

$\Delta(1950) F_{37}$

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

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 (\approx 1930) OUR ESTIMATE			
1928 \pm 8	ANISOVICH	10	DPWA Multichannel
1921.3 \pm 0.2	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
1945 \pm 2	MANLEY	92	IPWA $\pi N \rightarrow \pi N$ & $N\pi\pi$
1950 \pm 15	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
1913 \pm 8	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
1923.3 \pm 0.5	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
1936 \pm 5	VRANA	00	DPWA Multichannel
1947 \pm 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 \pm 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 (\approx 285) OUR ESTIMATE			
290 \pm 14	ANISOVICH	10	DPWA Multichannel
271.1 \pm 1.1	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
300 \pm 7	MANLEY	92	IPWA $\pi N \rightarrow \pi N$ & $N\pi\pi$
340 \pm 50	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
224 \pm 10	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
278.2 \pm 3.0	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
245 \pm 12	VRANA	00	DPWA Multichannel
302 \pm 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 \pm 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 (≈ 1880) OUR ESTIMATE			
1882 \pm 8	ANISOVICH	10	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. ● ● ●			
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 (≈ 240) OUR ESTIMATE			
262 \pm 12	ANISOVICH	10	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. ● ● ●			
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>
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>
–31	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
–32	HOEHLER	93	ARGD $\pi N \rightarrow \pi N$
–33 \pm 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

$\Delta(1950)$ 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 $\Delta(1232)\pi$, <i>F</i> -wave	
Γ_6 $\Delta(1232)\pi$, <i>H</i> -wave	
Γ_7 $N\rho$	<10 %
Γ_8 $N\rho$, $S=1/2$, <i>F</i> -wave	
Γ_9 $N\rho$, $S=3/2$, <i>F</i> -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

$\Gamma(N\pi)/\Gamma_{\text{total}}$	Γ_1/Γ
<u>VALUE</u>	<u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
0.35 to 0.45 OUR ESTIMATE	
0.44 ± 0.08	ANISOVICH 10 DPWA Multichannel
0.471 ± 0.001	ARNDT 06 DPWA $\pi N \rightarrow \pi N, \eta N$
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. ● ● ●	
0.480 ± 0.002	ARNDT 04 DPWA $\pi N \rightarrow \pi N, \eta N$
0.44 ± 0.01	VRANA 00 DPWA Multichannel
0.49	ARNDT 95 DPWA $\pi N \rightarrow N\pi$
0.44	CHEW 80 BPWA $\pi^+ \rho \rightarrow \pi^+ \rho$

$(\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \Delta(1950) \rightarrow \Sigma K$	$(\Gamma_1 \Gamma_2)^{1/2}/\Gamma$
<u>VALUE</u>	<u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
−0.053 ± 0.005	CANDLIN 84 DPWA $\pi^+ \rho \rightarrow \Sigma^+ K^+$

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 $\Delta(1232)\pi$.

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

$\Gamma(\Delta(1232)\pi, F\text{-wave})/\Gamma_{\text{total}}$				Γ_5/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
0.36 ± 0.01	VRANA	00	DPWA	Multichannel

$(\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}}$ 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	$\pi N \rightarrow N\pi\pi$

$\Delta(1950)$ PHOTON DECAY AMPLITUDES

Papers on γN amplitudes predating 1981 may be found in our 2006 edition, Journal of Physics, G **33** 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				
-0.083 ± 0.008	ANISOVICH	10	DPWA	Multichannel
-0.079 ± 0.006	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.068 ± 0.007	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
-0.094	DRECHSEL	07	DPWA	$\gamma N \rightarrow \pi N$
-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				
-0.092 ± 0.008	ANISOVICH	10	DPWA	Multichannel
-0.103 ± 0.006	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.094 ± 0.016	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
-0.121	DRECHSEL	07	DPWA	$\gamma N \rightarrow \pi N$
-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.

Δ(1950) REFERENCES

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	JPG 33 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, BRCO)
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	(KENT) 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