THE $\rho(1450)$ AND THE $\rho(1700)$

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In our 1988 edition, we replaced the $\rho(1600)$ entry with two new ones, the $\rho(1450)$ and the $\rho(1700)$, because there was emerging evidence that the 1600-MeV region actually contains two $\rho$-like resonances. ERKAL 86 had pointed out this possibility with a theoretical analysis on the consistency of $2\pi$ and $4\pi$ electromagnetic form factors and the $\pi\pi$ scattering length. DONNACHIE 87, with a full analysis of data on the $2\pi$ and $4\pi$ final states in $e^+e^-$ annihilation and photoproduction reactions, had also argued that in order to obtain a consistent picture, two resonances were necessary. The existence of $\rho(1450)$ was supported by the analysis of $\eta\rho^0$ mass spectra obtained in photoproduction and $e^+e^-$ annihilation (DONNACHIE 87B), as well as that of $e^+e^-\rightarrow\omega\pi$ (DONNACHIE 91).

The analysis of DONNACHIE 87 was further extended by CLEGG 88, 94 to include new data on $4\pi$ systems produced in $e^+e^-$ annihilation, and in $\tau$ decays ($\tau$ decays to $4\pi$ and $e^+e^-$ annihilation to $4\pi$ can be related by the Conserved Vector Current assumption). These systems were successfully analyzed using interfering contributions from two $\rho$-like states, and from the tail of the $\rho(770)$ decaying into two-body states. While specific conclusions on $\rho(1450)\rightarrow4\pi$ were obtained, little could be said about the $\rho(1700)$.

An analysis by CLEGG 90 of $6\pi$ mass spectra from $e^+e^-$ annihilation and from diffractive photoproduction provides evidence for two $\rho$ mesons at about 2.1 and 1.8 GeV that decay strongly into $6\pi$ states. While the former is a candidate for a new resonance ($\rho(2150)$), the latter could be a manifestation of the $\rho(1700)$ distorted by threshold effects.

Independent evidence for two $1^-$ states is provided by KILLIAN 80 in $4\pi$ electroproduction at $\langle Q^2 \rangle = 1$ (GeV/c)$^2$, and by FUKUI 88 in a high-statistics sample of the $\eta\pi\pi$ system in $\pi^-p$ charge exchange.

This scenario with two overlapping resonances is supported by other data. BISELLO 89 measured the pion form factor in the interval 1.35–2.4 GeV and observed a deep minimum.
around 1.6 GeV. The best fit was obtained with the hypothesis of ρ-like resonances at 1420 and 1770 MeV, with widths of about 250 MeV. ANTONELLI 88 found that the $e^+e^- \rightarrow \eta \pi^+\pi^-$ cross section is better fitted with two fully interfering Breit-Wigners, with parameters in fair agreement with those of DONNACHIE 87 and BISELLO 89. These results can be considered as a confirmation of the $\rho(1450)$.

Decisive evidence for the $\pi\pi$ decay mode of both $\rho(1450)$ and $\rho(1700)$ came from recent results in $\overline{p}p$ annihilation at rest (ABELE 97). It was shown that these resonances also possess a $K\overline{K}$ decay mode (ABELE 98, BERTIN 98B, ABELE 99D). High statistics studies of the decays $\tau \rightarrow \pi\pi\nu_\tau$ (BARATE 97M, URHEIM 97), and $\tau \rightarrow 4\pi\nu_\tau$ (EDWARDS 00), also require the $\rho(1450)$, but are not sensitive to the $\rho(1700)$, because it is too close to the $\tau$ mass.

The structure of these $\rho$ states is not yet completely clear. BARNES 97 and CLOSE 97C claim that $\rho(1450)$ has a mass consistent with radial $2S$, but its decays show characteristics of hybrids, and suggest that this state may be a $2S$-hybrid mixture. DONNACHIE 99 argues that hybrid states could have a $4\pi$ decay mode dominated by the $a_1\pi$. Such behavior has recently been observed by AKHMETSHIN 99E in $e^+e^- \rightarrow 4\pi$ in the energy range 1.05–1.38 GeV, and by EDWARDS 00 in $\tau \rightarrow 4\pi$ decays. More data should be collected to clarify the nature of the $\rho$ states, particularly in the energy range above 1.6 GeV.

We also list under the $\rho(1450)$ the $\phi\pi$ state with $J^{PC} = 1^{--}$ or $C'(1480)$ observed by BITYUKOV 87. While ACHASOV 96B shows that it may be a threshold effect, CLEG 88 and LANDSBERG 92 suggest two independent vector states with this decay mode. Note, however, that $C'(1480)$ in its $\phi\pi$ decay mode was not confirmed by $e^+e^- \rightarrow \phi\pi$ (DOLINSKY 91, BISELLO 91C) and $\overline{p}p$ (ABELE 97H) experiments.

Several observations on the $\omega\pi$ system in the 1200-MeV region (FRENKIEL 72, COSME 76, BARBER 80C, ASTON 80C, ATKINSON 84C, BRAU 88, AMSLER 93B) may be interpreted in terms of either $J^P = 1^- \rho(770) \rightarrow \omega\pi$ production (LAYSSAC 71), or $J^P = 1^+ b_1(1235)$ production (BRAU 88,
AMSLER 93B). We argue that no special entry for a $\rho(1250)$ is needed. The LASS amplitude analysis (ASTON 91B) showing evidence for $\rho(1270)$ is preliminary and needs confirmation. For completeness, the relevant observations are listed under the $\rho(1450)$. 