$\Delta(1232)\ P_{33}$

$I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$ Status: ****

Most of the results published before 1977 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

$\Delta(1232)$ MASSES

MIXED CHARGES

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1230 to 1234 (≈ 1232) OUR ESTIMATE				
1231±1	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
1232±3	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1233±2	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1233	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$

$\Delta(1232)^{++}$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1230.9±0.3	KOCH	80B	IPWA	$\pi N \rightarrow \pi N$
1231.1±0.2	PEDRONI	78		$\pi N \rightarrow \pi N$ 70–370 MeV

$\Delta(1232)^{+}$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1234.9±1.4	MIROSHNIC...	79		Fit photoproduction
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1231.6	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1231.2	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1231.8	BERENDS	75	IPWA	$\gamma p \rightarrow \pi N$

$\Delta(1232)^{0}$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1233.6±0.5	KOCH	80B	IPWA	$\pi N \rightarrow \pi N$
1233.8±0.2	PEDRONI	78		$\pi N \rightarrow \pi N$ 70–370 MeV

$m_{\Delta^0} - m_{\Delta^{++}}$

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
2.25±0.68	BERNICHA	96	Fit to PEDRONI 78
2.7 ±0.3	[1] PEDRONI	78	See the masses

Δ(1232) WIDTHS

MIXED CHARGES

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
115 to 125 (≈ 120) OUR ESTIMATE				
118±4	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
120±5	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
116±5	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
114	ARNDT	95	DPWA	$\pi N \to N\pi$

$\Delta(1232)^{++}$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
111.0±1.0	KOCH	80B	IPWA	$\pi N \to \pi N$
111.3±0.5	PEDRONI	78		$\pi N \to \pi N$ 70–370 MeV

$\Delta(1232)^{+}$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
131.1±2.4	MIROSHNIC...	79		Fit photoproduction
• • • We do not use the following data for averages, fits, limits, etc. • • •				
111.2	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
111.0	BARBOUR	78	DPWA	$\gamma N \to \pi N$

$\Delta(1232)^{0}$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
113.0±1.5	KOCH	80B	IPWA	$\pi N \to \pi N$
117.9±0.9	PEDRONI	78		$\pi N \to \pi N$ 70–370 MeV

Δ^{0}-Δ^{++} WIDTH DIFFERENCE

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
8.45±1.11	BERNICHA	96	Fit to PEDRONI 78
6.6 ±1.0	PEDRONI	78	See the widths

Δ(1232) POLE POSITIONS

REAL PART, MIXED CHARGES

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1211	ARNDT	95	DPWA	$\pi N \to N\pi$
1209	[2] HOEHLER	93	ARGD	$\pi N \to \pi N$
1210±1	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1210	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

–IMAGINARY PART, MIXED CHARGES

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
50	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
50	[2] HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
50 ± 1	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
50	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

REAL PART, $\Delta(1232)^{++}$

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
1209.6 ± 0.5	[3] VASAN	76B	Fit to CARTER 73
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1210.5 to 1210.8	[4] VASAN	76B	Fit to CARTER 73

–IMAGINARY PART, $\Delta(1232)^{++}$

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
50.4 ± 0.5	[3] VASAN	76B	Fit to CARTER 73
• • • We do not use the following data for averages, fits, limits, etc. • • •			
49.9 to 50.0	[4] VASAN	76B	Fit to CARTER 73

REAL PART, $\Delta(1232)^{+}$

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
1206.9 ± 0.9 to 1210.5 ± 1.8	MIROSHNIC...	79	Fit photoproduction
1208.0 ± 2.0	CAMPBELL	76	Fit photoproduction

–IMAGINARY PART, $\Delta(1232)^{+}$

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
55.6 ± 1.0 to 58.3 ± 1.1	MIROSHNIC...	79	Fit photoproduction
53.0 ± 2.0	CAMPBELL	76	Fit photoproduction

REAL PART, $\Delta(1232)^{0}$

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
1210.75 ± 0.6	[3] VASAN	76B	Fit to CARTER 73
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1210.2	[4] VASAN	76B	Fit to CARTER 73

–IMAGINARY PART, $\Delta(1232)^{0}$

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
52.8 ± 0.6	[3] VASAN	76B	Fit to CARTER 73
• • • We do not use the following data for averages, fits, limits, etc. • • •			
52.9 to 53.1	[4] VASAN	76B	Fit to CARTER 73

$\Delta(1232)$ ELASTIC POLE RESIDUES

ABSOLUTE VALUE, MIXED CHARGES

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
38	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
50	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
53 ± 2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
52	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

PHASE, MIXED CHARGES

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
-22	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
-48	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
-47 ± 1	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
-31	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

ABSOLUTE VALUE, $\Delta(1232)^{++}$

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
52.4 to 53.2	[3] VASAN	76B	Fit to CARTER 73
52.1 to 52.4	[4] VASAN	76B	Fit to CARTER 73

PHASE, $\Delta(1232)^{++}$

VALUE (rad)	*DOCUMENT ID*		*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
-0.822 to -0.833	[3] VASAN	76B	Fit to CARTER 73
-0.823 to -0.830	[4] VASAN	76B	Fit to CARTER 73

ABSOLUTE VALUE, $\Delta(1232)^{0}$

VALUE (MeV)	*DOCUMENT ID*		*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
54.8 to 55.0	[3] VASAN	76B	Fit to CARTER 73
55.2 to 55.3	[4] VASAN	76B	Fit to CARTER 73

PHASE, $\Delta(1232)^{0}$

VALUE (rad)	*DOCUMENT ID*		*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •			
-0.840 to -0.847	[3] VASAN	76B	Fit to CARTER 73
-0.848 to -0.856	[4] VASAN	76B	Fit to CARTER 73

Δ(1232) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	>99 %
Γ_2	$N\gamma$	0.54–0.61 %
Γ_3	$N\gamma$, helicity=1/2	0.12–0.14 %
Γ_4	$N\gamma$, helicity=3/2	0.41–0.47 %

Δ(1232) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.993 to 0.995 OUR ESTIMATE				
1.0	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1.0	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1.0	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.0	ARNDT	95	DPWA	$\pi N \to N\pi$

Δ(1232) PHOTON DECAY AMPLITUDES

Δ(1232) → $N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.140±0.005 OUR ESTIMATE				
−0.141±0.005	ARNDT	96	IPWA	$\gamma N \to \pi N$
−0.135±0.016	DAVIDSON	91B	FIT	$\gamma N \to \pi N$
−0.145±0.015	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
−0.138±0.004	AWAJI	81	DPWA	$\gamma N \to \pi N$
−0.147±0.001	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
−0.145±0.001	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
−0.136±0.006	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.143±0.004	LI	93	IPWA	$\gamma N \to \pi N$
−0.140±0.007	DAVIDSON	90	FIT	See DAVIDSON 91B
−0.142±0.007	BARBOUR	78	DPWA	$\gamma N \to \pi N$
−0.140	[5] NOELLE	78		$\gamma N \to \pi N$
−0.141±0.004	FELLER	76	DPWA	$\gamma N \to \pi N$

Δ(1232) → $N\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.258±0.006 OUR ESTIMATE				
−0.261±0.005	ARNDT	96	IPWA	$\gamma N \to \pi N$
−0.251±0.033	DAVIDSON	91B	FIT	$\gamma N \to \pi N$
−0.263±0.026	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
−0.259±0.006	AWAJI	81	DPWA	$\gamma N \to \pi N$
−0.264±0.002	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
−0.261±0.002	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
−0.247±0.010	CRAWFORD	80	DPWA	$\gamma N \to \pi N$

• • • We do not use the following data for averages, fits, limits, etc. • • •

−0.262±0.004		LI	93	IPWA	$\gamma N \rightarrow \pi N$
−0.254±0.011		DAVIDSON	90	FIT	See DAVIDSON 91B
−0.271±0.010		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
−0.247	[5]	NOELLE	78		$\gamma N \rightarrow \pi N$
−0.256±0.003		FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1232) \rightarrow N\gamma$, E_2/M_1 ratio

VALUE	DOCUMENT ID		TECN	COMMENT
−0.015 ±0.004 OUR AVERAGE				
−0.015 ±0.005	WORKMAN	92	IPWA	$\gamma N \rightarrow \pi N$
−0.0157±0.0072	DAVIDSON	91B	FIT	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.0107±0.0037	DAVIDSON	90	FIT	$\gamma N \rightarrow \pi N$
−0.015 ±0.002	DAVIDSON	86	FIT	$\gamma N \rightarrow \pi N$
+0.037 ±0.004	TANABE	85	FIT	$\gamma N \rightarrow \pi N$

$\Delta(1232)$ PHASE OF M1+(3/2) PHOTOPRODUCTION MULTIPOLE AMPLITUDE POLE RESIDUE

Information on the phase (and magnitude) of the M1+(3/2) multipole amplitude pole residue is contained implicitly in the paper of MIROSHNICHENKO 79. They find that the phase is consistent with being equal to that of the elastic pole residue.

$\Delta(1232)^{++}$ MAGNETIC MOMENT

The values are extracted from UCLA and SIN data on $\pi^+ p$ bremsstrahlung using a variety of different theoretical approximations and methods. Our estimate is *only* a rough guess of the range we expect the moment to lie within.

VALUE (μ_N)	DOCUMENT ID		COMMENT
3.7 to 7.5 OUR ESTIMATE			
• • • We do not use the following data for averages, fits, limits, etc. • • •			
4.52±0.50±0.45	BOSSHARD	91	$\pi^+ p \rightarrow \pi^+ p\gamma$ (SIN data)
3.7 to 4.2	LIN	91B	$\pi^+ p \rightarrow \pi^+ p\gamma$ (from UCLA data)
4.6 to 4.9	LIN	91B	$\pi^+ p \rightarrow \pi^+ p\gamma$ (from SIN data)
5.6 to 7.5	WITTMAN	88	$\pi^+ p \rightarrow \pi^+ p\gamma$ (from UCLA data)
6.9 to 9.8	HELLER	87	$\pi^+ p \rightarrow \pi^+ p\gamma$ (from UCLA data)
4.7 to 6.7	NEFKENS	78	$\pi^+ p \rightarrow \pi^+ p\gamma$ (UCLA data)

Δ(1232) FOOTNOTES

[1] Using $\pi^{\pm} d$ as well, PEDRONI 78 determine $(M^- - M^{++}) + (M^0 - M^+)/3 = 4.6 \pm 0.2$ MeV.

[2] See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

[3] This VASAN 76B value is from fits to the coulomb-barrier-corrected CARTER 73 phase shift.

[4] This VASAN 76B value is from fits to the CARTER 73 nuclear phase shift without coulomb barrier corrections.

[5] Converted to our conventions using $M = 1232$ MeV, $\Gamma = 110$ MeV from NOELLE 78.

Δ(1232) REFERENCES

For early references, see Physics Letters **111B** 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
BERNICHA	96	NP A597 623	+Lopez Castro, Pestieau	(LOUV, CINV)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
HOEHLER	93	πN Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
WORKMAN	92	PR C46 1546	+Arndt, Li	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BOSSHARD	91	PR D44 1962	+Amsler+ (ZURI, LBL, VILL, LAUS, UCLA, CATH)	
Also	90	PRL 64 2619	Bosshard+ (CATH, LAUS, LBL, VILL, UCLA, ZURI)	
DAVIDSON	91B	PR D43 71	+Mukhopadhyay, Wittman	(RPI)
LIN	91B	PR C44 1819	+Liou, Ding	(CUNY, CSOK)
Also	91	PR C43 R930	Lin, Liou	(CUNY)
DAVIDSON	90	PR D42 20	+Mukhopadhyay	(RPI)
WITTMAN	88	PR C37 2075		(TRIU)
HELLER	87	PR C35 718	+Kumano, Martinez, Moniz	(LANL, MIT, ILL)
DAVIDSON	86	PRL 56 804	+Mukhopadhyay, Wittman	(RPI)
TANABE	85	PR C31 1876	+Ohta	(KOMAB)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWAJI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
KOCH	80B	NP A336 331	+Pietarinen	(KARLT) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
MIROSHNIC...	79	SJNP 29 94 Translated from YAF 29 188.	Miroshnichenko, Nikiforov, Sanin+	(KFTI) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
NEFKENS	78	PR D18 3911	+Arman, Ballagh, Glodis, Haddock+	(UCLA, CATH) IJP
NOELLE	78	PTP 60 778		(NAGO)
PEDRONI	78	NP A300 321	+Gabathuler, Domingo, Hirt+	(SIN, ISNG, KARLE+) IJP
CAMPBELL	76	PR D14 2431	+Shaw, Ball	(BOIS, UCI, UTAH) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
VASAN	76B	NP B106 535		(CMU) IJP
Also	76	NP B106 526	Vasan	(CMU) IJP
BERENDS	75	NP B84 342	+Donnachie	(LEID, MCHS)
CARTER	73	NP B58 378	+Bugg, Carter	(CAVE, LOQM) IJP