

$\Delta(1950) F_{37}$ 

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

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**

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>1915 to 1950 (<math>\approx</math> 1930) OUR ESTIMATE</b>			
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	<sup>1</sup> LONGACRE	75	IPWA $\pi N \rightarrow N\pi\pi$

 **$\Delta(1950)$  BREIT-WIGNER WIDTH**

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>235 to 335 (<math>\approx</math> 285) OUR ESTIMATE</b>			
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	<sup>1</sup> 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>
<b>1870 to 1890 (<math>\approx</math> 1880) OUR ESTIMATE</b>			
1876	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
1878	<sup>2</sup> 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	<sup>3</sup> 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>
<b>220 to 260 (<math>\approx</math> 240) OUR ESTIMATE</b>			
227	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
230	<sup>2</sup> 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	<sup>3</sup> 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 $\theta$

<u>VALUE (<math>^\circ</math>)</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 ( $\Gamma_i/\Gamma$ )
$\Gamma_1$ $N\pi$	0.35 to 0.45
$\Gamma_2$ $\Sigma K$	
$\Gamma_3$ $N\pi\pi$	
$\Gamma_4$ $\Delta\pi$	20–30 %
$\Gamma_5$ $\Delta(1232)\pi$ , <i>F</i> -wave	
$\Gamma_6$ $\Delta(1232)\pi$ , <i>H</i> -wave	
$\Gamma_7$ $N\rho$	<10 %
$\Gamma_8$ $N\rho$ , $S=1/2$ , <i>F</i> -wave	
$\Gamma_9$ $N\rho$ , $S=3/2$ , <i>F</i> -wave	
$\Gamma_{10}$ $N\gamma$	0.08–0.13 %
$\Gamma_{11}$ $N\gamma$ , helicity=1/2	0.03–0.055 %
$\Gamma_{12}$ $N\gamma$ , helicity=3/2	0.05–0.075 %

## $\Delta(1950)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					$\Gamma_1/\Gamma$
<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>		
<b>0.35 to 0.45 OUR ESTIMATE</b>					
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	$\pi^+ p \rightarrow \pi^+ p$	

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

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>		
<b>+0.28 to +0.32 OUR ESTIMATE</b>					
+0.27 ± 0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N\pi\pi$	
+0.32	<sup>1</sup> LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$	

$\Gamma(\Delta(1232)\pi, F\text{-wave})/\Gamma_{\text{total}}$				$\Gamma_5/\Gamma$
VALUE	DOCUMENT ID	TECN	COMMENT	
$0.36 \pm 0.01$	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	<sup>1</sup> LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

## $\Delta(1950)$ PHOTON DECAY AMPLITUDES

Papers on  $\gamma N$  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	
<b><math>-0.076 \pm 0.012</math> OUR ESTIMATE</b>				
$-0.079 \pm 0.006$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.068 \pm 0.007$	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	$\gamma N \rightarrow \pi N$
$-0.102 \pm 0.003$	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	
<b><math>-0.097 \pm 0.010</math> OUR ESTIMATE</b>				
$-0.103 \pm 0.006$	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
$-0.094 \pm 0.016$	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	$\gamma N \rightarrow \pi N$
$-0.115 \pm 0.003$	LI	93	IPWA	$\gamma N \rightarrow \pi N$

## $\Delta(1950)$ FOOTNOTES

- <sup>1</sup> From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- <sup>2</sup> See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of  $N$  and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- <sup>3</sup> 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

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	$\pi N$ 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

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