THE $a_1(1260)$ AND $a_1(1640)$

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

(1) Hadronic Production: This comprises diffractive production with incident π^- (DAUM 80, 81B) and charge-exchange production with low-energy π^- (DANKOWYCH 81, ANDO 92). The 1980's experiments explain the $I^G LJ^P = 1^+ S0^+$ data using a phenomenological amplitude consisting of a rescattered Deck amplitude plus a direct resonance-production term. They agree on an $a_1(1260)$ mass of about 1270 MeV and a width of 300–380 MeV. ANDO 92 finds rather lower values for the mass (1121 MeV) and width (239 MeV) in a partial-wave analysis based on the isobar model of the $\pi^+\pi^-\pi^0$ system. However, in this analysis, only Breit-Wigner terms were considered. Recently BARBERIS 98B studied central production of the $\pi^+\pi^-\pi^0$ system, and observed the $a_1(1260)$ meson with a mass of 1240 MeV and a width of about 400 MeV.

CONDO 93 found no evidence for charge-exchange photoproduction of the $a_1(1260)$ (but found a clear signal of $a_2(1320)$ photoproduction). Similarly, MOLCHANOV 01 found no evidence for Coulomb production of $a_1(1260)$ studying coherent production of three pions (but observed a prominent signal of $a_2(1320)$). They show that it is consistent with either an extremely large $a_1(1260)$ hadronic width, or with a small radiative width to $\pi\gamma$, which could be accommodated if the a_1 mass is somewhat below 1260 MeV.

(2) τ Decay: Various experiments reported good data on $\tau \to a_1(1260)\nu_\tau \to \rho\pi\nu_\tau$ (RUCKSTUHL 86, SCHMIDKE 86, ALBRECHT 86B, BAND 87, ACKERSTAFF 97R, ABREU 98G, and ASNER 00). They are somewhat inconsistent concerning the $a_1(1260)$ mass, which can, however, be attributed to model-dependent systematic uncertainties (BOWLER 86, ALBRECHT 93C, ACKERSTAFF 97R). They all find a width greater than 400 MeV.

The discrepancies between the hadronic- and τ-decay results have stimulated several reanalyses. BASDEVANT 77, 78 used the early diffractive dissociation and τ decay data, and showed that they could be well reproduced with an a_1 resonance mass of

1180 ± 50 MeV and width of 400 ± 50 MeV. Later, BOWLER 86, TORNQVIST 87, ISGUR 89, and IVANOV 91 have studied the process $\tau \rightarrow 3\pi\nu_\tau$. Despite quite different approaches, they all found a good overall description of the τ-decay data with an $a_1(1260)$ mass near 1230 MeV, consistent with the hadronic data. However, their widths remain significantly larger (400–600 MeV) than those extracted from diffractive-hadronic data. This is also the case with the later OPAL experiment (ACKERSTAFF 97R). In the high statistics analysis of ACKERSTAFF 97R, the models of ISGUR 89 and KUHN 90 are used to fit distributions of the 3π invariant mass, as well as the 2π invariant mass projections of the Dalitz plot, and neither model is found to provide a completely satisfactory description of the data. Another recent high statistics analysis of ABREU 98G obtains a good description of the $\tau \rightarrow 3\pi$ data using the model of FEINDT 90, which includes the $a_1(1640)$ meson, most probably a radial excitation of the $a_1(1260)$ meson (BARNES 97), with a mass of 1700 MeV and a width of 300 MeV. A similar signal has been observed in various hadroproduction processes: by AMELIN 95B and CHUNG 02 in the D-wave of the $\rho\pi$ state, by GOUZ 92 in the $f_1(1285)\pi$ state, and by BAKER 99 in the $f_0(600)\pi$ state, as well as by BAKER 03 in the $\omega\pi^+\pi^-$ state. The existence of such a resonance is also suggested by the very big data sample of ASNER 00, which shows an excess of events at high 3π mass. Their data are better described by the a_1' contribution, though at a level below that reported by ABREU 98G. Since the statistical significance of the a_1' contribution is 2–3 standard deviations only, they conclude that more data is needed to establish the a_1' existence.

ASNER 00 has also performed the analysis of the substructures in the Dalitz plot and found significant contributions of the a_1 decay to $f_0(600)\pi$, $f_0(1370)\pi$, and $f_2(1270)\pi$. The contribution of the $a_1 \rightarrow f_0(600)\pi$ at a similar level has independently been observed in $e^+e^- \rightarrow 4\pi$ annihilation (AKHMETSHIN 99E), where the $2\pi^+2\pi^-$ final state was shown to be dominated by the $a_1(1260)\pi$ mechanism. Note that existence of the isoscalar contributions to the two-pion state, in addition to the isovector one ($\rho\pi$), will influence the ratio

$B(a_1^- \to \pi^-\pi^+\pi^-)/B(a_1^- \to \pi^-\pi^0\pi^0)$, which should be equal to 1 for the pure $\rho\pi$ state. The fit of ASNER 00 improves when the $K\overline{K}^*(892)$ threshold is included. Recently DRUTSKOY 02 found direct evidence for the decay mode $a_1(1260) \to K\overline{K}^*(892)+$ c.c. in B-meson decays.

BOWLER 88 showed that good fits to both the hadronic and the τ-decay data could be obtained with a width of about 400 MeV. 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.