

$\Delta(1950) 7/2^+$ $I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$ 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* (generic for all A,B,E,G) **G33** 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 $\pi N \rightarrow \pi N, \eta N$
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			
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 $\pi N \rightarrow N\pi\pi$

$\Delta(1950)$ POLE POSITION

REAL PART

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
1870 to 1890 (\approx 1880) OUR ESTIMATE			
1890 \pm 4	ANISOVICH	12A	DPWA Multichannel
1876	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
1878	² HOEHLER	93	ARGD $\pi N \rightarrow \pi N$
1890 \pm 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 \pm 8	ANISOVICH	10	DPWA Multichannel
1874	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
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

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
220 to 260 (\approx 240) OUR ESTIMATE			
243 \pm 8	ANISOVICH	12A	DPWA Multichannel
227	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
230	² HOEHLER	93	ARGD $\pi N \rightarrow \pi N$
260 \pm 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 \pm 12	ANISOVICH	10	DPWA Multichannel
236	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
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 $|r|$

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

PHASE θ

<u>VALUE ($^{\circ}$)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
-24 ± 3	ANISOVICH	12A	DPWA Multichannel
-31	ARNDT	06	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. ● ● ●			
-34	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
-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 $\Gamma_{pole}/2$.

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

<u>MODULUS (%)</u>	<u>PHASE ($^{\circ}$)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
5 ± 1	-65 ± 25	ANISOVICH	12A	DPWA Multichannel

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

<u>MODULUS (%)</u>	<u>PHASE ($^{\circ}$)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
12 ± 4	12 ± 10	ANISOVICH	12A	DPWA Multichannel

$\Delta(1950)$ DECAY MODES

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

<u>Mode</u>	<u>Fraction (Γ_j/Γ)</u>
Γ_1 $N\pi$	35–45 %
Γ_2 ΣK	
Γ_3 $N\pi\pi$	
Γ_4 $\Delta\pi$	20–30 %
Γ_5 $\Delta(1232)\pi, F\text{-wave}$	
Γ_6 $\Delta(1232)\pi, H\text{-wave}$	
Γ_7 $N\rho$	<10 %
Γ_8 $N\rho, S=1/2, F\text{-wave}$	
Γ_9 $N\rho, S=3/2, F\text{-wave}$	
Γ_{10} $N\gamma$	0.08–0.13 %
Γ_{11} $N\gamma, \text{helicity}=1/2$	0.03–0.055 %
Γ_{12} $N\gamma, \text{helicity}=3/2$	0.05–0.075 %

$\Delta(1950)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$ 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	$\pi N \rightarrow \pi N, \eta N$
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	$\pi N \rightarrow \pi N, \eta N$
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	$\pi^+ p \rightarrow \pi^+ p$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ 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	$\pi^+ p \rightarrow \Sigma^+ K^+$
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$\Gamma(\Sigma K)/\Gamma_{\text{total}}$ Γ_2/Γ
VALUE (%) DOCUMENT ID TECN COMMENT

0.4 ± 0.1	ANISOVICH	12A	DPWA	Multichannel
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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 $\Delta(1232)\pi$.

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

+0.28 to +0.32 OUR ESTIMATE

+0.32	¹ LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$
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• • • We do not use the following data for averages, fits, limits, etc. • • •

+0.27 ± 0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \ \& \ N\pi\pi$
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$\Gamma(\Delta(1232)\pi, F\text{-wave})/\Gamma_{\text{total}}$ 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
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$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \Delta(1950) \rightarrow N\rho, S=3/2, F\text{-wave}$ $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$
VALUE DOCUMENT ID TECN COMMENT

+0.24	¹ LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$
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$\Delta(1950)$ PHOTON DECAY AMPLITUDES

Papers on γN amplitudes predating 1981 may be found in our 2006 edition, *Journal of Physics* (generic for all A,B,E,G) **G33** 1 (2006).

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

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID	TECN	COMMENT
-0.076±0.012 OUR ESTIMATE			
-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 $\gamma N \rightarrow \pi N$

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

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID	TECN	COMMENT
-0.097±0.010 OUR ESTIMATE			
-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 $\gamma N \rightarrow \pi N$

$\Delta(1950)$ FOOTNOTES

- ¹ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ² See HOEHLER 93 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.

$\Delta(1950)$ REFERENCES

ANISOVICH	12A	EPJ A48 15	A.V. Anisovich <i>et al.</i>	(BONN, PNPI)
SHRESTHA	12A	PR C86 055203	M. Shrestha, D.M. Manley	(KSU)
WORKMAN	12A	PR C86 015202	R. Workman <i>et al.</i>	(GWU)
ANISOVICH	10	EPJ A44 203	A.V. Anisovich <i>et al.</i>	(BONN, PNPI)
DRECHSEL	07	EPJ A34 69	D. Drechsel, S.S. Kamalov, L. Tiator	(MAINZ, JINR)
ARNDT	06	PR C74 045205	R.A. Arndt <i>et al.</i>	(GWU)
PDG	06	JP G33 1	W.-M. Yao <i>et al.</i>	(PDG Collab.)
ARNDT	04	PR C69 035213	R.A. Arndt <i>et al.</i>	(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 <i>et al.</i>	(VPI, BRCC)

HOEHLER	93	πN Newsletter 9 1	G. Hohler	(KARL)
LI	93	PR C47 2759	Z.J. Li <i>et al.</i>	(VPI)
MANLEY	92	PR D45 4002	D.M. Manley, E.M. Saleski	(KSA) IJP
Also		PR D30 904	D.M. Manley <i>et al.</i>	(VPI)
ARNDT	91	PR D43 2131	R.A. Arndt <i>et al.</i>	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	D.J. Candlin <i>et al.</i>	(EDIN, RAL, LOWC)
PDG	82	PL 111B 1	M. Roos <i>et al.</i>	(HELS, CIT, CERN)
AWAJI	81	Bonn Conf. 352	N. Awaji, R. Kajikawa	(NAGO)
Also		NP B197 365	K. Fujii <i>et al.</i>	(NAGO)
CHEW	80	Toronto Conf. 123	D.M. Chew	(LBL) IJP
CUTKOSKY	80	Toronto Conf. 19	R.E. Cutkosky <i>et al.</i>	(CMU, LBL) IJP
Also		PR D20 2839	R.E. Cutkosky <i>et al.</i>	(CMU, LBL) IJP
HOEHLER	79	PDAT 12-1	G. Hohler <i>et al.</i>	(KARLT) IJP
Also		Toronto Conf. 3	R. Koch	(KARLT) IJP
LONGACRE	78	PR D17 1795	R.S. Longacre <i>et al.</i>	(LBL, SLAC)
LONGACRE	75	PL 55B 415	R.S. Longacre <i>et al.</i>	(LBL, SLAC) IJP
