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

$I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$ 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 **G33** 1 (2006).

$\Delta(1950)$ BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1915 to 1950 (≈ 1930) OUR ESTIMATE				
1917 ± 4	GUTZ	14	DPWA	Multichannel
1915 ± 6	ANISOVICH	12A	DPWA	Multichannel
1921.3 ± 0.2	ARNDT	06	DPWA	$\pi N \rightarrow \pi N, \eta N$
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. • • •				
1918 ± 1	SHRESTHA	12A	DPWA	Multichannel
1928 ± 8	ANISOVICH	10	DPWA	Multichannel
1923.3 ± 0.5	ARNDT	04	DPWA	$\pi N \rightarrow \pi N, \eta N$
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	$\gamma N \rightarrow \pi N$
1945 ± 2	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
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				
251 ± 8	GUTZ	14	DPWA	Multichannel
246 ± 10	ANISOVICH	12A	DPWA	Multichannel
271.1 ± 1.1	ARNDT	06	DPWA	$\pi N \rightarrow \pi N, \eta N$
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. • • •				
259 ± 4	SHRESTHA	12A	DPWA	Multichannel
290 ± 14	ANISOVICH	10	DPWA	Multichannel
278.2 ± 3.0	ARNDT	04	DPWA	$\pi N \rightarrow \pi N, \eta N$
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 $\gamma N \rightarrow \pi N$
300 ± 7		MANLEY	92	IPWA $\pi N \rightarrow \pi N$ & $N \pi \pi$
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					
1888± 4		GUTZ	14	DPWA	Multichannel
1877± 2±1	[2]	SVARC	14	MLS	$\pi N \rightarrow \pi N$
1890± 4		ANISOVICH	12A	DPWA	Multichannel
1876		ARNDT	06	DPWA	$\pi N \rightarrow \pi N$, ηN
1878	[3]	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. • • •					
1871		SHRESTHA	12A	DPWA	Multichannel
1882± 8		ANISOVICH	10	DPWA	Multichannel
1874		ARNDT	04	DPWA	$\pi N \rightarrow \pi N$, ηN
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	[4]	LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$

−2×IMAGINARY PART

VALUE (MeV)		*DOCUMENT ID*		*TECN*	*COMMENT*
220 to 260 (≈ 240) OUR ESTIMATE					
245± 8		GUTZ	14	DPWA	Multichannel
223± 4±1	[2]	SVARC	14	MLS	$\pi N \rightarrow \pi N$
243± 8		ANISOVICH	12A	DPWA	Multichannel
227		ARNDT	06	DPWA	$\pi N \rightarrow \pi N$, ηN
230	[3]	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. • • •					
220		SHRESTHA	12A	DPWA	Multichannel
262±12		ANISOVICH	10	DPWA	Multichannel
236		ARNDT	04	DPWA	$\pi N \rightarrow \pi N$, ηN
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	[4]	LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$

Δ(1950) ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
58±2	GUTZ	14	DPWA	Multichannel
44±1	[2] SVARC	14	MLS	$\pi N \to \pi N$
58±2	ANISOVICH	12A	DPWA	Multichannel
53	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
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	$\pi N \to \pi N$, ηN
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	GUTZ	14	DPWA	Multichannel
−39±1±1	[2] SVARC	14	MLS	$\pi N \to \pi N$
−24±3	ANISOVICH	12A	DPWA	Multichannel
−31	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
−32	HOEHLER	93	ARGD	$\pi N \to \pi N$
−33±8	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−34	ARNDT	04	DPWA	$\pi N \to \pi N$, ηN
−17	ARNDT	95	DPWA	$\pi N \to N \pi$
−23	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

Δ(1950) INELASTIC POLE RESIDUE

The "normalized residue" is the residue divided by $\Gamma_{pole}/2$.

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

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

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

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

Normalized residue in $N\pi \to \Delta(1950) \to \Delta(1232)\eta$

MODULUS (%)	PHASE (°)	DOCUMENT ID		TECN	COMMENT
3.5±0.5	**90 ± 25**	GUTZ	14	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	$\Delta(1232)\eta$	
Γ_8	$N\rho$	<10 %
Γ_9	$N\rho$, S=1/2, F-wave	
Γ_{10}	$N\rho$, S=3/2, F-wave	
Γ_{11}	$N\gamma$	0.08–0.13 %
Γ_{12}	$N\gamma$, helicity=1/2	0.03–0.055 %
Γ_{13}	$N\gamma$, helicity=3/2	0.05–0.075 %

$\Delta(1950)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ — Γ_1/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
35 to 45 OUR ESTIMATE				
46 ±2	GUTZ	14	DPWA	Multichannel
45 ±2	ANISOVICH	12A	DPWA	Multichannel
47.1±0.1	ARNDT	06	DPWA	$\pi N \rightarrow \pi N$, ηN
39 ±4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
38 ±2	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
45.6±0.4	SHRESTHA	12A	DPWA	Multichannel
44 ±8	ANISOVICH	10	DPWA	Multichannel
48.0±0.2	ARNDT	04	DPWA	$\pi N \rightarrow \pi N$, ηN
44 ±1	VRANA	00	DPWA	Multichannel
49	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
38 ±1	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
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	$\pi^+ p \rightarrow \Sigma^+ K^+$

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

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

Note: Signs of couplings from $\pi N \rightarrow N\pi\pi$ 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				
+0.32	[1] LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+0.27±0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$

$\Gamma(\Delta(1232)\pi$, 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
• • • We do not use the following data for averages, fits, limits, etc. • • •				
8 ±1	SHRESTHA	12A	DPWA	Multichannel

$\Gamma(\Delta(1232)\eta)/\Gamma_{total}$ — Γ_7/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
<1	GUTZ	14	DPWA	Multichannel

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1950) \rightarrow N\rho$, S=3/2, F-wave — $(\Gamma_1\Gamma_{10})^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.24	[1] LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$\Delta(1950)$ PHOTON DECAY AMPLITUDES

Papers on γN amplitudes predating 1981 may be found in our 2006 edition, Journal of Physics **G33** 1 (2006).

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

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.076±0.012 OUR ESTIMATE				
−0.067±0.005	GUTZ	14	DPWA	Multichannel
−0.071±0.004	ANISOVICH	12A	DPWA	Multichannel
−0.083±0.004	WORKMAN	12A	DPWA	$\gamma N \rightarrow N\pi$
−0.068±0.007	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.065±0.001	SHRESTHA	12A	DPWA	Multichannel
−0.083±0.008	ANISOVICH	10	DPWA	Multichannel
−0.094	DRECHSEL	07	DPWA	$\gamma N \rightarrow \pi N$
−0.079±0.006	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
−0.102±0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$

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±0.004	GUTZ	14	DPWA	Multichannel
−0.094±0.005	ANISOVICH	12A	DPWA	Multichannel
−0.096±0.004	WORKMAN	12A	DPWA	$\gamma N \rightarrow N\pi$
−0.094±0.016	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.083±0.001	SHRESTHA	12A	DPWA	Multichannel
−0.092±0.008	ANISOVICH	10	DPWA	Multichannel
−0.121	DRECHSEL	07	DPWA	$\gamma N \rightarrow \pi N$
−0.103±0.006	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
−0.115±0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$

Δ(1950) FOOTNOTES

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

[2] Fit to the amplitudes of HOEHLER 79.

[3] 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.

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

Δ(1950) REFERENCES

GUTZ	14	EPJ A50 74	E. Gutz et al.	(CBELSA/TAPS Collab.)	
SVARC	14	PR C89 045205	A. Svarc et al.		
ANISOVICH	12A	EPJ A48 15	A.V. Anisovich et al.	(BONN, PNPI)	
SHRESTHA	12A	PR C86 055203	M. Shrestha, D.M. Manley	(KSU)	
WORKMAN	12A	PR C86 015202	R. Workman et al.	(GWU)	
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	JP G33 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	(KSA)	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