explained within the context of CP invariance either by postulating the existence of a spinless particle state S in the neighborhood of the K^0 mass, which mixes with $K_+ = (K^0 + \bar{K}^0)/\sqrt{2}$ and gives rise to the long-lived $\pi^+\pi^-$ component, or by ascribing the LLD effect to the action of a scalar cosmological field which, by causing K^0 and $\bar{K}^0$ to have slightly different energies, acts as a regenerating medium. It is reported[1] that there is maximal constructive interference between the regeneration amplitude which is essentially purely imaginary,[6] due to a material regenerator, and the LLD amplitude; therefore, the LLD amplitude must be purely imaginary[6] too. A classical long-range field would provide a real energy difference between K^0 and $\bar{K}^0$ and therefore give rise to a real[6] LLD amplitude; consequently, the observed interference effect provides strong evidence against the cosmological hypothesis.[7] Thus the particle-mixture theory remains as the sole survivor for explaining the LLD effect within the framework of CP invariance.

The result of reference 1 further restricts the parameters of the particle-mixture theory. Whereas on the basis of the experiments reported in references 2-4, one knew that the mass of the state Ψ_L must equal the K^0 mass to the accuracy of the mass determination in those experiments, i.e., of the order of 1 MeV, the observed interference requires that this equality hold to within the width γ_1 of the short-lived component,[8] viz., $|m_2 - m_L| \leq \gamma_1 \sim 10^{-5}$ eV.

According to the particle-mixture theory, which is devised solely to save CP invariance, the $CP = -1$ component of neutral kaons, $K_2 = K_- = (K^0 - \bar{K}^0)/\sqrt{2}$, cannot contribute to 2π decays. The occurrence of interference must be understood as follows. Due to the different interactions of K^0 and $\bar{K}^0$ with matter, the state K_2 will no longer be characterized by simple exponential decay within the regenerating medium. Using the notation of reference 5 and retaining quantities only to lowest order in θ and δ (see below), the states which undergo pure exponential decay are

$$|\Psi_S'\rangle = |\Psi_S\rangle - \delta|K_2\rangle, \quad |K_2'\rangle = |K_2\rangle + \delta|\Psi_S\rangle, \tag{1}$$

and $|\Psi_L\rangle$, which we assume to be negligibly affected[5] by the regenerator. A neutral kaon beam within the medium is described by the state vector

$$\begin{aligned} |\Psi(t)\rangle = a|\Psi_S'\rangle \exp[-(\gamma_1'/2 + im_1')t] \\ + b|K_2'\rangle \exp[-(\gamma_2'/2 + im_2')t] \\ + c|\Psi_L\rangle \exp[-(\gamma_L/2 + im_L)t], \end{aligned} \tag{2}$$