S-WAVE $\pi\pi$, $K\overline{K}$, AND $\eta\eta$ INTERACTIONS

In this note, we discuss results on the nonstrange $I^G J^{PC} = 0^+0^{++}$ partial wave (S-wave). It has been observed in its coupling to the $\pi\pi$, $K\overline{K}$, $\eta\eta$, 4π, and $\eta\eta'$ systems. We list the claimed resonances under five separate entries covering the mass range from $\pi\pi$ threshold to about 1600 MeV: $f_0(980)$, $f_0(1300)$, $f_0(1370)$, $f_0(1525)$, and $f_0(1590)$. See also the Notes on the $a_0(980)$ and on Non-$q\bar{q}$ Mesons.

Below 1100 MeV, the essential contributions come from $\pi\pi$ and $K\overline{K}$ final states. The $I = 0$ S-wave $\pi\pi$ phase shift δ_0^0 (GRAYER 74, ROSSELET 77) shows a rapid step of 180° near the $K\overline{K}$ threshold, which is the $f_0(980)$ resonance, superimposed over a large "background" phase shift which reaches 90° a little above 1000 MeV. Above this energy, it continues to grow slowly, as expected for a very broad resonance. This is the $f_0(1300)$, which was the $f_0(1400)$ of our 1992 edition and which evolved from the $\epsilon(1200)$ (our 1976 edition). The $\pi\pi$ S-wave inelasticity is not accurately known, and the $\pi\pi \to K\overline{K}$ cross sections (COHEN 80, ETKIN 82, POLYCHRONAKOS 79, WETZEL 76) may have large uncertainties.

Using the data available in 1986, including data on $\pi^+\pi^-$ and K^+K^- central production (AKESSON 86) and on $J/\psi(1S) \to \phi\pi\pi$ and $J/\psi(1S) \to K^+K^-$, the coupled-channel analyses of AU 87 suggested that four resonances were needed to describe the 1-GeV region. But, adding to their analysis new data on $J/\psi(1S) \to \phi\pi\pi$ and $\phi K\overline{K}$ (MALIK 86, FALVARD 88, LOCKMAN 89), on $D_s^+ \to \pi^+\pi^+\pi^-$ (ANJOS 89), and on $K^+K^- \to K_S^0 K_S^0$ (ASTON 88), and relaxing the constraints on $\pi\pi \to K\overline{K}$ cross sections (LINDENBAUM 92), MORGAN 93 now favors a single Breit-Wigner resonance for the $f_0(980)$ described by two poles, $E^{II} = (988 \pm 10) - (24 \pm 6)i$ MeV and $E^{III} = 978 - 28i$ MeV, corresponding to resonance parameters $m_0 = 983$ MeV, $\Gamma_0 = 52$ MeV, and $g^2_{K\overline{K}}/g^2_{\pi\pi} \approx 0.85$. In a similar coupled-channel analysis, but limited to fitting elastic-scattering data (GRAYER 74, ROSSELET 77), and the centrally produced $\pi\pi$ and $K\overline{K}$ data (AKESSON 86), ZOU 93 also finds two poles in the 1 GeV region, $E^{II} = 988 - 25i$ MeV in agreement with MORGAN 93, while their $E^{III} = 914 - 219i$ MeV, has a large imaginary part.

Below 900 MeV, BECKER 79B excludes a resonance behaviour for δ_0^0 in their $\pi^- p$ (polarized) $\rightarrow \pi^+\pi^- n$ data. In contrast, SVEC 92, using their data on $\pi^+ n$ (polarized) $\rightarrow \pi^+\pi^- p$, which only span the range 600–900 MeV, suggests a narrow scalar state at 750 MeV (Γ = 100–200 MeV); the associated δ_0^0 values differ substantially from the recent consensus and would reopen the old UP-DOWN ambiguity of the early 1970's (see our 1984 edition). The DOWN option was long ago selected by requiring continuity of δ_0^0 and its associated inelasticity above 900 MeV to reproduce the observed rapid variations of the $\pi\pi$ elastic cross sections through the $K\overline{K}$ threshold region (PROTOPOPESCU 73). Indeed, attempts to introduce an UP-type δ_0^0 tend to contradict dispersion relations (PENNINGTON 93). Thus, the interpretation of SVEC 92 must be treated with some reservation.

Both MORGAN 93 and ZOU 93 have to add a background term in the $f_0(980)$ region, which may be interpreted as a very broad ($\Gamma \approx 700$ MeV) resonance with mass in the 1000–1500 MeV range. Many broad $\pi\pi$ elastic resonances have been claimed in the 1000–1500 MeV region, and we collect them all under one entry, the $f_0(1300)$.

Above 1200 MeV, there is increasing evidence that the 0^+0^{++} sector is dominated by the 4π channel and that the $\eta\eta$ channel cannot be neglected. For the 4π channel, the information comes mainly from the analysis of $\overline{p}n \rightarrow 5\pi$ (GASPERO 93, ADAMO 93, AMSLER 94). AMSLER 94 finds a large production of a 0^{++} resonance decaying into 4π, mostly $\rho\rho$, with $M = 1374 \pm 38$ MeV and $\Gamma = 357 \pm 61$ MeV, and quote a 4π:2π branching ratio of order 5:1. The same resonance is observed in $\overline{p}p \rightarrow \eta\eta\pi^0$ (AMSLER 93C) and in $\overline{p}p \rightarrow 3\pi^0$ (AKER 91) leading to an $\eta\eta$:$\pi\pi$ branching ratio of order 1:3.

Thus we collect all the broad $\pi\pi$ inelastic S-wave resonance claims under a new entry, the $f_0(1370)$, although they could be the $f_0(1300)$, provided the inelasticity of the latter is in fact larger than is presently believed.

In a simultaneous fit to the $\overline{p}p \rightarrow 3\pi^0$ and $\overline{p}p \rightarrow \eta\eta\pi^0$ data, ANISOVITCH 94 find again the $f_0(1370)$ and, in addition, they observe another scalar resonance with $M = 1520 \pm 25$ MeV and $\Gamma = 146 \pm 25$ MeV. We list this observation under the $f_0(1525)$, although it perhaps does not belong there.

The fifth scalar entry is the $f_0(1590)$ of the GAMS collaboration (BINON 83).