$\Delta(1950)$ 7/2$^+$

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

Most of the results published before 1975 were last included in our 1982 edition, Physics Letters **111B** 1 (1982). Some further obsolete results published before 1984 were last included in our 2006 edition, Journal of Physics, G **33** 1 (2006).

$\Delta(1950)$ BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1915 to 1950 (≈ 1930) OUR ESTIMATE				
1915 ± 6	ANISOVICH	12A	DPWA	Multichannel
1921.3 ± 0.2	ARNDT	06	DPWA	$\pi N \rightarrow \pi N$, ηN
1945 ± 2	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N \pi\pi$
1950 ± 15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1913 ± 8	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1928 ± 8	ANISOVICH	10	DPWA	Multichannel
1923.3 ± 0.5	ARNDT	04	DPWA	$\pi N \rightarrow \pi N$, ηN
1936 ± 5	VRANA	00	DPWA	Multichannel
1947 ± 9	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1921	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1940	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1925 ± 20	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
$1855.0^{+11.0}_{-10.0}$	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1925	[1] LONGACRE	75	IPWA	$\pi N \rightarrow N \pi\pi$

$\Delta(1950)$ BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
235 to 335 (≈ 285) OUR ESTIMATE				
246 ± 10	ANISOVICH	12A	DPWA	Multichannel
271.1 ± 1.1	ARNDT	06	DPWA	$\pi N \rightarrow \pi N$, ηN
300 ± 7	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N \pi\pi$
340 ± 50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
224 ± 10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
290 ± 14	ANISOVICH	10	DPWA	Multichannel
278.2 ± 3.0	ARNDT	04	DPWA	$\pi N \rightarrow \pi N$, ηN
245 ± 12	VRANA	00	DPWA	Multichannel
302 ± 9	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
232	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
306	LI	93	IPWA	$\gamma N \rightarrow \pi N$
330 ± 40	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
$157.2^{+22.0}_{-19.0}$	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
240	[1] LONGACRE	75	IPWA	$\pi N \rightarrow N \pi\pi$

Δ(1950) POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1870 to 1890 (≈ 1880) OUR ESTIMATE				
1890± 4	ANISOVICH	12A	DPWA	Multichannel
1876	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
1878	[2] HOEHLER	93	ARGD	$\pi N \to \pi N$
1890±15	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1882± 8	ANISOVICH	10	DPWA	Multichannel
1874	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
1910	VRANA	00	DPWA	Multichannel
1880	ARNDT	95	DPWA	$\pi N \to N\pi$
1884	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
1924 or 1924	[3] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
220 to 260 (≈ 240) OUR ESTIMATE				
243± 8	ANISOVICH	12A	DPWA	Multichannel
227	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
230	[2] HOEHLER	93	ARGD	$\pi N \to \pi N$
260±40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
262±12	ANISOVICH	10	DPWA	Multichannel
236	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
230	VRANA	00	DPWA	Multichannel
236	ARNDT	95	DPWA	$\pi N \to N\pi$
238	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
258 or 258	[3] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$

Δ(1950) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
58±2	ANISOVICH	12A	DPWA	Multichannel
53	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
47	HOEHLER	93	ARGD	$\pi N \to \pi N$
50±7	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
57	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
54	ARNDT	95	DPWA	$\pi N \to N\pi$
61	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
-24 ± 3	ANISOVICH	12A	DPWA	Multichannel
-31	ARNDT	06	DPWA	$\pi N \rightarrow \pi N$, ηN
-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. • • •				
-34	ARNDT	04	DPWA	$\pi N \rightarrow \pi N$, ηN
-17	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
-23	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

$\Delta(1950)$ INELASTIC POLE RESIDUE

The "normalized residue" is the residue divided by Γ_{pole}.

Normalized residue in $N\pi \rightarrow \Delta(1950) \rightarrow \Sigma K$

MODULUS (%)	PHASE (°)	DOCUMENT ID		TECN	COMMENT
5±1	**−65 ± 25**	ANISOVICH	12A	DPWA	Multichannel

Normalized residue in $N\pi \rightarrow \Delta(1950) \rightarrow \Delta\pi$, F-wave

MODULUS (%)	PHASE (°)	DOCUMENT ID		TECN	COMMENT
12±4	**12 ± 10**	ANISOVICH	12A	DPWA	Multichannel

$\Delta(1950)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	35–45 %
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 %

Δ(1950) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
35 to 45 OUR ESTIMATE				
45 ±2	ANISOVICH	12A	DPWA	Multichannel
47.1±0.1	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
38 ±1	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
39 ±4	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
38 ±2	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
44 ±8	ANISOVICH	10	DPWA	Multichannel
48.0±0.2	ARNDT	04	DPWA	$\pi N \to \pi N$, ηN
44 ±1	VRANA	00	DPWA	Multichannel
49	ARNDT	95	DPWA	$\pi N \to N\pi$
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	$\pi^+ p \to \Sigma^+ K^+$

$\Gamma(\Sigma K)/\Gamma_{total}$ — Γ_2/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
0.4±0.1	ANISOVICH	12A	DPWA	Multichannel

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	$\pi N \to N\pi\pi$

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

VALUE (%)	DOCUMENT ID		TECN	COMMENT
2.8±1.4	ANISOVICH	12A	DPWA	Multichannel
36 ±1	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	$\pi N \to N\pi\pi$

Δ(1950) PHOTON DECAY AMPLITUDES

Papers on γN amplitudes predating 1981 may be found in our 2006 edition, Journal of Physics, G **33** 1 (2006).

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

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.076±0.012 OUR ESTIMATE				
0.071±0.004	ANISOVICH	12A	DPWA	Multichannel
−0.079±0.006	ARNDT	96	IPWA	$\gamma N \to \pi N$
−0.068±0.007	AWAJI	81	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.083±0.008	ANISOVICH	10	DPWA	Multichannel
−0.094	DRECHSEL	07	DPWA	$\gamma N \to \pi N$
−0.102±0.003	LI	93	IPWA	$\gamma N \to \pi N$

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

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.097±0.010 OUR ESTIMATE				
−0.094±0.005	ANISOVICH	12A	DPWA	Multichannel
−0.103±0.006	ARNDT	96	IPWA	$\gamma N \to \pi N$
−0.094±0.016	AWAJI	81	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.092±0.008	ANISOVICH	10	DPWA	Multichannel
−0.121	DRECHSEL	07	DPWA	$\gamma N \to \pi N$
−0.115±0.003	LI	93	IPWA	$\gamma N \to \pi N$

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 $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

Δ(1950) REFERENCES

ANISOVICH	12A	EPJ A48 15	A.V. Anisovich *et al.*	(BONN, PNPI)
ANISOVICH	10	EPJ A44 203	A.V. Anisovich *et al.*	(BONN, PNPI)
DRECHSEL	07	EPJ A34 69	D. Drechsel, S.S. Kamalov, L. Tiator	(MAINZ, JINR)
ARNDT	06	PR C74 045205	R.A. Arndt *et al.*	(GWU)
PDG	06	JPG 33 1	W.-M. Yao *et al.*	(PDG Collab.)
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		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 1	M. Roos *et al.*	(HELS, CIT, CERN)
AWAJI	81	Bonn Conf. 352	N. Awaji, R. Kajikawa	(NAGO)
Also		NP B197 365	K. Fujii *et al.*	(NAGO)
CHEW	80	Toronto Conf. 123	D.M. Chew	(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	R.E. Cutkosky *et al.*	(CMU, LBL) IJP
Also		PR D20 2839	R.E. Cutkosky *et al.*	(CMU, LBL) IJP
HOEHLER	79	PDAT 12-1	G. Hohler *et al.*	(KARLT) IJP
Also		Toronto Conf. 3	R. Koch	(KARLT) IJP
LONGACRE	78	PR D17 1795	R.S. Longacre *et al.*	(LBL, SLAC)
LONGACRE	75	PL 55B 415	R.S. Longacre *et al.*	(LBL, SLAC) IJP