$a_1(1260)$

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

THE $a_1(1260)$

Updated March 2000 by S. Eidelman (Novosibirsk).

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 $I^GLJ^P = 1^+S0^+$ data using a phenomenological amplitude consisting of a rescattered Deck amplitude, plus a direct resonance-production term. They agree on a 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.

(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 $\tau \to 3\pi\nu_\tau$. 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. 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 $\tau \to 3\pi$ data using the model of FEINDT 90, which includes the a_1' meson, a radial excitation of the $a_1(1260)$ meson, with a mass of 1700 MeV and a width of 300 MeV. A similar signal has been observed by AMELIN 95B in the D and S waves of the $\rho\pi$ state, as well as by GOUZ 92 in the $f_1(1285)\pi$ 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 2–3σ only, they conclude that more data is needed to establish the existence of the a_1'.

ASNER 00 has also performed an analysis of the substructures in the Dalitz plot, and found significant contributions

of the a_1 decay to $\sigma\pi$, $f_0(1370)\pi$, and $f_2(1270)\pi$. The contribution of the $a_1 \to \sigma\pi$ at a similar level has independently been observed in $e^+e^- \to 4\pi$ 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 the existence of isoscalar contributions to the two-pion state, in addition to the isovector one ($\rho\pi$), will influence the ratio $\mathrm{B}(a_1^- \to \pi^-\pi^+\pi^-)/\mathrm{B}(a_1^- \to \pi^-\pi^0\pi^0)$, which should be equal to 1 for the pure $\rho\pi$ state.

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.

CONDO 93 found no evidence for charge-exchange photoproduction of the $a_1(1260)$ (but found a clear signal of $a_2(1320)$ photoproduction). 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.

$a_1(1260)$ MASS

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
1230±40 OUR ESTIMATE						
• • • We do not use the following data for averages, fits, limits, etc. • • •						
1331±10± 3	37k	[1] ASNER	00	CLE2		10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$
1255± 7± 6	5904	[2] ABREU	98G	DLPH		e^+e^-
1207± 5± 8	5904	[3] ABREU	98G	DLPH		e^+e^-
1196± 4± 5	5904	[4,5] ABREU	98G	DLPH		e^+e^-

1240 ± 10		BARBERIS	98B			$450\ pp \rightarrow p_f \pi^+ \pi^- \pi^0 p_s$
$1262 \pm 9 \pm 7$	[2,6]	ACKERSTAFF	97R	OPAL		$E_{cm}^{ee} = 88$–94, $\tau \rightarrow 3\pi\nu$
$1210 \pm 7 \pm 2$	[3,6]	ACKERSTAFF	97R	OPAL		$E_{cm}^{ee} = 88$–94, $\tau \rightarrow 3\pi\nu$
$1211 \pm 7^{+50}_{-0}$	[3]	ALBRECHT	93C	ARG		$\tau^+ \rightarrow \pi^+\pi^+\pi^-\nu$
1121 ± 8	[7]	ANDO	92	SPEC		$8\ \pi^- p \rightarrow \pi^+\pi^-\pi^0 n$
1242 ± 37	[8]	IVANOV	91	RVUE		$\tau \rightarrow \pi^+\pi^+\pi^-\nu$
1260 ± 14	[9]	IVANOV	91	RVUE		$\tau \rightarrow \pi^+\pi^+\pi^-\nu$
1250 ± 9	[10]	IVANOV	91	RVUE		$\tau \rightarrow \pi^+\pi^+\pi^-\nu$
1208 ± 15		ARMSTRONG	90	OMEG	0	$300.0 pp \rightarrow pp\pi^+\pi^-\pi^0$
1220 ± 15	[11]	ISGUR	89	RVUE		$\tau^+ \rightarrow \pi^+\pi^+\pi^-\nu$
1260 ± 25	[12]	BOWLER	88	RVUE		
$1166 \pm 18 \pm 11$		BAND	87	MAC		$\tau^+ \rightarrow \pi^+\pi^+\pi^-\nu$
$1164 \pm 41 \pm 23$		BAND	87	MAC		$\tau^+ \rightarrow \pi^+\pi^0\pi^0\nu$
1250 ± 40	[11]	TORNQVIST	87	RVUE		
1046 ± 11		ALBRECHT	86B	ARG		$\tau^+ \rightarrow \pi^+\pi^+\pi^-\nu$
$1056 \pm 20 \pm 15$		RUCKSTUHL	86	DLCO		$\tau^+ \rightarrow \pi^+\pi^+\pi^-\nu$
$1194 \pm 14 \pm 10$		SCHMIDKE	86	MRK2		$\tau^+ \rightarrow \pi^+\pi^+\pi^-\nu$
1255 ± 23		BELLINI	85	SPEC		$40\ \pi^- A \rightarrow \pi^-\pi^+\pi^- A$
1240 ± 80	[13]	DANKOWY...	81	SPEC	0	$8.45\ \pi^- p \rightarrow n 3\pi$
1280 ± 30	[13]	DAUM	81B	CNTR		$63,94\ \pi^- p \rightarrow p 3\pi$
1041 ± 13	[14]	GAVILLET	77	HBC	+	$4.2\ K^- p \rightarrow \Sigma 3\pi$

[1] From a fit to the 3π mass spectrum including the $K\overline{K}^*(892)$ threshold.
[2] Uses the model of KUHN 90.
[3] Uses the model of ISGUR 89.
[4] Includes the effect of a possible a_1' state.
[5] Uses the model of FEINDT 90.
[6] Supersedes AKERS 95P
[7] Average and spread of values using 2 variants of the model of BOWLER 75.
[8] Reanalysis of RUCKSTUHL 86.
[9] Reanalysis of SCHMIDKE 86.
[10] Reanalysis of ALBRECHT 86B.
[11] From a combined reanalysis of ALBRECHT 86B, SCHMIDKE 86, and RUCKSTUHL 86.
[12] From a combined reanalysis of ALBRECHT 86B and DAUM 81B.
[13] Uses the model of BOWLER 75.
[14] Produced in K^- backward scattering.

$a_1(1260)$ WIDTH

VALUE (MeV)	*EVTS*	*DOCUMENT ID*		*TECN*	*CHG*	*COMMENT*
250 to 600 OUR ESTIMATE						
• • • We do not use the following data for averages, fits, limits, etc. • • •						
$814 \pm 36 \pm 13$	37k	[15] ASNER	00	CLE2		10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$
450 ± 50	22k	[16] AKHMETSHIN	99E	CMD2		1.05–1.38 $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$
570 ± 10		[17] BONDAR	99	RVUE		$e^+e^- \to 4\pi$, $\tau \to 3\pi\nu_\tau$
$587 \pm 27 \pm 21$	5904	[18] ABREU	98G	DLPH		e^+e^-
$478 \pm 3 \pm 15$	5904	[19] ABREU	98G	DLPH		e^+e^-
$425 \pm 14 \pm 8$	5904	[20,21] ABREU	98G	DLPH		e^+e^-
400 ± 35		BARBERIS	98B			450 $pp \to p_f\pi^+\pi^-\pi^0 p_s$
$621 \pm 32 \pm 58$		[18,22] ACKERSTAFF	97R	OPAL		$E_{\rm cm}^{ee}$= 88–94, $\tau \to 3\pi\nu$
$457 \pm 15 \pm 17$		[19,22] ACKERSTAFF	97R	OPAL		$E_{\rm cm}^{ee}$= 88–94, $\tau \to 3\pi\nu$
$446 \pm 21 {}^{+140}_{-0}$		[19] ALBRECHT	93C	ARG		$\tau^+ \to \pi^+\pi^+\pi^-\nu$
239 ± 11		ANDO	92	SPEC		8 $\pi^- p \to \pi^+\pi^-\pi^0 n$
$266 \pm 13 \pm 4$		[23] ANDO	92	SPEC		8 $\pi^- p \to \pi^+\pi^-\pi^0 n$
$465 {}^{+228}_{-143}$		[24] IVANOV	91	RVUE		$\tau \to \pi^+\pi^+\pi^-\nu$
$298 {}^{+40}_{-34}$		[25] IVANOV	91	RVUE		$\tau \to \pi^+\pi^+\pi^-\nu$
488 ± 32		[26] IVANOV	91	RVUE		$\tau \to \pi^+\pi^+\pi^-\nu$
430 ± 50		ARMSTRONG	90	OMEG	0	300.0$pp \to pp\pi^+\pi^-\pi^0$
420 ± 40		[27] ISGUR	89	RVUE		$\tau^+ \to \pi^+\pi^+\pi^-\nu$
396 ± 43		[28] BOWLER	88	RVUE		
$405 \pm 75 \pm 25$		BAND	87	MAC		$\tau^+ \to \pi^+\pi^+\pi^-\nu$
$419 \pm 108 \pm 57$		BAND	87	MAC		$\tau^+ \to \pi^+\pi^0\pi^0\nu$
521 ± 27		ALBRECHT	86B	ARG		$\tau^+ \to \pi^+\pi^+\pi^-\nu$
$476 {}^{+132}_{-120} \pm 54$		RUCKSTUHL	86	DLCO		$\tau^+ \to \pi^+\pi^+\pi^-\nu$
$462 \pm 56 \pm 30$		SCHMIDKE	86	MRK2		$\tau^+ \to \pi^+\pi^+\pi^-\nu$
292 ± 40		BELLINI	85	SPEC		40 $\pi^- A \to \pi^-\pi^+\pi^- A$
380 ± 100		[29] DANKOWY...	81	SPEC	0	8.45 $\pi^- p \to n3\pi$
300 ± 50		[29] DAUM	81B	CNTR		63,94 $\pi^- p \to p3\pi$
230 ± 50		[30] GAVILLET	77	HBC	+	4.2 $K^- p \to \Sigma 3\pi$

[15] From a fit to the 3π mass spectrum including the $K\overline{K}^*(892)$ threshold.
[16] Using the $a_1(1260)$ mass of 1230 MeV.
[17] From AKHMETSHIN 99E and ASNER 00 data using the $a_1(1260)$ mass of 1230 MeV.
[18] Uses the model of KUHN 90.
[19] Uses the model of ISGUR 89.
[20] Includes the effect of a possible a_1' state.
[21] Uses the model of FEINDT 90.
[22] Supersedes AKERS 95P
[23] Average and spread of values using 2 variants of the model of BOWLER 75.
[24] Reanalysis of RUCKSTUHL 86.
[25] Reanalysis of SCHMIDKE 86.
[26] Reanalysis of ALBRECHT 86B.
[27] From a combined reanalysis of ALBRECHT 86B, SCHMIDKE 86, and RUCKSTUHL 86.
[28] From a combined reanalysis of ALBRECHT 86B and DAUM 81B.
[29] Uses the model of BOWLER 75.
[30] Produced in K^- backward scattering.

$a_1(1260)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$(\rho\pi)_{S-\text{wave}}$	seen
Γ_2	$(\rho\pi)_{D-\text{wave}}$	seen
Γ_3	$(\rho(1450)\pi)_{S-\text{wave}}$	seen
Γ_4	$(\rho(1450)\pi)_{D-\text{wave}}$	seen
Γ_5	$\sigma\pi$	seen
Γ_6	$f_0(980)\pi$	not seen
Γ_7	$f_0(1370)\pi$	seen
Γ_8	$f_2(1270)\pi$	seen
Γ_9	$K\overline{K}^*(892)+\text{c.c.}$	seen
Γ_{10}	$\pi(1300)\pi$	not seen
Γ_{11}	$\pi\gamma$	seen

$a_1(1260)$ PARTIAL WIDTHS

$\Gamma(\pi\gamma)$ Γ_{11}

VALUE (keV)	*DOCUMENT ID*		*TECN*	*COMMENT*
640±246	ZIELINSKI	84C	SPEC	200 π^+ Z $\rightarrow$ Z3π

D-wave/S-wave AMPLITUDE RATIO IN DECAY OF $a_1(1260) \rightarrow \rho\pi$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
−0.107±0.016 OUR AVERAGE				
−0.10 ±0.02 ±0.02	[31,32] ACKERSTAFF	97R	OPAL	E_{cm}^{ee}= 88–94, $\tau \rightarrow$
−0.11 ±0.02	[31] ALBRECHT	93C	ARG	$3\pi\nu$ $\tau^+ \rightarrow \pi^+\pi^+\pi^-\nu$

[31] Uses the model of ISGUR 89.
[32] Supersedes AKERS 95P.

$a_1(1260)$ BRANCHING RATIOS

$\Gamma((\rho\pi)_{S\text{-wave}})/\Gamma_{\text{total}}$ Γ_1/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
68.11	37k	[34] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma((\rho\pi)_{D\text{-wave}})/\Gamma_{\text{total}}$ Γ_2/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.36 \pm 0.17 \pm 0.06$	37k	[34] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma((\rho(1450)\pi)_{S\text{-wave}})/\Gamma_{\text{total}}$ Γ_3/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.30 \pm 0.64 \pm 0.17$	37k	[34,35] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma((\rho(1450)\pi)_{D\text{-wave}})/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.43 \pm 0.28 \pm 0.06$	37k	[34,35] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma(\sigma\pi)/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$16.18 \pm 3.85 \pm 1.28$	37k	[34,36] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma(f_0(980)\pi)/\Gamma_{\text{total}}$ Γ_6/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
not seen	37k	ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma(f_0(1370)\pi)/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$4.29 \pm 2.29 \pm 0.73$	37k	[34,37] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma(f_2(1270)\pi)/\Gamma_{total}$ Γ_8/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.14 \pm 0.06 \pm 0.02$	37k	[34,38] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma(K\overline{K}^*(892)+\text{c.c.})/\Gamma_{total}$ Γ_9/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$3.3 \pm 0.5 \pm 0.1$	37k	[39] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma(\pi(1300)\pi)/\Gamma_{total}$ Γ_{10}/Γ

VALUE (units 10^{-2})	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •						
<0.01	90	37k	[40,41] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$
<0.019	90	37k	[40,42] ASNER	00	CLE2	10.6 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma(\sigma\pi)/\Gamma((\rho\pi)_{S\text{-wave}})$ Γ_5/Γ_1

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
~ 0.3	28k	AKHMETSHIN	99E	CMD2	1.05–1.38 $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$
0.003 ± 0.003		[33] LONGACRE	82	RVUE	

[33] Uses multichannel Aitchison-Bowler model (BOWLER 75). Uses data from GAVILLET 77, DAUM 80, and DANKOWYCH 81.
[34] From a fit to the Dalitz plot.
[35] Assuming for $\rho(1450)$ mass and width of 1370 and 386 MeV respectively.
[36] Assuming for σ mass and width of 860 and 880 MeV respectively.
[37] Assuming for $f_0(1370)$ mass and width of 1186 and 350 MeV respectively.
[38] Assuming for $f_2(1270)$ mass and width of 1275 and 185 MeV respectively.
[39] From a fit to the 3π mass spectrum including the $K\overline{K}^*(892)$ threshold.
[40] Assuming for $\pi(1300)$ mass and width of 1300 and 400 MeV respectively. From a fit to the Dalitz plot.
[41] Assuming $\pi(1300) \to \rho\pi$ decay.
[42] Assuming $\pi(1300) \to \sigma\pi$ decay.

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