$a_1(1260)$

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

THE $a_1(1260)$

Updated March 2002 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 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.

(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 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, 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 $\tau \to 3\pi$ 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 2–3 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 $a_1 \to f_0(600)\pi$ 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 existence of the 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). 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.

References

References may be found at the end of the $a_1(1260)$ Listing.

$a_1(1260)$ 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 $pp \to p_f\pi^+\pi^-\pi^0 p_s$

1262± 9± 7	[2,6]	ACKERSTAFF	97R	OPAL	E_{cm}^{ee}= 88–94, $\tau \rightarrow 3\pi\nu$
1210± 7± 2	[3,6]	ACKERSTAFF	97R	OPAL	E_{cm}^{ee}= 88–94, $\tau \rightarrow 3\pi\nu$
1211± 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±18±11		BAND	87	MAC	$\tau^+ \rightarrow \pi^+\pi^+\pi^-\nu$
1164±41±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±20±15		RUCKSTUHL	86	DLCO	$\tau^+ \rightarrow \pi^+\pi^+\pi^-\nu$
1194±14±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 $\pi^- p \rightarrow n3\pi$
1280±30	[13]	DAUM	81B	CNTR	63,94 $\pi^- p \rightarrow p3\pi$
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		$E^{ee}_{\rm cm}$= 88–94, $\tau \to 3\pi\nu$
$457 \pm 15 \pm 17$		[19,22] ACKERSTAFF	97R	OPAL		$E^{ee}_{\rm cm}$= 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	$\pi^+\pi^-\pi^0$	
Γ_2	$\pi^0\pi^0\pi^0$	
Γ_3	$(\rho\pi)_{S-\text{wave}}$	seen
Γ_4	$(\rho\pi)_{D-\text{wave}}$	seen
Γ_5	$(\rho(1450)\pi)_{S-\text{wave}}$	seen
Γ_6	$(\rho(1450)\pi)_{D-\text{wave}}$	seen
Γ_7	$\sigma\pi$	seen
Γ_8	$f_0(980)\pi$	not seen
Γ_9	$f_0(1370)\pi$	seen
Γ_{10}	$f_2(1270)\pi$	seen
Γ_{11}	$K\overline{K}^*(892)+\text{c.c.}$	seen
Γ_{12}	$\pi\gamma$	seen

$a_1(1260)$ PARTIAL WIDTHS

$\Gamma(\pi\gamma)$ Γ_{12}

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

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

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, $\tau \to$
−0.11 ±0.02	[31]	ALBRECHT	93C	ARG	$\tau^+ \xrightarrow{3\pi\nu} \pi^+\pi^+\pi^-\nu$

[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_3/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
60.19	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_4/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$1.30\pm0.60\pm0.22$	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_5/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$0.56\pm0.84\pm0.32$	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_6/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$2.04\pm1.20\pm0.28$	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_7/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$18.76\pm4.29\pm1.48$	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_8/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_9/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$7.40\pm2.71\pm1.26$	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_{10}/Γ

VALUE (units 10^{-2})	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$1.19 \pm 0.49 \pm 0.17$	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_{11}/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 $e^+e^- \to \tau^+\tau^-$, $\tau^- \to \pi^-\pi^0\pi^0\nu_\tau$

$\Gamma(\sigma\pi)/\Gamma((\rho\pi)_{S-wave})$ Γ_7/Γ_3

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.

$\Gamma(\pi^0\pi^0\pi^0)/\Gamma(\pi^+\pi^-\pi^0)$ Γ_2/Γ_1

VALUE	CL%	DOCUMENT ID		COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<0.008	90	[40] BARBERIS	01	450 $pp \to p_f 3\pi^0 p_s$

[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] Inconsistent with observatons of $\sigma\pi$, $f_0(1370)\pi$, and $f_2(1270)\pi$ decay modes.

$a_1(1260)$ REFERENCES

BARBERIS	01	PL B507 14	D. Barberis *et al.*	
ASNER	00	PR D61 012002	D.M. Asner *et al.*	(CLEO Collab.)
AKHMETSHIN	99E	PL B466 392	R.R. Akhmetshin *et al.*	(Novosibirsk CMD-2 Collab.)
BONDAR	99	PL B466 403	A.E. Bondar *et al.*	(Novosibirsk CMD-2 Collab.)
ABREU	98G	PL B426 411	P. Abreu *et al.*	(DELPHI Collab.)
BARBERIS	98B	PL B422 399	D. Barberis *et al.*	(WA 102 Collab.)
ACKERSTAFF	97R	ZPHY C75 593	K. Ackerstaff *et al.*	(OPAL Collab.)
AKERS	95P	ZPHY C67 45	R. Akers *et al.*	(OPAL Collab.)
ALBRECHT	93C	ZPHY C58 61	H. Albrecht *et al.*	(ARGUS Collab.)
ANDO	92	PL B291 496	A. Ando *et al.*	(KEK, KYOT, NIRS, SAGA+)
IVANOV	91	ZPHY C49 563	Y.P. Ivanov, A.A. Osipov, M.K. Volkov	(JINR)
ARMSTRONG	90	ZPHY C48 213	T.A. Armstrong, M. Benayoun, W. Beusch	
FEINDT	90	ZPHY C48 681	M. Feindt	(HAMB)
KUHN	90	ZPHY C48 445	J.H. Kuhn *et al.*	(MPIM)
ISGUR	89	PR D39 1357	N. Isgur, C. Morningstar, C. Reader	(TNTO)

BOWLER	88	PL B209 99	M.G. Bowler	(OXF)
BAND	87	PL B198 297	H.R. Band *et al.*	(MAC Collab.)
TORNQVIST	87	ZPHY C36 695	N.A. Tornqvist	(HELS)
ALBRECHT	86B	ZPHY C33 7	H. Albrecht *et al.*	(ARGUS Collab.)
RUCKSTUHL	86	PRL 56 2132	W. Ruckstuhl *et al.*	(DELCO Collab.)
SCHMIDKE	86	PRL 57 527	W.B. Schmidke *et al.*	(Mark II Collab.)
BELLINI	85	SJNP 41 781	D. Bellini *et al.*	
		Translated from YAF 41 1223.		
ZIELINSKI	84C	PRL 52 1195	M. Zielinski *et al.*	(ROCH, MINN, FNAL)
LONGACRE	82	PR D26 83	R.S. Longacre	(BNL)
DANKOWY...	81	PRL 46 580	J.A. Dankowych *et al.*	(TNTO, BNL, CARL+)
DAUM	81B	NP B182 269	C. Daum *et al.*	(AMST, CERN, CRAC, MPIM+)
DAUM	80	PL 89B 281	C. Daum *et al.*	(AMST, CERN, CRAC, MPIM+) JP
GAVILLET	77	PL 69B 119	P. Gavillet *et al.*	(AMST, CERN, NIJM+) JP
BOWLER	75	NP B97 227	M.G. Bowler *et al.*	(OXFTP, DARE)

OTHER RELATED PAPERS

FEUILLAT	01	PL B501 37	M. Feuillat, J.L. Lucio, M.J. Pestieau	
MOLCHANOV	01	PL B521 171	V.V. Molchanov *et al.*	(FNAL SELEX Collab.)
ZAIMIDOROGA	99	PAN 30 1	O.A. Zaimidoroga	
		Translated from SJPN 30 5.		
AMELIN	95B	PL B356 595	D.V. Amelin *et al.*	(SERP, TBIL)
BOLONKIN	95	PAN 58 1535	B.V. Bolonkin *et al.*	(ITEP)
		Translated from YAF 58 1628.		
WINGATE	95	PRL 74 4596	M. Wingate, T. de Grand	(COLO, FSU)
CONDO	93	PR D48 3045	G.T. Condo *et al.*	(SLAC Hybrid Collab.)
GOUZ	92	Dallas HEP 92, p. 572	Yu.P. Gouz *et al.*	(VES Collab.)
		Proceedings XXVI Int. Conf. on High Energy Physics		
IIZUKA	89	PR D39 3357	J. Iizuka, H. Koibuchi, F. Masuda	(NAGO, IBAR+)
BOWLER	86	PL B182 400	M.G. Bowler	(OXF)
BASDEVANT	78	PRL 40 994	J.L. Basdevant, E.L. Berger	(FNAL, ANL) JP
BASDEVANT	77	PR D16 657	J.L. Basdevant, E.L. Berger	(FNAL, ANL) JP
ADERHOLZ	64	PL 10 226	M. Aderholz *et al.*	(AACH3, BERL, BIRM+)
GOLDHABER	64	PRL 12 336	G. Goldhaber *et al.*	(LRL, UCB)
LANDER	64	PRL 13 346A	R.L. Lander *et al.*	(UCSD) JP
BELLINI	63	NC 29 896	G. Bellini *et al.*	(MILA)