$a_1(1260)$

$I^G(J^{PC}) = 1^-(1^{++})$

NOTE ON THE $a_1(1260)$

For some time, even the existence of this broad bump as a genuine resonance in the 3π mass spectrum was questioned. Today the $a_1(1260)$ situation is still not satisfactorily understood, and its resonance parameters are not well determined. For an attempt to fit the leptonic data with two resonances, see IIZUKA 89.

The main experimental data on the $a_1(1260)$ can be grouped into two classes:

(1) Hadronic production—There are two high-statistics experiments: Diffractive production with incident π^- (DAUM 80, 81B) and charge-exchange production with low-energy π^- (DANKOWYCH 81), both on hydrogen. The extraction of the $a_1(1260)$ parameters from these experiments is troubled by the presence of coherent background, attributed to the Deck effect. Both experiments perform a partial-wave analysis. The phenomenological amplitude used to explain the 1^+S0^+ data consists of a rescattered Deck amplitude (calculated from one-pion exchange and not allowed to vary), plus a direct resonance-production term. Both experiments agree on a mass of about 1270 MeV, but DAUM 81B finds a somewhat smaller width than does DANKOWYCH 81 ($\simeq$ 300 MeV versus $\simeq$ 380 MeV). Rather lower values for the $a_1(1260)$ mass and width (1121$\pm$8 MeV and 239$\pm$11 MeV) have been obtained from a partial-wave analysis based on the isobar model of the $\pi^+\pi^-\pi^0$ system in a high-statistics π^-p charge-exchange reaction (ANDO 92). However, in this analysis, only Breit-Wigner terms were considered.

(2) τ decay—Four experiments have reported good data on $\tau \rightarrow a_1(1260)\nu_\tau$, $\rightarrow \rho\pi\nu_\tau$ (RUCKSTUHL 86, SCHMIDKE 86, ALBRECHT 86B, and BAND 87). Here the $a_1(1260)$ from τ decay is expected to be (almost) free from background. The four sets of data show some inconsistencies in the values quoted for the mass. However, according to BOWLER 86, this can be attributed to the different assumptions and approximations made in fitting the data. Furthermore, all these τ decays seem to indicate a consistent $a_1(1260)$ width greater than 400 MeV, considerably larger than that found by DAUM 81B. A recent analysis by ALBRECHT 93C on new ARGUS τ decay data confirms that the model-dependent systematic uncertainties of the parameters are much larger than the now small statistical errors.

The discrepancies between the hadronic and the τ decay results have stimulated several reanalyses. BOWLER 86, TORNQVIST 87, ISGUR 89, and IVANOV 91 have studied the process $\tau \rightarrow 3\pi\nu_\tau$ (BOWLER 86 has fit the data of ALBRECHT 86B and SCHMIDKE 86, while TORNQVIST 87, ISGUR 89, and IVANOV 91 have also used RUCKSTUHL 86).

BOWLER 86 assumes that the 3π state is wholly $a_1(1260)$, with no background, coherent or incoherent. His fits to the data always use the same theoretical form with a "normal" Breit-Wigner shape and various behaviors of the $a_1(1260)$ axial coupling as a function of the 3π mass.

TORNQVIST 87 fits a modified Breit-Wigner form to the data that includes, besides $\rho\pi$ and $K^*(892)\overline{K} + \overline{K}^*(892)K$ threshold effects, an energy-dependent real part of the $a_1(1260)$ mass parameter ("running mass shift function").

ISGUR 89 deduces a full mass-dependent covariant amplitude for $\tau \rightarrow 3\pi\nu_\tau$ from theory; all the ambiguities due to the non-pointlike nature of the hadrons (such as unknown off-shell behaviors of propagators and vertices) are associated with a parameterized nonresonant background amplitude. Since this background is small anyway, the $a_1(1260)$ parameters do not depend critically on its form.

Despite these quite different approaches, all three analyses find a good overall description of all the τ decay data with an $a_1(1260)$ mass near 1230 MeV, consistent with the hadronic data; however, their widths (400 MeV for BOWLER 86, 420 MeV for ISGUR 89, and 600 MeV for TORNQVIST 87) remain significantly higher than that extracted from diffractive-hadronic data.

IVANOV 91, using a phenomenological meson Lagrangian based on a four-quark interaction, obtains $a_1(1260)$ parameters consistent with those mentioned above.

BOWLER 88 returned to the diffractive data and investigated their consistency with an $a_1(1260)$ width greater than 400 MeV, as required by the τ-decay data. He verified that a width of about 300 MeV is a direct consequence of the particular fixed shape DAUM 81B used for the Deck amplitude. Freeing this shape, good fits are obtained with a width of about 400 MeV. He then finds no contradiction between the hadronic and τ-decay data, and the $a_1(1260)$ parameters are well constrained. However, applying the same type of analysis to the ANDO 92 data, the low mass and narrow width they obtained with the Breit-Wigner PWA do not change appreciably.

No evidence for charge-exchange photoproduction of the $a_1(1260)$ is observed by CONDO 93. This lack of evidence (together with a clear signal of $a_2(1320)$ photoproduction) is shown to be consistent with either an extremely large $a_1(1260)$ hadronic width or with a small radiative width $\Gamma\ [a_1(1260) \rightarrow \pi\gamma]$, which this could be accommodated if the a_1 mass is somewhat below 1260 MeV.