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

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 in the annihilation reactions $e^+e^- \to \pi^+\pi^-$, $2\pi^+2\pi^-$, and $\pi^+\pi^-\pi^0\pi^0$, and in the photoproduction reactions $\gamma p \to \pi^+\pi^- p$, $2\pi^+2\pi^- p$, and $\pi^+\pi^-\pi^0\pi^0 p$, had also argued that to obtain a consistent picture two resonances, whose masses and widths could be fixed reasonably well, were necessary. This picture was supported by the analysis of DONNACHIE 87B of $J^P = 1^-$ $\eta\rho^0$ mass spectra obtained in photoproduction and in $e^+e^-$ annihilations; the analysis showed the need for a contribution from a $\rho$ meson with a mass of about 1470 MeV, but could say little about a higher-mass resonance (actually the data could be explained without it). Confirmation of the decay $\rho(1450) \to \omega\pi$, and a tight constraint on the mass due to strong interference with the $\rho(770)$ tail, was found by DONNACHIE 91 in an analysis of $e^+e^- \to \omega\pi$.

The analysis of DONNACHIE 87 was extended by CLEGG 88 to include new data on $4\pi$ systems produced in $e^+e^-$ annihilation and in $\tau$ decay ($4\pi$ $\tau$ decays and $4\pi$ annihilation reactions 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 $\rho(1450) \to 4\pi$ were obtained, the quality of the data used by CLEGG 88 prevented any conclusion on $\rho(1700) \to 4\pi$ decay.

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, 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 with significant statistics (280 $e^+e^- \to \pi^+\pi^-$ events with very low background); a deep minimum is observed around 1.6 GeV, and the best fit to the form factor is obtained with the hypothesis of $\rho$-like resonances at 1420 and 1770 MeV with widths of about 250 MeV. ANTONELLI 88 found that the $e^+e^- \to \eta\pi^+\pi^-$ cross section (using three different $\eta$ decay modes) is better fitted with two fully interfering Breit-Wigners, with parameters in fair agreement with those of DONNACHIE 87 and BISELLO 89.

These results (although ANTONELLI 88 is statistically less significant than BISELLO 89) have also resolved the disagreement between DONNACHIE 87 and FUKUI 88 on the $\rho(1450)$ width in favor of the DONNACHIE 87 value. From this point of view, the two experiments can be considered as solid confirmation of the $\rho(1450)$. For the possibility that its $\phi\pi$ mode actually contains two independent vector states, see LANDSBERG 92.

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 $J^P = 1^-$ $\rho(770) \to \pi\omega$ 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 $\rho(1450)$.