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

Updated April 2006 by S. Eidelman (Novosibirsk) and
J.J Hernandez-Rey (Valencia).

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 ρ-like resonances. ERKAL 86 had pointed out this possibility with a theoretical analysis on the consistency of 2π and 4π electromagnetic form factors and the $\pi\pi$ scattering length. DONNACHIE 87, with a full analysis of data on the 2π and 4π 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 4π systems produced in e^+e^- annihilation, and in τ decays (τ decays to 4π and e^+e^- annihilation to 4π can be related by the Conserved Vector Current assumption). These systems were successfully analyzed using interfering contributions from two ρ-like states, and from the tail of the $\rho(770)$ decaying into two-body states. While specific conclusions on $\rho(1450) \rightarrow 4\pi$ were obtained, little could be said about the $\rho(1700)$.

Independent evidence for two 1^- states is provided by KILLIAN 80 in 4π electroproduction at $\langle Q^2 \rangle = 1$ $(\mathrm{GeV}/c)^2$, 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 $\tau \to \pi\pi\nu_\tau$ (BARATE 97M, URHEIM 97), and $\tau \to 4\pi\nu_\tau$ (EDWARDS 00A), also require the $\rho(1450)$, but are not sensitive to the $\rho(1700)$, because it is too close to the τ mass. Recently in a very high statistics study of the $\tau \to \pi\pi\nu_\tau$ decay performed at Belle (ABE 05H) both $\rho(1450)$ and $\rho(1700)$ were observed for the first time in τ decays.

The structure of these ρ 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 4π decay mode dominated by the $a_1\pi$. Such behavior has recently been observed by AKHMETSHIN 99E in $e^+e^- \to 4\pi$ in the energy range 1.05–1.38 GeV, and by EDWARDS 00A in $\tau \to 4\pi$ decays. ALEXANDER 01B observed the $\rho(1450) \to \omega\pi$ decay mode in B-meson decays, however, didn't find $\rho(1700) \to \omega\pi^0$. A similar conclusion is made by AKHMETSHIN 03B who studied the process $e^+e^- \to \omega\pi^0$. Various decay modes of the $\rho(1450)$ and $\rho(1700)$ were observed in $\bar{p}n$ and $\bar{p}p$ annihilation (ABELE 01B, BARGIOTTI 03B), but no definite conclusions could be drawn. More data should be collected to clarify the nature of the ρ 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, CLEGG 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^- (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 $J^P = 1^-$ $\rho(770) \to \omega\pi$ 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 $\rho(1450)$.

Evidence for ρ-like mesons decaying into 6π states was first noted by CLEGG 90 in the analysis of 6π mass spectra from e^+e^- annihilation (BISELLO 81, CASTRO 88) and diffractive photoproduction (ATKINSON 85). CLEGG 90 argued that two states at about 2.1 and 1.8 GeV exist: 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. Recently, the E687 Collaboration at Fermilab reported an observation of a narrow dip structure at 1.9 GeV in the $3\pi^+3\pi^-$ diffractive photoproduction (FRABETTI 01). A similar effect of the dip in the cross section of $e^+e^- \to 6\pi$ around 1.9 GeV has been earlier reported by DM2 (CASTRO 88), where 6π included both $3\pi^+3\pi^-$ and $2\pi^+2\pi^-2\pi^0$. Later the dip in the R value (the total cross section of $e^+e^- \to$ hadrons divided by the cross section of $e^+e^- \to \mu^+\mu^-$) was observed by ANTONELLI 96, again around 1.9 GeV. This energy is close to the $N\bar{N}$ threshold which hints to the possible relation between the dip and $N\bar{N}$, e.g., the frequently discussed narrow $N\bar{N}$ resonance or just a threshold effect. Such behaviour is also characteristic of exotic objects like vector $q\bar{q}$ hybrids. Note that AGNELLO 02 failed to find this state in the reaction $\bar{n}p \to 3\pi^+2\pi^-\pi^0$. A reanalysis of the E687 data by FRABETTI 04 shows that a dip may arise due to interference of a narrow object with a broad $\rho(1700)$ independently of the nature of the former. Recently BaBar studied the processes $e^+e^- \to 3\pi^+3\pi^-$ and $e^+e^- \to 2\pi^+2\pi^-2\pi^0$ using the radiative return and observed a structure around 1.9 GeV in both final states (AUBERT 06D). The data are not well described by a single Breit-Wigner state, and a good fit is achieved while taking into account the interference of such a structure with a Jacob-Slansky amplitude for continuum. The mass of this state obtained by BaBar is consistent with ANTONELLI 96 and FRABETTI 01, but the width is substantially larger. We list these observations under a separate particle $\rho(1900)$, which needs confirmation.