Δ BARYONS
$(S = 0, I = 3/2)$

$\Delta^{++} = uuu$, $\Delta^{+} = uud$, $\Delta^{0} = udd$, $\Delta^{-} = ddd$

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

$I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$ 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	$\pi N \rightarrow \pi N$

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

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1230.9±0.3	KOCH	80B	IPWA	$\pi N \rightarrow \pi N$
1230.6±0.2	ZIDELL	80	DPWA	$\pi N \rightarrow \pi N$ 0–350 MeV
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	$\pi N \rightarrow \pi N$
1232.5±0.3	ZIDELL	80	DPWA	$\pi N \rightarrow \pi N$ 0–350 MeV
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. • • •			
2.7±0.3	[1] PEDRONI	78	See the masses

$\Delta(1232)$ WIDTHS

MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
115 to 125 (≈ 120) OUR ESTIMATE				
118±4	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
120±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
116±5	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

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

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
111.0±1.0	KOCH	80B	IPWA	$\pi N \rightarrow \pi N$
113.2±0.3	ZIDELL	80	DPWA	$\pi N \rightarrow \pi N$ 0–350 MeV
111.3±0.5	PEDRONI	78		$\pi N \rightarrow \pi N$ 70–370 MeV

*CITATION: L. Montanet et al., Physical Review D50, 1173 (1994) and 1995 off-year partial update for the 1996 edition (URL: http://pdg.lbl.gov/)

$\Delta(1232)^+$ 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	$\gamma N \rightarrow \pi N$
111.0	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1232)^0$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
113.0±1.5	KOCH	80B	IPWA	$\pi N \rightarrow \pi N$
121.3±0.4	ZIDELL	80	DPWA	$\pi N \rightarrow \pi N$ 0–350 MeV
117.9±0.9	PEDRONI	78		$\pi N \rightarrow \pi N$ 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. • • •			
6.6±1.0	PEDRONI	78	See the widths

$\Delta(1232)$ POLE POSITIONS

REAL PART, MIXED CHARGES

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1209	[2] HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1210	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1210±1	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1210	ARNDT	85	DPWA	See ARNDT 91

−IMAGINARY PART, MIXED CHARGES

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
100	[2] HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
50	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
50±1	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
50	ARNDT	85	DPWA	See ARNDT 91

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

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1210.70±0.16	[3] ZIDELL	80	DPWA	$\pi N \rightarrow \pi N$ 0–350 MeV
1209.6 ±0.5	[4] VASAN	76B		Fit to CARTER 73
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1210.4 ±0.17	[5] ZIDELL	78		
1210.5 to 1210.8	[6] VASAN	76B		Fit to CARTER 73

−IMAGINARY PART, $\Delta(1232)^{++}$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
49.61 ±0.12	[3] ZIDELL	80	DPWA	$\pi N \rightarrow \pi N$ 0–350 MeV
50.4 ±0.5	[4] VASAN	76B		Fit to CARTER 73
• • • We do not use the following data for averages, fits, limits, etc. • • •				
49.745±0.14	[5] ZIDELL	78		
49.9 to 50.0	[6] 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		TECN	COMMENT
1210.30±0.36	[3] ZIDELL	80	DPWA	$\pi N \to \pi N$ 0–350 MeV
1210.75±0.6	[4] VASAN	76B		Fit to CARTER 73
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1209.5 ±0.41	[5] ZIDELL	78		
1210.2	[6] VASAN	76B		Fit to CARTER 73

−IMAGINARY PART, $\Delta(1232)^0$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
54.0 ±0.26	[3] ZIDELL	80	DPWA	$\pi N \to \pi N$ 0–350 MeV
52.8 ±0.6	[4] VASAN	76B		Fit to CARTER 73
• • • We do not use the following data for averages, fits, limits, etc. • • •				
52.45±0.2	[5] ZIDELL	78		
52.9 to 53.1	[6] VASAN	76B		Fit to CARTER 73

$\Delta(1232)$ ELASTIC POLE RESIDUES

ABSOLUTE VALUE, MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
50	HOEHLER	93	ARGD	$\pi N \to \pi N$
52	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
53±2	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE, MIXED CHARGES

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−48	HOEHLER	93	ARGD	$\pi N \to \pi N$
−31	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
−47±1	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

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	[4] VASAN	76B	Fit to CARTER 73
52.1 to 52.4	[6] 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	[4] VASAN	76B	Fit to CARTER 73
−0.823 to −0.830	[6] 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	[4] VASAN	76B	Fit to CARTER 73
55.2 to 55.3	[6] 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	[4] VASAN	76B	Fit to CARTER 73
−0.848 to −0.856	[6] VASAN	76B	Fit to CARTER 73

$\Delta(1232)$ 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	$N\gamma$	0.55–0.61 %
Γ_3	$N\gamma$, helicity=1/2	
Γ_4	$N\gamma$, helicity=3/2	

$\Delta(1232)$ 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	$\pi N \to \pi N$

$\Delta(1232)$ PHOTON DECAY AMPLITUDES

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

VALUE ($\mathrm{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.141±0.005 OUR ESTIMATE				
−0.143±0.004	LI	93	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. • • •				
−0.133±0.007	ARNDT	90B	IPWA	See LI 93
−0.137	ARNDT	90B	FIT	See LI 93
−0.140±0.007	DAVIDSON	90	FIT	See DAVIDSON 91B
−0.142±0.007	BARBOUR	78	DPWA	$\gamma N \to \pi N$
−0.140	[7] NOELLE	78		$\gamma N \to \pi N$
−0.141±0.004	FELLER	76	DPWA	$\gamma N \to \pi N$

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

VALUE ($\mathrm{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.257±0.008 OUR ESTIMATE				
−0.262±0.004	LI	93	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. • • •				
−0.244±0.008	ARNDT	90B	IPWA	See LI 93
−0.246	ARNDT	90B	FIT	See LI 93
−0.254±0.011	DAVIDSON	90	FIT	See DAVIDSON 91B
−0.271±0.010	BARBOUR	78	DPWA	$\gamma N \to \pi N$
−0.247	[7] NOELLE	78		$\gamma N \to \pi N$
−0.256±0.003	FELLER	76	DPWA	$\gamma N \to \pi N$

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

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

$\Delta(1232)$ 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)

$\Delta(1232)$ 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 and HOEHLER 94 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] The accuracy claimed by ZIDELL 80 on the real part is considerably better than is allowed by uncertainties in the beam momentum.
[4] This VASAN 76B value is from fits to the coulomb-barrier-corrected CARTER 73 phase shift.
[5] ZIDELL 78 fits the nuclear phase shift without coulomb barrier corrections.
[6] This VASAN 76B value is from fits to the CARTER 73 nuclear phase shift without coulomb barrier corrections.
[7] Converted to our conventions using $M = 1232$ MeV, $\Gamma = 110$ MeV from NOELLE 78.

$\Delta(1232)$ REFERENCES

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

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)	
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)	
ARNDT	90B	PR C42 1864	+Workman, Li, Roper	(VPI)	
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)	
ARNDT	85	PR D32 1085	+Ford, Roper	(VPI)	
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
ZIDELL	80	PR D21 1255	+Arndt, Roper	(VPI)	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
ZIDELL	78	LNC 21 140	+Arndt, Roper	(VPI)	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

$\Delta(1600)$ P_{33}

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

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

The various analyses are not in good agreement.

$\Delta(1600)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1550 to 1700 (≈ 1600) OUR ESTIMATE				
1706±10	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1600±50	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1522±13	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1706	LI	93	IPWA	$\gamma N \to \pi N$
1690	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
1560	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1640	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Delta(1600)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
250 to 450 (≈ 350) OUR ESTIMATE				
430± 73	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
300±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
220± 40	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
215	LI	93	IPWA	$\gamma N \to \pi N$
250	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
180	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
300	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Delta(1600)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1550	[3] HOEHLER	93	SPED	$\pi N \to \pi N$
1612	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
1550±40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1581	ARNDT	85	DPWA	See ARNDT 91
1609 or 1610	[4] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
1541 or 1542	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
230	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
200±60	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
300	ARNDT	85	DPWA	See ARNDT 91
323 or 325	[4] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
178 or 178	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$\Delta(1600)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
16	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
17±4	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
− 73	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
−150±30	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(1600)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	10–25 %
Γ_2	ΣK	
Γ_3	$N\pi\pi$	75–90 %
Γ_4	$\Delta\pi$	40–70 %
Γ_5	$\Delta(1232)\pi$, P-wave	
Γ_6	$\Delta(1232)\pi$, F-wave	
Γ_7	$N\rho$	<25 %
Γ_8	$N\rho$, S=1/2, P-wave	
Γ_9	$N\rho$, S=3/2, P-wave	
Γ_{10}	$N\rho$, S=3/2, F-wave	
Γ_{11}	$N(1440)\pi$	10–35 %
Γ_{12}	$N(1440)\pi$, P-wave	
Γ_{13}	$p\gamma$	~ 0 %
Γ_{14}	$N\gamma$, helicity=1/2	
Γ_{15}	$N\gamma$, helicity=3/2	

$\Delta(1600)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.10 to 0.25 OUR ESTIMATE				
0.12±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.18±0.04	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.21±0.06	HOEHLER	79	IPWA	$\pi N \to \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.36 to −0.28 OUR ESTIMATE				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.006 to 0.042	[5] DEANS	75	DPWA	$\pi N \to \Sigma K$

Note: Signs of couplings from $\pi N \to N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to \Delta(1232)\pi$, P-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.27 to +0.33 OUR ESTIMATE				
+0.29±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
+0.24±0.05	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
+0.34	[1,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
+0.30	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to \Delta(1232)\pi$, F-wave — $(\Gamma_1\Gamma_6)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.15 to −0.03 OUR ESTIMATE				
−0.07	[1,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to N\rho$, S=1/2, P-wave — $(\Gamma_1\Gamma_8)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.10	[1,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to N\rho$, S=3/2, P-wave — $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.10	[1,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to N(1440)\pi$, P-wave — $(\Gamma_1\Gamma_{12})^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.15 to +0.23 OUR ESTIMATE				
$+0.16\pm0.02$	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
$+0.23\pm0.04$	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$

$\Delta(1600)$ PHOTON DECAY AMPLITUDES

$\Delta(1600) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
-0.026 ± 0.020 OUR ESTIMATE				
-0.026 ± 0.002	LI	93	IPWA	$\gamma N \to \pi N$
-0.039 ± 0.030	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
-0.046 ± 0.013	AWAJI	81	DPWA	$\gamma N \to \pi N$
0.005 ± 0.020	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
-0.200	[7] WADA	84	DPWA	Compton scattering
0.000 ± 0.030	BARBOUR	78	DPWA	$\gamma N \to \pi N$
$0.0\ \pm0.020$	FELLER	76	DPWA	$\gamma N \to \pi N$

$\Delta(1600) \to N\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
-0.006 ± 0.017 OUR ESTIMATE				
-0.016 ± 0.002	LI	93	IPWA	$\gamma N \to \pi N$
-0.013 ± 0.014	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
0.025 ± 0.031	AWAJI	81	DPWA	$\gamma N \to \pi N$
-0.009 ± 0.020	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.023	WADA	84	DPWA	Compton scattering
0.000 ± 0.045	BARBOUR	78	DPWA	$\gamma N \to \pi N$
$0.0\ \pm0.015$	FELLER	76	DPWA	$\gamma N \to \pi N$

$\Delta(1600)$ FOOTNOTES

[1] LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

[2] From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

[3] See HOEHLER 93 and HOEHLER 94 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.

[4] LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

[5] The range given is from the four best solutions. DEANS 75 disagrees with $\pi^+ p \to \Sigma^+ K^+$ data of WINNIK 77 around 1920 MeV.

[6] LONGACRE 77 considers this coupling to be well determined.

[7] WADA 84 is inconsistent with other analyses — see the Note on N and Δ Resonances.

$\Delta(1600)$ REFERENCES

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

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
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)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
ARNDT	85	PR D32 1085	+Ford, Roper	(VPI)
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
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)
BARNHAM	80	NP B168 243	+Glickman, Mier-Jedrzejowicz+	(LOIC)

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) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

$\Delta(1620)\ S_{31}$

$I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$ Status: ∗∗∗∗

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

$\Delta(1620)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1615 to 1675 (≈ 1620) OUR ESTIMATE				
1672 ± 7	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
1620 ±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1610 ± 7	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1669	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1620	BARNHAM	80	IPWA	$\pi N \rightarrow N\pi\pi$
1712.8± 6.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1786.7± 2.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1657	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1662	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1580	[2] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
1600	[3] LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$\Delta(1620)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
120 to 180 (≈ 150) OUR ESTIMATE				
154 ±37	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
140 ±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
139 ±18	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
184	LI	93	IPWA	$\gamma N \rightarrow \pi N$
120	BARNHAM	80	IPWA	$\pi N \rightarrow N\pi\pi$
228.3±18.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$ (lower mass)
30.0± 6.4	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$ (higher mass)
161	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
180	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
120	[2] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
150	[3] LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$\Delta(1620)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1608	[4] HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1587	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1600±15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1599	ARNDT	85	DPWA	See ARNDT 91
1583 or 1583	[5] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$
1575 or 1572	[2] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
116	[4] HOEHLER	93	SPED	$\pi N \to \pi N$
120	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
120 ± 20	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
120	ARNDT	85	DPWA	See ARNDT 91
143 or 149	[5] LONGACRE	78	IPWA	$\pi N \to N \pi \pi$
119 or 128	[2] LONGACRE	77	IPWA	$\pi N \to N \pi \pi$

$\Delta(1620)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
19	HOEHLER	93	SPED	$\pi N \to \pi N$
15	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
15 ± 2	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
− 95	HOEHLER	93	SPED	$\pi N \to \pi N$
−125	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
-110 ± 20	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(1620)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	20–30 %
Γ_2	$N\pi\pi$	70–80 %
Γ_3	$\Delta\pi$	30–60 %
Γ_4	$\Delta(1232)\pi$, D-wave	
Γ_5	$N\rho$	7–25 %
Γ_6	$N\rho$, S=1/2, S-wave	
Γ_7	$N\rho$, S=3/2, D-wave	
Γ_8	$N(1440)\pi$	
Γ_9	$N\gamma$	0.02–0.06 %
Γ_{10}	$N\gamma$, helicity=1/2	

$\Delta(1620)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.2 to 0.3 OUR ESTIMATE				
0.09 ± 0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.25 ± 0.03	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.35 ± 0.06	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.60	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$ (lower mass)
0.36	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$ (higher mass)

Note: Signs of couplings from $\pi N \to N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1620) \to \Delta(1232)\pi$, D-wave — $(\Gamma_1\Gamma_4)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.36 to −0.28 OUR ESTIMATE				
-0.24 ± 0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
-0.33 ± 0.06	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
−0.39	[2,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
−0.40	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1620) \to N\rho$, S=1/2, S-wave $\qquad (\Gamma_1\Gamma_6)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.12 to +0.22 OUR ESTIMATE				
+0.15±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
+0.40±0.10	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
+0.08	[2,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
+0.28	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1620) \to N\rho$, S=3/2, D-wave $\qquad (\Gamma_1\Gamma_7)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.15 to −0.03 OUR ESTIMATE				
−0.06±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
−0.13	[2,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1620) \to N(1440)\pi$ $\qquad (\Gamma_1\Gamma_8)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
0.11±0.05	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$

Δ(1620) PHOTON DECAY AMPLITUDES

$\Delta(1620) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
+0.030±0.014 OUR ESTIMATE				
0.042±0.003	LI	93	IPWA	$\gamma N \to \pi N$
0.035±0.010	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
0.010±0.015	AWAJI	81	DPWA	$\gamma N \to \pi N$
−0.022±0.007	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
−0.026±0.008	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
0.021±0.020	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
0.126±0.021	TAKEDA	80	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.066	WADA	84	DPWA	Compton scattering
+0.034±0.028	BARBOUR	78	DPWA	$\gamma N \to \pi N$
−0.005±0.016	FELLER	76	DPWA	$\gamma N \to \pi N$

Δ(1620) FOOTNOTES

[1] CHEW 80 reports two S_{31} resonances at somewhat higher masses than other analyses. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

[2] LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

[3] From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

[4] See HOEHLER 93 and HOEHLER 94 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.

[5] LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

[6] LONGACRE 77 considers this coupling to be well determined.

Δ(1620) REFERENCES

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

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
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)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
ARNDT	85	PR D32 1085	+Ford, Roper	(VPI)
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/9B2		(KARLT)
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)

BARNHAM	80	NP B168 243	+Glickman, Mier-Jedrzejowicz+	(LOIC)
CHEW	80	Toronto Conf. 123		(LBL) IJP
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) IJP
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

$\Delta(1700)$ D_{33}

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

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

Δ(1700) MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1670 to 1770 (≈ 1700) OUR ESTIMATE				
1762 ±44	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1710 ±30	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1680 ±70	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1655	LI	93	IPWA	$\gamma N \to \pi N$
1650	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
$1718.4^{+13.1}_{-13.0}$	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
1622	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
1629	BARBOUR	78	DPWA	$\gamma N \to \pi N$
1600	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1680	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

Δ(1700) WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
200 to 400 (≈ 300) OUR ESTIMATE				
600 ±250	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
280 ± 80	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
230 ± 80	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
348	LI	93	IPWA	$\gamma N \to \pi N$
160	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
193.3± 26.0	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
209	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
216	BARBOUR	78	DPWA	$\gamma N \to \pi N$
200	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
240	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

Δ(1700) POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1651	[4] HOEHLER	93	SPED	$\pi N \to \pi N$
1646	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
1675±25	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1668	ARNDT	85	DPWA	See ARNDT 91
1681 or 1672	[5] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
1600 or 1594	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
159	[4] HOEHLER	93	SPED	$\pi N \to \pi N$
208	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
220±40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
320	ARNDT	85	DPWA	See ARNDT 91
245 or 241	[5] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
208 or 201	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$\Delta(1700)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
10	HOEHLER	93	SPED	$\pi N \to \pi N$
13	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
13±3	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−22	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
−20±25	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(1700)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	10–20 %
Γ_2	ΣK	
Γ_3	$N\pi\pi$	80–90 %
Γ_4	$\Delta\pi$	30–60 %
Γ_5	$\Delta(1232)\pi$, S-wave	25–50 %
Γ_6	$\Delta(1232)\pi$, D-wave	1–7 %
Γ_7	$N\rho$	30–55 %
Γ_8	$N\rho$, S=1/2, D-wave	
Γ_9	$N\rho$, S=3/2, S-wave	5–20 %
Γ_{10}	$N\rho$, S=3/2, D-wave	
Γ_{11}	$N\gamma$	0.16–0.28 %
Γ_{12}	$N\gamma$, helicity=1/2	
Γ_{13}	$N\gamma$, helicity=3/2	

$\Delta(1700)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.10 to 0.20 OUR ESTIMATE				
0.14±0.06	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.12±0.03	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.20±0.03	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.16	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1700) \to \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.002	LIVANOS	80	DPWA	$\pi p \to \Sigma K$
0.001 to 0.011	[6] DEANS	75	DPWA	$\pi N \to \Sigma K$

Note: Signs of couplings from $\pi N \to N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1700) \rightarrow \Delta(1232)\pi$, S-wave $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.21 to +0.29 OUR ESTIMATE				
+0.32±0.06	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
+0.18±0.04	BARNHAM	80	IPWA	$\pi N \rightarrow N\pi\pi$
+0.30	[2,7] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
+0.24	[3] LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1700) \rightarrow \Delta(1232)\pi$, D-wave $(\Gamma_1\Gamma_6)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.05 to +0.11 OUR ESTIMATE				
+0.08±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
0.14±0.04	BARNHAM	80	IPWA	$\pi N \rightarrow N\pi\pi$
+0.05	[2,7] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
+0.10	[3] LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1700) \rightarrow N\rho$, S=1/2, D-wave $(\Gamma_1\Gamma_8)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.17±0.05	BARNHAM	80	IPWA	$\pi N \rightarrow N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1700) \rightarrow N\rho$, S=3/2, S-wave $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
±0.11 to ±0.19 OUR ESTIMATE				
+0.10±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
+0.04	[2,7] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
−0.30	[3] LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1700) \rightarrow N\rho$, S=3/2, D-wave $(\Gamma_1\Gamma_{10})^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
0.18±0.07	BARNHAM	80	IPWA	$\pi N \rightarrow N\pi\pi$

$\Delta(1700)$ PHOTON DECAY AMPLITUDES

$\Delta(1700) \rightarrow N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
+0.114±0.013 OUR ESTIMATE				
0.121±0.004	LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.111±0.017	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.089±0.033	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
0.112±0.006	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
0.130±0.006	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
0.123±0.022	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+0.130±0.037	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
+0.072±0.033	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1700) \rightarrow N\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
+0.091±0.029 OUR ESTIMATE				
0.115±0.004	LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.107±0.015	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.060±0.015	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
0.047±0.007	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
0.050±0.007	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
0.102±0.015	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+0.098±0.036	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
+0.087±0.023	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1700)$ FOOTNOTES

[1] Problems with CHEW 80 are discussed in section 2.1.11 of HOEHLER 83.
[2] LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \rightarrow N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
[3] From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
[4] See HOEHLER 93 and HOEHLER 94 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.
[5] LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \rightarrow N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
[6] The range given is from the four best solutions. DEANS 75 disagrees with $\pi^+ p \rightarrow \Sigma^+ K^+$ data of WINNIK 77 around 1920 MeV.
[7] LONGACRE 77 considers this coupling to be well determined.

$\Delta(1700)$ REFERENCES

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

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
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)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
ARNDT	85	PR D32 1085	+Ford, Roper	(VPI)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/9B2		(KARLT)
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)
BARNHAM	80	NP B168 243	+Glickman, Mier-Jedrzejowicz+	(LOIC)
CHEW	80	Toronto Conf. 123		(LBL) IJP
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) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

$\Delta(1750)$ P_{31}

$I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$ Status: $*$

OMITTED FROM SUMMARY TABLE

$\Delta(1750)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
≈ 1750 OUR ESTIMATE				
1744 ±36	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1715.2±21.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1778.4± 9.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$\Delta(1750)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
300 ±120	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
93.3± 55.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
23.0± 29.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$\Delta(1750)$ DECAY MODES

	Mode
Γ_1	$N\pi$
Γ_2	$N\pi\pi$
Γ_3	$N(1440)\pi$

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.08±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.18	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
0.20	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$(\Gamma_i\Gamma_f)^{½}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1700) \rightarrow N(1440)\pi$ — $(\Gamma_1\Gamma_3)^{½}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.15±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$

$\Delta(1750)$ FOOTNOTES

[1] CHEW 80 reports four resonances in the P_{31} wave — see also the $\Delta(1910)$. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

$\Delta(1750)$ REFERENCES

MANLEY	92	PR D45 4002	+Saleski	(KENT)
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
HOEHLER	83	Landolt-Boernstein 1/9B2		(KARLT)
CHEW	80	Toronto Conf. 123		(LBL)

$\Delta(1900)\ S_{31}$

$I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$ Status: ∗∗∗

$\Delta(1900)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1850 to 1950 (≈ 1900) OUR ESTIMATE				
1920 ±24	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
1890 ±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1908 ±30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1918.5±23.0	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1803	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1900)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
140 to 240 (≈ 200) OUR ESTIMATE				
263 ±39	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
170 ±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
140 ±40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
93.5±54.0	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
137	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1900)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1780	[1] HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1870±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
2029 or 2025	[2] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
180±50	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
not seen	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
164 or 163	[2] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$

$\Delta(1900)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
10±3	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
+20±40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(1900)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	10–30 %
Γ_2	ΣK	
Γ_3	$N\pi\pi$	
Γ_4	$\Delta\pi$	
Γ_5	$\Delta(1232)\pi$, D-wave	
Γ_6	$N\rho$	
Γ_7	$N\rho$, S=1/2, S-wave	
Γ_8	$N\rho$, S=3/2, D-wave	
Γ_9	$N(1440)\pi$, S-wave	
Γ_{10}	$N\gamma$, helicity=1/2	

$\Delta(1900)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.1 to 0.3 OUR ESTIMATE				
0.41±0.04	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.10±0.03	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.08±0.04	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.28	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1900) \to \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
<0.03	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.076	[3] DEANS	75	DPWA	$\pi N \to \Sigma K$
0.11	LANGBEIN	73	IPWA	$\pi N \to \Sigma K$ (sol. 1)
0.12	LANGBEIN	73	IPWA	$\pi N \to \Sigma K$ (sol. 2)

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1900) \to \Delta(1232)\pi$, D-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.25±0.07	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1900) \to N\rho$, S=1/2, S-wave — $(\Gamma_1\Gamma_7)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.14±0.11	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1900) \to N\rho$, S=3/2, D-wave — $(\Gamma_1\Gamma_8)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.37±0.07	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$(\Gamma_i \Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1900) \rightarrow N(1440)\pi$, S-wave $(\Gamma_1 \Gamma_9)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
-0.16 ± 0.11	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$

$\Delta(1900)$ PHOTON DECAY AMPLITUDES

$\Delta(1900) \rightarrow N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($\mathrm{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
-0.004 ± 0.016	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.029 ± 0.008	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
-0.006 to -0.025	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1900)$ FOOTNOTES

[1] See HOEHLER 93 and HOEHLER 94 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.

[2] LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \rightarrow N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

[3] The value given is from solution 1; the resonance is not present in solutions 2, 3, or 4.

$\Delta(1900)$ REFERENCES

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

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
HOEHLER	93	πN Newsletter 9 1		(KARL)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
AWAJI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
CHEW	80	Toronto Conf. 123		(LBL) IJP
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) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LANGBEIN	73	NP B53 251	+Wagner	(MUNI) IJP

$\Delta(1905)$ F_{35}

$I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$ Status: ∗∗∗∗

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

$\Delta(1905)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1870 to 1920 (≈ 1905) OUR ESTIMATE				
1881 ± 18	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
1910 ± 30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1905 ± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1960 ± 40	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
$1787.0^{+6.0}_{-5.7}$	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1880	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1892	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1830	[1] LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$\Delta(1905)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
280 to 440 (≈ 350) OUR ESTIMATE				
327 ± 51	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N \pi \pi$
400 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
260 ± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
270 ± 40	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
$66.0^{+24.0}_{-16.0}$	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
193	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
159	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
220	[1] LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

$\Delta(1905)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1829	[2] HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1794	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1830±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1830	ARNDT	85	DPWA	See ARNDT 91
1813 or 1808	[3] LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$

−2×IMAGINARY PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
303	[2] HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
230	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
280±60	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
180	ARNDT	85	DPWA	See ARNDT 91
193 or 187	[3] LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$

$\Delta(1905)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
25	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
14	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
25±8	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

PHASE θ

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
−40	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
−50±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(1905)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	5–15 %
Γ_2	ΣK	
Γ_3	$N\pi\pi$	85–95 %
Γ_4	$\Delta\pi$	<25 %
Γ_5	$\Delta(1232)\pi$, P-wave	
Γ_6	$\Delta(1232)\pi$, F-wave	
Γ_7	$N\rho$	>60 %
Γ_8	$N\rho$, S=3/2, P-wave	
Γ_9	$N\rho$, S=3/2, F-wave	
Γ_{10}	$N\rho$, S=1/2, F-wave	
Γ_{11}	$N\gamma$	0.01–0.04 %
Γ_{12}	$N\gamma$, helicity=1/2	
Γ_{13}	$N\gamma$, helicity=3/2	

$\Delta(1905)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.05 to 0.15 OUR ESTIMATE				
0.12±0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.08±0.03	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.15±0.02	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.11	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1905) \to \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.015±0.003	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.013	LIVANOS	80	DPWA	$\pi p \to \Sigma K$
0.021 to 0.054	[4] DEANS	75	DPWA	$\pi N \to \Sigma K$

Note: Signs of couplings from $\pi N \to N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1905) \to \Delta(1232)\pi$, P-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.04±0.05	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1905) \to \Delta(1232)\pi$, F-wave — $(\Gamma_1\Gamma_6)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.02±0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
+0.20	[1] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+0.17	[5] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$
+0.06	[6] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1905) \to N\rho$, S=3/2, P-wave — $(\Gamma_1\Gamma_8)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.030 to +0.36 OUR ESTIMATE				
+0.33 ±0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
+0.33	[1] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+0.26	[5] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$
+0.11 to +0.33	[7] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$

$\Delta(1905)$ PHOTON DECAY AMPLITUDES

$\Delta(1905) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
+0.037±0.016 OUR ESTIMATE				
0.055±0.004	LI	93	IPWA	$\gamma N \to \pi N$
0.021±0.010	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
0.043±0.020	AWAJI	81	DPWA	$\gamma N \to \pi N$
0.022±0.010	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
0.031±0.009	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
0.024±0.014	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+0.033±0.018	BARBOUR	78	DPWA	$\gamma N \to \pi N$

$\Delta(1905) \rightarrow N\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE ($\mathrm{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.031±0.030 OUR ESTIMATE				
0.002±0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$
−0.056±0.028	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
−0.025±0.023	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
−0.029±0.007	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
−0.045±0.006	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
−0.072±0.035	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.055±0.019	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1905)$ FOOTNOTES

[1] From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

[2] See HOEHLER 93 and HOEHLER 94 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] LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \rightarrow N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

[4] The range given for DEANS 75 is from the four best solutions.

[5] A Breit-Wigner fit to the HERNDON 75 IPWA.

[6] A Breit-Wigner fit to the NOVOSELLER 78B IPWA.

[7] A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near 90°.

$\Delta(1905)$ REFERENCES

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

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
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)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
ARNDT	85	PR D32 1085	+Ford, Roper	(VPI)
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
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)
CHEW	80	Toronto Conf. 123		(LBL) IJP
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) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER	78	NP B137 509		(CIT) IJP
NOVOSELLER	78B	NP B137 445		(CIT) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

$\Delta(1910)\ P_{31}$

$I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$ Status: ∗∗∗∗

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

$\Delta(1910)$ MASS

VALUE (MeV)		*DOCUMENT ID*		*TECN*	*COMMENT*
1870 to 1920 (≈ 1910) OUR ESTIMATE					
1882 ±10		MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1910 ±40		CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1888 ±20		HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1960.1±21.0	1	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
$2121.4^{+13.0}_{-14.3}$	1	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
1921		CRAWFORD	80	DPWA	$\gamma N \to \pi N$
1899		BARBOUR	78	DPWA	$\gamma N \to \pi N$
1790	2	LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$\Delta(1910)$ WIDTH

VALUE (MeV)		*DOCUMENT ID*		*TECN*	*COMMENT*
190 to 270 (≈ 250) OUR ESTIMATE					
239 ±25		MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
225 ±50		CUTKOSKY	80	IPWA	$\pi N \to \pi N$
280 ±50		HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
152.9±60.0	1	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
172.2±37.0	1	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
351		CRAWFORD	80	DPWA	$\gamma N \to \pi N$
230		BARBOUR	78	DPWA	$\gamma N \to \pi N$
170	2	LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$\Delta(1910)$ POLE POSITION

REAL PART

VALUE (MeV)		*DOCUMENT ID*		*TECN*	*COMMENT*
1874	3	HOEHLER	93	SPED	$\pi N \to \pi N$
1950		ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
1880±30		CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
1792 or 1801	2	LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)		*DOCUMENT ID*		*TECN*	*COMMENT*
283	3	HOEHLER	93	SPED	$\pi N \to \pi N$
398		ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
200±40		CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
172 or 165	2	LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$\Delta(1910)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
38	HOEHLER	93	SPED	$\pi N \to \pi N$
37	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
20±4	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
−91	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
−90±30	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(1910)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	15–30 %
Γ_2	ΣK	
Γ_3	$N\pi\pi$	
Γ_4	$\Delta\pi$	
Γ_5	$\Delta(1232)\pi$, P-wave	
Γ_6	$N\rho$	
Γ_7	$N\rho$, S=3/2, P-wave	
Γ_8	$N(1440)\pi$	
Γ_9	$N(1440)\pi$, P-wave	
Γ_{10}	$N\gamma$, helicity=1/2	

$\Delta(1910)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.15 to 0.3 OUR ESTIMATE				
0.23±0.08	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.19±0.03	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.24±0.06	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.17	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
0.40	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$

$(\Gamma_i\Gamma_f)^{½}/\Gamma_{total}$ in $N\pi \to \Delta(1910) \to \Sigma K$ — $(\Gamma_1\Gamma_2)^{½}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
$<$ 0.03	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.019	LIVANOS	80	DPWA	$\pi p \to \Sigma K$
0.082 to 0.184	[4] DEANS	75	DPWA	$\pi N \to \Sigma K$

Note: Signs of couplings from $\pi N \to N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

$(\Gamma_i\Gamma_f)^{½}/\Gamma_{total}$ in $N\pi \to \Delta(1910) \to \Delta(1232)\pi$, P-wave — $(\Gamma_1\Gamma_5)^{½}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.06	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{½}/\Gamma_{total}$ in $N\pi \to \Delta(1910) \to N\rho$, S=3/2, P-wave — $(\Gamma_1\Gamma_7)^{½}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.29	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+0.17	[5] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{½}/\Gamma_{total}$ in $N\pi \to \Delta(1910) \to N(1440)\pi$, P-wave — $(\Gamma_1\Gamma_9)^{½}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.39±0.04	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$\Delta(1910)$ PHOTON DECAY AMPLITUDES

$\Delta(1910) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV$^{-1/2}$)	*DOCUMENT ID*		*TECN*	*COMMENT*
+0.013±0.022 OUR ESTIMATE				
0.032±0.003	LI	93	IPWA	$\gamma N \to \pi N$
0.014±0.030	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
0.025±0.011	AWAJI	81	DPWA	$\gamma N \to \pi N$
−0.012±0.005	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
−0.031±0.004	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
−0.005±0.030	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.035±0.021	BARBOUR	78	DPWA	$\gamma N \to \pi N$

$\Delta(1910)$ FOOTNOTES

[1] CHEW 80 reports four resonances in the P_{31} wave — see also the $\Delta(1750)$. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

[2] LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

[3] See HOEHLER 93 and HOEHLER 94 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.

[4] The range given for DEANS 75 is from the four best solutions.

[5] Evidence for this coupling is weak; see NOVOSELLER 78. This coupling assumes the mass is near 1820 MeV.

$\Delta(1910)$ REFERENCES

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

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
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)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/9B2		(KARLT)
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)
CHEW	80	Toronto Conf. 123		(LBL) IJP
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) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
NOVOSELLER	78	NP B137 509		(CIT) IJP
Also	78B	NP B137 445	Novoseller	(CIT) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP

$\Delta(1920)\ P_{33}$

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

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

$\Delta(1920)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1900 to 1970 (≈ 1920) OUR ESTIMATE				
2014 ±16	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
1920 ±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1868 ±10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1840 ±40	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
1955.0±13.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
$2065.0^{+13.6}_{-12.9}$	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$\Delta(1920)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
150 to 300 (≈ 200) OUR ESTIMATE				
152 ± 55	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
300 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
220 ± 80	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
200 ± 40	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
88.3± 35.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
62.0± 44.0	[1] CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$\Delta(1920)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1900	[2] HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1900±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

−2×IMAGINARY PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
300±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

$\Delta(1920)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
24±4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

PHASE θ

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
−150±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(1920)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	5–20 %
Γ_2	ΣK	
Γ_3	$N\pi\pi$	
Γ_4	$\Delta(1232)\pi$, P-wave	
Γ_5	$N(1440)\pi$, P-wave	
Γ_6	$N\gamma$, helicity=1/2	
Γ_7	$N\gamma$, helicity=3/2	

$\Delta(1920)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.05 to 0.2 OUR ESTIMATE				
0.02±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.20±0.05	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.14±0.04	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.24	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
0.18	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1920) \to \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.052±0.015	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.049	LIVANOS	80	DPWA	$\pi p \to \Sigma K$
0.048 to 0.120	[3] DEANS	75	DPWA	$\pi N \to \Sigma K$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1920) \to \Delta(1232)\pi$, P-wave — $(\Gamma_1\Gamma_4)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.13±0.04	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.3	[4] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$
0.27	[5] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1920) \to N(1440)\pi$, P-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.06±0.07	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$\Delta(1920)$ PHOTON DECAY AMPLITUDES

$\Delta(1920) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
0.040±0.014	AWAJI	81	DPWA	$\gamma N \to \pi N$

$\Delta(1920) \to N\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
0.023±0.017	AWAJI	81	DPWA	$\gamma N \to \pi N$

$\Delta(1920)$ FOOTNOTES

[1] CHEW 80 reports two P_{33} resonances in this mass region. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.
[2] See HOEHLER 93 and HOEHLER 94 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] The range given for DEANS 75 is from the four best solutions.
[4] A Breit-Wigner fit to the HERNDON 75 IPWA; the phase is near $-90°$.
[5] A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near $-90°$.

*CITATION: L. Montanet et al., Physical Review D50, 1173 (1994) and 1995 off-year partial update for the 1996 edition (URL: http://pdg.lbl.gov/)

$\Delta(1920)$ REFERENCES

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

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
HOEHLER	93	πN Newsletter 9 1		(KARL)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
HOEHLER	83	Landolt-Boernstein 1/9B2		(KARLT)
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)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
NOVOSELLER	78	NP B137 509		(CIT)
NOVOSELLER	78B	NP B137 445		(CIT)
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)

$\Delta(1930)\ D_{35}$

$I(J^P) = \frac{3}{2}(\frac{5}{2}^-)$ Status: ∗∗∗

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

The various analyses are not in good agreement.

$\Delta(1930)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1920 to 1970 (≈ 1930) OUR ESTIMATE				
1956 ±22	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
1940 ±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1901 ±15	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1963	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$1910.0^{+15.0}_{-17.2}$	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
2000	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
2024	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1930)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
250 to 450 (≈ 350) OUR ESTIMATE				
530 ±140	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
320 ± 60	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
195 ± 60	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
260	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$74.8^{+\ 17.0}_{-\ 16.0}$	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
442	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
462	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1930)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1850	[1] HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
2018	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1890±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
180	[1] HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
398	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
260±60	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

Δ(1930) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
20	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
15	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
18±6	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−24	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
−20±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

Δ(1930) DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	10–20 %
Γ_2	ΣK	
Γ_3	$N\pi\pi$	
Γ_4	$N\gamma$, helicity=1/2	
Γ_5	$N\gamma$, helicity=3/2	

Δ(1930) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.1 to 0.2 OUR ESTIMATE				
0.18±0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
0.14±0.04	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.04±0.03	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.11	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1930) \rightarrow \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
$<$ 0.015	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.031	LIVANOS	80	DPWA	$\pi p \rightarrow \Sigma K$
0.018 to 0.035	[2] DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1930) \rightarrow N\pi\pi$ — $(\Gamma_1\Gamma_3)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
not seen	LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

Δ(1930) PHOTON DECAY AMPLITUDES

$\Delta(1930) \rightarrow N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.015±0.017 OUR ESTIMATE				
−0.019±0.001	LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.009±0.009	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
−0.030±0.047	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.062±0.064	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1930) \rightarrow N\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.010±0.022 OUR ESTIMATE				
0.009±0.001	LI	93	IPWA	$\gamma N \rightarrow \pi N$
−0.025±0.011	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
−0.033±0.060	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+0.019±0.054	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1930)$ FOOTNOTES

[1] See HOEHLER 93 and HOEHLER 94 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.

[2] The range given for DEANS 75 is from the four best solutions.

$\Delta(1930)$ REFERENCES

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

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
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)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
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)
CHEW	80	Toronto Conf. 123		(LBL) IJP
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) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

$\Delta(1940)\ D_{33}$

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

OMITTED FROM SUMMARY TABLE

$\Delta(1940)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 1940 OUR ESTIMATE				
2057 ±110	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
2058.1± 34.5	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1940 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(1940)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
460 ±320	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
198.4± 45.5	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
200 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(1940)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1900±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1915 or 1926	[1] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
200±60	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
190 or 186	[1] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$

$\Delta(1940)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
8 ± 3	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
135 ± 45	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(1940)$ DECAY MODES

	Mode
Γ_1	$N\pi$
Γ_2	ΣK
Γ_3	$N\pi\pi$
Γ_4	$\Delta(1232)\pi$, S-wave
Γ_5	$\Delta(1232)\pi$, D-wave
Γ_6	$N\rho$, S=3/2, S-wave
Γ_7	$N\gamma$, helicity=1/2
Γ_8	$N\gamma$, helicity=3/2

$\Delta(1940)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.18 ± 0.12	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.18	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
0.05 ± 0.02	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to \Delta(1940) \to \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
<0.015	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to \Delta(1940) \to \Delta(1232)\pi$, S-wave — $(\Gamma_1\Gamma_4)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
$+0.11\pm0.10$	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to \Delta(1940) \to \Delta(1232)\pi$, D-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
$+0.27\pm0.16$	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to \Delta(1940) \to N\rho$, S=3/2, S-wave — $(\Gamma_1\Gamma_6)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
$+0.25\pm0.10$	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$\Delta(1940)$ PHOTON DECAY AMPLITUDES

$\Delta(1940) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
-0.036 ± 0.058	AWAJI	81	DPWA	$\gamma N \to \pi N$

$\Delta(1940) \to N\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
-0.031 ± 0.012	AWAJI	81	DPWA	$\gamma N \to \pi N$

$\Delta(1940)$ FOOTNOTES

[1] LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

*CITATION: L. Montanet et al., Physical Review D50, 1173 (1994) and 1995 off-year partial update for the 1996 edition (URL: http://pdg.lbl.gov/)

$\Delta(1940)$ REFERENCES

MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
AWAJI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)

$\Delta(1950)\ F_{37}$

$I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$ Status: ∗∗∗∗

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

$\Delta(1950)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1940 to 1960 (≈ 1950) OUR ESTIMATE				
1945 ± 2	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1950 ±15	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1913 ± 8	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1940	LI	93	IPWA	$\gamma N \to \pi N$
1925 ±20	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$
$1855.0^{+11.0}_{-10.0}$	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
1902	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
1912	BARBOUR	78	DPWA	$\gamma N \to \pi N$
1925	[1] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Delta(1950)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
290 to 350 (≈ 300) OUR ESTIMATE				
300 ± 7	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
340 ±50	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
224 ±10	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
306	LI	93	IPWA	$\gamma N \to \pi N$
330 ±40	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$
$157.2^{+22.0}_{-19.0}$	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
225	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
198	BARBOUR	78	DPWA	$\gamma N \to \pi N$
240	[1] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Delta(1950)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1878	[2] HOEHLER	93	ARGD	$\pi N \to \pi N$
1884	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
1890±15	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1858	ARNDT	85	DPWA	See ARNDT 91
1924 or 1924	[3] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
230	[2] HOEHLER	93	ARGD	$\pi N \to \pi N$
238	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
260±40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
238	ARNDT	85	DPWA	See ARNDT 91
258 or 258	[3] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$

$\Delta(1950)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
47	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
61	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
50±7	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−32	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
−23	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
−33±8	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(1950)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	35–40 %
Γ_2	ΣK	
Γ_3	$N\pi\pi$	
Γ_4	$\Delta\pi$	20–30 %
Γ_5	$\Delta(1232)\pi$, F-wave	
Γ_6	$\Delta(1232)\pi$, H-wave	
Γ_7	$N\rho$	<10 %
Γ_8	$N\rho$, S=1/2, F-wave	
Γ_9	$N\rho$, S=3/2, F-wave	
Γ_{10}	$N\gamma$	0.10–0.15 %
Γ_{11}	$N\gamma$, helicity=1/2	
Γ_{12}	$N\gamma$, helicity=3/2	

$\Delta(1950)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.35 to 0.4 OUR ESTIMATE				
0.38±0.01	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
0.39±0.04	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.38±0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.44	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1950) \rightarrow \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.053±0.005	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.022 to 0.040	[4] DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$

Note: Signs of couplings from $\pi N \rightarrow N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1950) \rightarrow \Delta(1232)\pi$, F-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.28 to +0.32 OUR ESTIMATE				
+0.27±0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
+0.32	[1] LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.21	[5] NOVOSELLER	78	IPWA	$\pi N \rightarrow N\pi\pi$
0.38	[6] NOVOSELLER	78	IPWA	$\pi N \rightarrow N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1950) \to N\rho$, S=3/2, F-wave — $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.24	[1] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.24	[7] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$
0.43	[8] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$

$\Delta(1950)$ PHOTON DECAY AMPLITUDES

$\Delta(1950) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.085±0.017 OUR ESTIMATE				
−0.102±0.003	LI	93	IPWA	$\gamma N \to \pi N$
−0.068±0.007	AWAJI	81	DPWA	$\gamma N \to \pi N$
−0.091±0.005	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
−0.083±0.005	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
−0.067±0.014	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.058±0.013	BARBOUR	78	DPWA	$\gamma N \to \pi N$

$\Delta(1950) \to N\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.101±0.014 OUR ESTIMATE				
−0.115±0.003	LI	93	IPWA	$\gamma N \to \pi N$
−0.094±0.016	AWAJI	81	DPWA	$\gamma N \to \pi N$
−0.101±0.005	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
−0.100±0.005	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
−0.082±0.017	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.075±0.020	BARBOUR	78	DPWA	$\gamma N \to \pi N$

$\Delta(1950)$ FOOTNOTES

[1] From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

[2] See HOEHLER 93 and HOEHLER 94 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] LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

[4] The range given is from the four best solutions. DEANS 75 disagrees with $\pi^+ p \to \Sigma^+ K^+$ data of WINNIK 77 around 1920 MeV.

[5] A Breit-Wigner fit to the HERNDON 75 IPWA; the phase is near −60°.

[6] A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near −60°.

[7] A Breit-Wigner fit to the HERNDON 75 IPWA; the phase is near 120°.

[8] A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near 120°.

$\Delta(1950)$ REFERENCES

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
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)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
ARNDT	85	PR D32 1085	+Ford, Roper	(VPI)
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
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)
CHEW	80	Toronto Conf. 123		(LBL) IJP

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) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER	78	NP B137 509		(CIT) IJP
NOVOSELLER	78B	NP B137 445		(CIT) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

$\Delta(2000)\ F_{35}$

$I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$ Status: ∗

OMITTED FROM SUMMARY TABLE

$\Delta(2000)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
≈ 2000 OUR ESTIMATE				
1752± 32	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
2200±125	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2000)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
251± 93	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
400±125	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2000)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
2150±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

−2×IMAGINARY PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
350±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2000)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
16±5	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
150±90	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2000)$ DECAY MODES

	Mode
Γ_1	$N\pi$
Γ_2	$N\pi\pi$
Γ_3	$\Delta(1232)\pi$, P-wave
Γ_4	$\Delta(1232)\pi$, F-wave
Γ_5	$N\rho$, S=3/2, P-wave

$\Delta(2000)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ Γ_1/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.02±0.01	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.07±0.04	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(2000) \to \Delta(1232)\pi$, P-wave — $(\Gamma_1\Gamma_3)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.07±0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(2000) \to \Delta(1232)\pi$, F-wave — $(\Gamma_1\Gamma_4)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.09±0.04	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(2000) \to N\rho$, S=3/2, P-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.06±0.01	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$\Delta(2000)$ REFERENCES

MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL)
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)

$\Delta(2150)$ S_{31}

$I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$ Status: *

OMITTED FROM SUMMARY TABLE

$\Delta(2150)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2150 OUR ESTIMATE				
2047.4± 27.0	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
2203.2± 8.4	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
2150 ±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2150)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
121.6± 62.0	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
120.5± 45.0	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
200 ±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2150)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2140±80	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
200±80	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2150)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
7±2	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−60±90	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2150)$ DECAY MODES

	Mode
Γ_1	$N\pi$
Γ_2	ΣK

Δ(2150) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.41	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
0.37	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
0.08±0.02	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(2150) \to \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
<0.03	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$

Δ(2150) FOOTNOTES

[1] CHEW 80 reports two S_{31} resonances in this mass region. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

Δ(2150) REFERENCES

CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
HOEHLER	83	Landolt-Boernstein 1/9B2		(KARLT)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)

Δ(2200) G_{37}

$I(J^P) = \frac{3}{2}(\frac{7}{2}^-)$ Status: ∗

OMITTED FROM SUMMARY TABLE

The various analyses are not in good agreement.

Δ(2200) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2200 OUR ESTIMATE				
2200±80	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
2215±60	HOEHLER	79	IPWA	$\pi N \to \pi N$
2280±80	HENDRY	78	MPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2280±40	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$

Δ(2200) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
450±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
400±100	HOEHLER	79	IPWA	$\pi N \to \pi N$
400±150	HENDRY	78	MPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
400± 50	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$

Δ(2200) POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2100±50	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
340±80	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

Δ(2200) ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
8±3	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
-70 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(2200)$ DECAY MODES

	Mode
Γ_1	$N\pi$
Γ_2	ΣK

$\Delta(2200)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$ $\qquad\Gamma_1/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
0.06 ± 0.02	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.05 ± 0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
0.09 ± 0.02	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \Delta(2200) \rightarrow \Sigma K$ $\qquad(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
-0.014 ± 0.005	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$

$\Delta(2200)$ REFERENCES

CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

$\Delta(2300)\ H_{39}$

$I(J^P) = \frac{3}{2}(\frac{9}{2}^+)$ Status: $**$

OMITTED FROM SUMMARY TABLE

$\Delta(2300)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2300 OUR ESTIMATE				
$2204.5\pm\ \ 3.4$	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
$2400\ \ \pm125$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$2217\ \ \pm\ 80$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$2450\ \ \pm100$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2400	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$

$\Delta(2300)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
$32.3\pm\ \ 1.0$	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
$425\ \ \pm150$	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$300\ \ \pm100$	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$500\ \ \pm200$	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
200	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$

$\Delta(2300)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2370 ± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
420±160	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

Δ(2300) ELASTIC POLE RESIDUE

MODULUS $\lvert r \rvert$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
10±4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−20±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

Δ(2300) DECAY MODES

	Mode
Γ_1	$N\pi$
Γ_2	ΣK

Δ(2300) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.05	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
0.06±0.02	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.03±0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
0.08±0.02	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(2300) \rightarrow \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.017	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$

Δ(2300) REFERENCES

CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

$\Delta(2350)\ D_{35}$

$I(J^P) = \frac{3}{2}(\frac{5}{2}^-)$ Status: ∗

OMITTED FROM SUMMARY TABLE

Δ(2350) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2350 OUR ESTIMATE				
2171± 18	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
2400±125	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2305± 26	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

Δ(2350) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
264± 51	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
400±150	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
300± 70	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

$\Delta(2350)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2400±125	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
400±150	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(2350)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
15±8	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−70±70	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(2350)$ DECAY MODES

	Mode
Γ_1	$N\pi$
Γ_2	ΣK

$\Delta(2350)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.020±0.003	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
0.20 ±0.10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.04 ±0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(2350) \rightarrow \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
<0.015	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$

$\Delta(2350)$ REFERENCES

MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP

$\Delta(2390)$ F_{37}

$I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$ Status: $*$

OMITTED FROM SUMMARY TABLE

$\Delta(2390)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
≈ 2390 OUR ESTIMATE				
2350±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
2425± 60	HOEHLER	79	IPWA	$\pi N \to \pi N$

$\Delta(2390)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
300±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
300± 80	HOEHLER	79	IPWA	$\pi N \to \pi N$

$\Delta(2390)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
2350±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

−2×IMAGINARY PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
260±100	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2390)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
12±6	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

PHASE θ

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
−90±60	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

$\Delta(2390)$ DECAY MODES

	Mode
Γ_1	$N\pi$
Γ_2	ΣK

$\Delta(2390)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ Γ_1/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.08±0.04	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.07±0.04	HOEHLER	79	IPWA	$\pi N \to \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(2390) \to \Sigma K$ $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.015	CANDLIN	84	DPWA	$\pi^+ p \to \Sigma^+ K^+$

$\Delta(2390)$ REFERENCES

CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP

$\Delta(2400)$ G_{39}

$I(J^P) = \frac{3}{2}(\frac{9}{2}^-)$ Status: $**$

OMITTED FROM SUMMARY TABLE

$\Delta(2400)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
≈ 2400 OUR ESTIMATE				
2300±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2468± 50	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2200±100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$\Delta(2400)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
330±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
480±100	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
450±200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$\Delta(2400)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
2260±60	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

−2×IMAGINARY PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
320±160	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(2400)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
8±4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

PHASE θ

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
−25±15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(2400)$ DECAY MODES

	Mode
Γ_1	$N\pi$
Γ_2	ΣK

$\Delta(2400)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.05±0.02	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.06±0.03	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
0.10±0.03	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(2400) \rightarrow \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
<0.015	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$

$\Delta(2400)$ REFERENCES

CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

$\Delta(2420)$ $H_{3,11}$

$I(J^P) = \frac{3}{2}(\frac{11}{2}^+)$ Status: ∗∗∗∗

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

$\Delta(2420)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
2300 to 2500 (≈ 2420) OUR ESTIMATE				
2400 ±125	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2416 ± 17	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2400 ± 60	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
2400	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
2358.0± 9.0	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$\Delta(2420)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
300 to 500 (≈ 400) OUR ESTIMATE				
450 ±150	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
340 ± 28	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
460 ±100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
400	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
202.2± 45.0	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$\Delta(2420)$ POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
2300	[1] HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
2360±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

−2×IMAGINARY PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
620	[1] HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
420±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(2420)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
39	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
18±6	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

PHASE θ

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
−60	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
−30±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

$\Delta(2420)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	5–15 %
Γ_2	ΣK	

$\Delta(2420)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.05 to 0.15 OUR ESTIMATE				
0.08 ± 0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.08 ± 0.015	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
0.11 ± 0.02	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.22	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(2420) \rightarrow \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
-0.016	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$

$\Delta(2420)$ FOOTNOTES

[1] See HOEHLER 93 and HOEHLER 94 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.

$\Delta(2420)$ REFERENCES

HOEHLER	94	πN Newsletter 10 (to be pub.)		(KARL)
HOEHLER	93	πN Newsletter 9 1		(KARL)
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

$\Delta(2750)$ $I_{3,13}$

$I(J^P) = \frac{3}{2}(\frac{13}{2}^-)$ Status: $**$

OMITTED FROM SUMMARY TABLE

$\Delta(2750)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2750 OUR ESTIMATE				
2794 ± 80	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2650 ± 100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$\Delta(2750)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
350 ± 100	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
500 ± 100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$\Delta(2750)$ DECAY MODES

	Mode
Γ_1	$N\pi$

$\Delta(2750)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.04 ± 0.015	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
0.05 ± 0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$\Delta(2750)$ REFERENCES

HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

$\Delta(2950)$ $K_{3,15}$

$I(J^P) = \frac{3}{2}(\frac{15}{2}^+)$ Status: ∗∗

OMITTED FROM SUMMARY TABLE

$\Delta(2950)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
≈ 2950 OUR ESTIMATE				
2990±100	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2850±100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$\Delta(2950)$ WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
330±100	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
700±200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$\Delta(2950)$ DECAY MODES

	Mode
Γ_1	$N\pi$

$\Delta(2950)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ **Γ_1/Γ**

VALUE	*DOCUMENT ID*		*TECN*	*COMMENT*
0.04±0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
0.03±0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

$\Delta(2950)$ REFERENCES

HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

$\Delta(\sim 3000$ Region) Partial-Wave Analyses

OMITTED FROM SUMMARY TABLE

We list here miscellaneous high-mass candidates for isospin-3/2 resonances found in partial-wave analyses.

Our 1982 edition also had a $\Delta(2850)$ and a $\Delta(3230)$. The evidence for them was deduced from total cross-section and 180° elastic cross-section measurements. The $\Delta(2850)$ has been resolved into the $\Delta(2750)$ $I_{3,13}$ and $\Delta(2950)$ $K_{3,15}$. The $\Delta(3230)$ is perhaps related to the $K_{3,13}$ of HENDRY 78 and to the $L_{3,17}$ of KOCH 80.

$\Delta(\sim 3000)$ MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
≈ 3000 OUR ESTIMATE				
3300	[1] KOCH	80	IPWA	$\pi N \rightarrow \pi N$ $L_{3,17}$ wave
3500	[1] KOCH	80	IPWA	$\pi N \rightarrow \pi N$ $M_{3,19}$ wave
2850±150	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $I_{3,11}$ wave
3200±200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $K_{3,13}$ wave
3300±200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $L_{3,17}$ wave
3700±200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $M_{3,19}$ wave
4100±300	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $N_{3,21}$ wave

$\Delta(\sim 3000)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
700±200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $I_{3,11}$ wave
1000±300	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $K_{3,13}$ wave
1100±300	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $L_{3,17}$ wave
1300±400	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $M_{3,19}$ wave
1600±500	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $N_{3,21}$ wave

$\Delta(\sim 3000)$ DECAY MODES

	Mode
Γ_1	$N\pi$

$\Delta(\sim 3000)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ **Γ_1/Γ**

VALUE	DOCUMENT ID		TECN	COMMENT
0.06 ±0.02	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $I_{3,11}$ wave
0.045±0.02	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $K_{3,13}$ wave
0.03 ±0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $L_{3,17}$ wave
0.025±0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $M_{3,19}$ wave
0.018±0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$ $N_{3,21}$ wave

$\Delta(\sim 3000)$ FOOTNOTES

[1] In addition, KOCH 80 reports some evidence for an S_{31} $\Delta(2700)$ and a P_{33} $\Delta(2800)$.

$\Delta(\sim 3000)$ REFERENCES

KOCH	80	Toronto Conf. 3		(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)