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SU(3) Symmetry in Electron-Positron Annihilation

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Exact SU(3) predicts equal production of $\pi^+\pi^-$ and K^+K^- final states, while $K^0\bar{K}^0$ is forbidden as a result of cancelation between isovector and isoscalar photon contributions. Symmetry breaking destroys coherence between ρ-, ω-, and φ-like photon components. Branching ratios $\pi^+\pi^-/K^+K^-/K^0/\bar{K}^0$ calculated under various coherence assumptions give different results. Experimental measurements should test this interference and give insight into the role of photon SU(3) structure in deep annihilation.

The assumption of SU(3) symmetry in e^+e^- annihilation processes leads to interesting predictions for the case of two-meson final states. Cross sections for annihilation into two charged pions and two charged kaons are equal, i.e.,

$$\sigma(e^+e^- \to K^+K^-) = \sigma(e^+e^- \to \pi^+\pi^-); \tag{1a}$$

annihilation into two neutral kaons is forbidden!

$$\sigma(e^+e^- \to K^0\bar{K}^0) = 0. \quad (1b)$$

These predictions follow simply from U-spin considerations.[1] The photon is a U-spin scalar; the $\pi^+\pi^-$ and K^+K^- states are a U-spin mirror pair and must be equally produced from a scalar initial state. The selection rule against neutral-kaon pair production is seen from the U-spin analog of G parity, under which the neutral kaons are odd and the photon is also odd. This selection rule is the U-spin analog of the G-parity selection rule forbidding the $\omega \to 2\pi$ decay. An SU(3) rotation which transforms isospin into U spin takes the isoscalar ω into the U-spin scalar photon and the isovector charged pions into the U-spin vector neutral kaons.

The failure of these striking predictions to agree with experiment below 1 GeV is due to obvious SU(3) symmetry-breaking mechanisms. At low energies, annihilation is dominated by production[2] of the vector mesons ρ, ω, and φ. In the SU(3) symmetry limit the three states are degenerate and the two-kaon channel is either open or closed for all of them. In the real world the two-kaon threshold is at 988 MeV and only pions are observed below these energies. The two-kaon channel is open only for the φ and closed for the ρ and ω.

It is interesting to examine these predictions at higher masses where all two-meson channels are open and the process might be dominated by some SU(3) nonet of higher vector particles.[3] The experimental data should be checked for some qualitative indication of the SU(3) selection rule forbidding neutral-kaon pair production. This would appear as a suppression of production of neutral-kaon pairs relative to charged-kaon pairs, resulting from some interference between the contributions of the isoscalar and isovector components of the photon.

Quantitative predictions including effects of SU(3) symmetry breaking can be calculated by assuming various possibilities for coherence or incoherence of the contributions from ρ-, ω-, and φ-like components. The contributions from each photon component to the amplitude for each final state are listed in Table I. The two-pion amplitude has been normalized to unity.

The predicted branching ratios for the different final states can be calculated under various assumptions regarding the photon components, as listed in Table II. These cases are sufficiently different qualitatively to be of experimental interest. In the absence of isoscalar-isovector interference, the charged- and neutral-kaon rates are equal. However, even with coherent contributions only from the ω and not from the φ there is already a $\frac{5}{2}$ ratio of charged to neutral kaons.

Note that symmetry breaking always suppresses the total kaon rate relative to the total pion rate from the equality predicted by SU(3). This is because of the absence of the φ-ω interference term, which enhances both charged- and neutral-kaon pairs.

Recent experimenal data[4] at 1.5–1.7 GeV show that

$$\sigma(K^+K^-)/[\sigma(\pi^+\pi^-) + \sigma(K^+K^-)] = 0.53 \pm 0.13.$$

This is consistent with unbroken SU(3), but the broken-SU(3) predictions with incoherent φ and/or ω are within 2 standard deviations. It would be very interesting to check the neutral-kaon pair production to see if the SU(3) suppression factor is present. Upper bounds on the $K^0\bar{K}^0$ production could be obtained from the inclusive K_1 production, which might be easier to measure experimentally:

$$\sigma(e^+e^- \to K^0\bar{K}^0) \leq \sigma(e^+e^- \to K_1X). \quad (2)$$

The above discussion also has interesting implications for the application of SU(3) symmetry in various models for the deep inelastic processes.

TABLE I. Annihilation amplitudes.

Photon component	$A(\pi^+\pi^-)$	$A(K^+K^-)$	$A(K_1K_2)$
ρ	1	1/2	−1/2
ω	0	1/6	1/6
φ	0	1/3	1/3

TABLE II. Branching ratios.

Photon component assumptions	$\frac{\sigma(K^+K^-)}{\sigma(\pi^+\pi^-)}$	$\frac{\sigma(K_1K_2)}{\sigma(\pi^+\pi^-)}$
All channels coherent, all channels open	1	0
Kaon channels closed for ρ and ω	1/9	1/9
Incoherent ρ, ω, and φ; all channels open	7/18	7/18
Coherent ρ and ω, incoherent φ; all channels open	5/9	2/9

It is tempting to assume that SU(3) symmetry is broken primarily by the $K\pi$ mass difference. Thus SU(3) predictions relating kaon and pion production processes should be violated, but predictions involving only pions or only kaons might be better satisfied. This approach fails completely in the present example where SU(3) symmetry breaking drastically affects the ratio of neutral- to charged-kaon production. The crucial feature is the coherence implicitly assumed in all SU(3) predictions between the contributions of the ρ-, ω, and φ-like components.

This example suggests another criterion for testing the applications of SU(3) for deep inelastic processes. The photon should be broken down into its ρ-, ω-, and φ-like components and the role of interference terms between these components in any prediction should be carefully considered. An important effect of SU(3) symmetry breaking could be to cancel all these interference terms and give quite different predictions.

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Long-Range Correlations

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Recent S-matrix arguments for the existence of nonplanar contributions to scattering amplitudes are reviewed and compared with experiment. The correct normalization of the two-particle correlation function is discussed.

It has long been maintained by field theorists that important distinctions exist between planar and nonplanar contributions to the scattering amplitude.[1] S-matrix theorists, on the other hand, have argued that no such distinction exists.[2] This question is important because the two approaches have tended to disagree even on such parameters as the sign of the cut,[2-4] and it is well known that only the nonplanar graphs contribute to the cuts in field theory. In view of the fact that the field-theory sign is experimentally correct,[5] one is lead to reconsider the S-matrix arguments to see if something has been missed. In two recent papers,[6] hereafter denoted by I and II, this problem was discussed in detail, the conclusion being that indeed a distinction does exist and that terms associated with nonplanar contributions have not been included in the usual S-matrix discussions.[2,3] The purpose of this note is to show that the presence of such terms is supported by the two-particle correlation data.

The conclusions of I and II are based on general arguments which involve only the momenta of the produced particles and consequently are largely model independent. It will expedite the discussion, however, to assume that the Pomeranchukon is a simple pole whose cuts are to be calculated. The general picture that emerges then is that the pole contribution to the total cross sections is generated by the unitarity sum from production amplitudes containing a single dynamic entity, hereafter called a correlation chain, which emits particles in some ordered fashion. An example is the familiar multiperipheral chain.[7] The single-chain production amplitudes also contribute to the cut and, in fact, if only these contributions are kept, the sign of the resulting cut is positive.[2,3]

As was shown in I, however, there are necessarily additional contributions from amplitudes containing two or more overlapping correlation chains, leading to nonplanar contributions to the total cross section (see, for example, Fig. 1). That multiple-chain contributions must be present is also obvious from the fact that the elastic amplitude itself must contain at least two chains to account for the intermediate states of the