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

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

$\Delta(1950)$ BREIT-WIGNER MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1915 to 1950 (≈ 1930) OUR ESTIMATE				
1923.3 ± 0.5	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
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. • • •				
1936 ± 5	VRANA	00	DPWA	Multichannel
1947 ± 9	ARNDT	96	IPWA	$\gamma N \to \pi N$
1921	ARNDT	95	DPWA	$\pi N \to N \pi$
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	$\pi N \to N \pi \pi$

$\Delta(1950)$ BREIT-WIGNER WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
235 to 335 (≈ 285) OUR ESTIMATE				
278.2 ± 3.0	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
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. • • •				
245 ± 12	VRANA	00	DPWA	Multichannel
302 ± 9	ARNDT	96	IPWA	$\gamma N \to \pi N$
232	ARNDT	95	DPWA	$\pi N \to N \pi$
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
1870 to 1890 (≈ 1880) OUR ESTIMATE				
1874	ARNDT	04	DPWA	$\pi N \rightarrow \pi N, \eta N$
1878	[2] HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1890±15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1910	VRANA	00	DPWA	Multichannel
1880	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
1884	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1924 or 1924	[3] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
220 to 260 (≈ 240) OUR ESTIMATE				
236	ARNDT	04	DPWA	$\pi N \rightarrow \pi N, \eta N$
230	[2] HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
260±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
230	VRANA	00	DPWA	Multichannel
236	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
238	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
258 or 258	[3] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$

$\Delta(1950)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
57	ARNDT	04	DPWA	$\pi N \rightarrow \pi N, \eta N$
47	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
50±7	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
54	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
61	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−34	ARNDT	04	DPWA	$\pi N \rightarrow \pi N, \eta N$
−32	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
−33±8	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−17	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
−23	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

$\Delta(1950)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	0.35 to 0.45
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}	$N\gamma$	0.08–0.13 %
Γ_{11}	$N\gamma$, helicity=1/2	0.03–0.055 %
Γ_{12}	$N\gamma$, helicity=3/2	0.05–0.075 %

$\Delta(1950)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.35 to 0.45 OUR ESTIMATE				
0.480 ± 0.002	ARNDT	04	DPWA	$\pi N \to \pi N$, ηN
0.38 ± 0.01	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.39 ± 0.04	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.38 ± 0.02	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.44 ± 0.01	VRANA	00	DPWA	Multichannel
0.49	ARNDT	95	DPWA	$\pi N \to N\pi$
0.44	CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$

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

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

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 $N\pi \to \Delta(1950) \to \Delta(1232)\pi$, 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	$\pi N \to \pi N$ & $N\pi\pi$
+0.32	[1] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.21	[5] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$
0.38	[6] NOVOSELLER	78	IPWA	$\pi N \to N\pi\pi$

$\Gamma(\Delta(1232)\pi$, F-wave$)/\Gamma_{total}$ — Γ_5/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.36±0.01	VRANA	00	DPWA	Multichannel

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ 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
−0.076±0.012 OUR ESTIMATE				
−0.079±0.006	ARNDT	96	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. • • •				
−0.102±0.003	LI	93	IPWA	$\gamma N \to \pi N$
−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
−0.097±0.010 OUR ESTIMATE				
−0.103±0.006	ARNDT	96	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. • • •				
−0.115±0.003	LI	93	IPWA	$\gamma N \to \pi N$
−0.075±0.020	BARBOUR	78	DPWA	$\gamma N \to \pi N$

Δ(1950) FOOTNOTES

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

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

[3] 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 is from the four best solutions. DEANS 75 disagrees with $\pi^+ p \rightarrow \Sigma^+ K^+$ 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 $120°$.

Δ(1950) REFERENCES

ARNDT	04	PR C69 035213	R.A. Arndt *et al.*	(GWU, TRIU)	
VRANA	00	PRPL 328 181	T.P. Vrana, S.A. Dytman,, T.-S.H. Lee	(PITT+)	
ARNDT	96	PR C53 430	R.A. Arndt, I.I. Strakovsky, R.L. Workman	(VPI)	
ARNDT	95	PR C52 2120	R.A. Arndt *et al.*	(VPI, BRCO)	
HOEHLER	93	πN Newsletter 9 1	G. Hohler	(KARL)	
LI	93	PR C47 2759	Z.J. Li *et al.*	(VPI)	
MANLEY	92	PR D45 4002	D.M. Manley, E.M. Saleski	(KENT)	IJP
Also	84	PR D30 904	D.M. Manley *et al.*	(VPI)	
ARNDT	91	PR D43 2131	R.A. Arndt *et al.*	(VPI, TELE)	IJP
CANDLIN	84	NP B238 477	D.J. Candlin *et al.*	(EDIN, RAL, LOWC)	
PDG	82	PL 111B	M. Roos *et al.*	(HELS, CIT, CERN)	
AWAJI	81	Bonn Conf. 352	N. Awaji, R. Kajikawa	(NAGO)	
Also	82	NP B197 365	K. Fujii *et al.*	(NAGO)	
ARAI	80	Toronto Conf. 93	I. Arai	(INUS)	
Also	82	NP B194 251	I. Arai, H. Fujii	(INUS)	
CHEW	80	Toronto Conf. 123	D.M. Chew	(LBL)	IJP
CRAWFORD	80	Toronto Conf. 107	R.L. Crawford	(GLAS)	
CUTKOSKY	80	Toronto Conf. 19	R.E. Cutkosky *et al.*	(CMU, LBL)	IJP
Also	79	PR D20 2839	R.E. Cutkosky *et al.*	(CMU, LBL)	IJP
HOEHLER	79	PDAT 12-1	G. Hohler *et al.*	(KARLT)	IJP
Also	80	Toronto Conf. 3	R. Koch	(KARLT)	IJP
BARBOUR	78	NP B141 253	I.M. Barbour, R.L. Crawford, N.H. Parsons	(GLAS)	
LONGACRE	78	PR D17 1795	R.S. Longacre *et al.*	(LBL, SLAC)	
NOVOSELLER	78	NP B137 509	D.E. Novoseller	(CIT)	IJP
NOVOSELLER	78B	NP B137 445	D.E. Novoseller	(CIT)	IJP
WINNIK	77	NP B128 66	M. Winnik *et al.*	(HAIF)	I
DEANS	75	NP B96 90	S.R. Deans *et al.*	(SFLA, ALAH)	IJP
HERNDON	75	PR D11 3183	D. Herndon *et al.*	(LBL, SLAC)	
LONGACRE	75	PL 55B 415	R.S. Longacre *et al.*	(LBL, SLAC)	IJP