COMMENTS

Interpretation of ρ^0-ω^0 Coherence in $\bar{p}p$ Annihilation*

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It is noted that the quark-rearrangement model provides a simple explanation of both the coherence and phase of the ρ^0 and ω^0 amplitudes as observed in the $\rho^0\pi^+\pi^-$ and $\omega^0\pi^+\pi^-$ final states of low-energy $\bar{p}p$ annihilation.

For several years it has been known that experimental data[1-4] show a strong similarity between the following two low-energy annihilation reactions:

$$\bar{p}p \to \rho^0\pi^+\pi^-, \tag{1}$$

$$\bar{p}p \to \omega^0\pi^+\pi^-. \tag{2}$$

For these reactions, the production cross sections for ρ^0 and ω^0 seem to be equal to within ~30% for most regions of phase space. Furthermore, there is a large ρ-ω interference effect in the $\rho^0 \to \pi^+\pi^-$ peak of Reaction (1), yielding the experimental result that the ρ^0 and ω^0 production amplitudes are everywhere in phase, with a relative phase of 0 ± 30 deg. The observed ρ/ω coherence, averaged over all spin states and regions of phase space, is 50–100%.

The purpose of this note is to point out a very simple interpretation of this remarkable and unexplained ρ^0/ω^0 amplitude similarity, within the framework of the quark-rearrangement model.[5] In this model, it is assumed that a three-meson final state is reached in annihilation processes by a rearrangement of the (uud) and $(\bar{u}\bar{u}\bar{d})$ quarks in $p\bar{p}$ processes into three quark-antiquark systems, as shown in Fig. 1(a).

In applying this model to the above reactions, the π^+ and π^- are taken as $(u\bar{d})$ and $(\bar{u}d)$, respectively, leaving $(\bar{u}u)$ as the neutral meson. Since

$$\bar{u}u = (1/\sqrt{2})(\rho^0 + \omega^0), \tag{3}$$

this model yields ρ^0 and ω^0 production amplitudes which are everywhere equal in phase and magnitude, as indicated by the experimental data. (Of course, it is the dominance of the same $\bar{u}u$ state in $e^+e^- \to \rho^0/\omega^0$ which also gives a relative production phase of 0° in that case.)

Several comments should be made regarding the above result: (1) If, instead of quark rearrangement, a quark diagram of the type shown in Fig. 1(b) is used, there is substantial freedom in the choice of the amplitude. In general, both $\bar{u}u$ and $\bar{d}d$ states will be produced, and no simple relationship between ρ and ω production will result. In addition to Fig. 1(a), in which the mesons are emitted by three separate quark lines, and Fig. 1(b), where the mesons are emitted by a single quark line, a third case (not shown) is possible in which meson emission is from two quark lines. This third case will lead to production of both $\bar{u}u$ and $\bar{d}d$ states.

These three classes of quark diagrams have been analyzed by Eylon and Harari.[6] They concluded that at sufficiently high energy the rear-

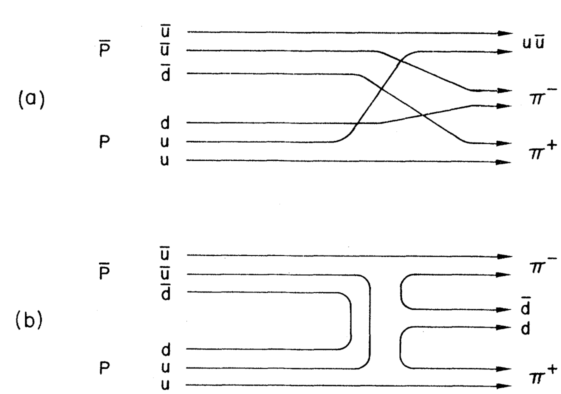

FIG. 1. (a) The quark-rearrangement diagram; a meson is emitted from each of the three quark lines. (b) A planar diagram in which the mesons are emitted from a single quark line.

rangement type of annihilation [Fig. 1(a)] should dominate. The present argument indicates that the diagram of Fig. 1(a) may be dominant even down to energies near the $\bar{N}N$ threshold.

(2) If one attempts to relate ρ and ω production using baryon exchange diagrams instead of quark diagrams, the results depend upon the couplings for $\bar{N}N\rho$, $\bar{N}N\omega$, and $N\bar{\Delta}\rho$ vertices for the various helicity states, so that a simple equality between ρ and ω is not likely to result.

(3) In terms of an s-channel picture, the observed equality of ρ and ω amplitudes corresponds to a degeneracy between s-channel states of opposite G parity. However, if more than one quark emits mesons, as in the quark-rearrangement picture, there does not exist a simple s-channel state which would be an ordinary $(q\bar{q})$ meson.

(4) The simplicity of the quark-rearrangement model and its natural accommodation of the experimental data on ρ/ω amplitudes suggest that further analysis of $\bar{N}N$ annihilation data in terms of such quark diagrams could yield new insights into the $\bar{N}N$ annihilation process.

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Charge-Density Waves and Superconductivity in $NbSe_2$

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A review of the experimental evidence indicates that a recent suggestion by Morris that there is a connection between superconductivity and charge-density waves in $NbSe_2$ is incorrect, and that, if anything, the presence of a charge-density wave has a small inhibitive effect on superconductivity in this material.

In a recent Letter Morris[1] suggested that there may be a relation between superconductivity and charge-density waves (CDW) in $NbSe_2$, the evidence being that both these properties vanished simultaneously with the addition of a critical amount of iron or manganese impurity. It appears to me that CDW's and superconductivity can exist independently of each other in $NbSe_2$ and that any interaction between the two is secondary. The evidence is as follows.

(a) Superconductivity can exist without CDW's: In earlier work[2] it was found that about 1% iodine suppresses the CDW transition, as seen in the Hall coefficient, without having any apparent effect on the superconductivity.

(b) Superconductivity exists with CDW's: In neutron-diffraction experiments Moncton, Axe, and DiSalvo[3] found that CDW's exist below the superconducting transition without any noticeable effect of this transition on them.

(c) CDW's exist without superconductivity: This occurs in pure specimens between 7.3 and 35 K and can also be seen below 7.3 K with a magnetic field strong enough to suppress the superconductivity (this is shown by the point at 4.2 K for specimen Q in Fig. 1 of Ref. 2).

The observations of Morris would thus appear to result from *coincidence* in which destruction of superconductivity due to pair breaking by the magnetic impurities occurs at the same Fe or Mn content at which the CDW's are destroyed by conventional electron scattering.

Morris's suggestion is diametrically opposed to the situation in $2H$-TaS_2 where, following Thompson's first suggestion,[4] it now seems well established that an increase in the superconducting transition temperature from 0.8 to ~4 K occurs when the CDW distortion is removed.[5] There