# $\Delta(1950)\ F_{37}$

$I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$ 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 1980 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** | | | | |
| 1921.3 ± 0.2 | ARNDT | 06 | DPWA | $\pi N \to \pi N, \eta N$ |
| 1945 ± 2 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 1950 ± 15 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 1913 ± 8 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1923.3 ± 0.5 | ARNDT | 04 | DPWA | $\pi N \to \pi N, \eta N$ |
| 1936 ± 5 | VRANA | 00 | DPWA | Multichannel |
| 1947 ± 9 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| 1921 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 1940 | LI | 93 | IPWA | $\gamma N \to \pi N$ |
| 1925 ± 20 | CANDLIN | 84 | DPWA | $\pi^+ p \to \Sigma^+ K^+$ |
| $1855.0^{+11.0}_{-10.0}$ | CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |
| 1902 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| 1925 | [1] LONGACRE | 75 | IPWA | $\pi N \to N\pi\pi$ |

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

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **235 to 335 (≈ 285) OUR ESTIMATE** | | | | |
| 271.1 ± 1.1 | ARNDT | 06 | DPWA | $\pi N \to \pi N, \eta N$ |
| 300 ± 7 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 340 ± 50 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 224 ± 10 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 278.2 ± 3.0 | ARNDT | 04 | DPWA | $\pi N \to \pi N, \eta N$ |
| 245 ± 12 | VRANA | 00 | DPWA | Multichannel |
| 302 ± 9 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| 232 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 306 | LI | 93 | IPWA | $\gamma N \to \pi N$ |
| 330 ± 40 | CANDLIN | 84 | DPWA | $\pi^+ p \to \Sigma^+ K^+$ |
| $157.2^{+22.0}_{-19.0}$ | CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |
| 225 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| 240 | [1] LONGACRE | 75 | IPWA | $\pi N \to N\pi\pi$ |

# $\Delta$(1950) POLE POSITION

## REAL PART

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1870 to 1890 (≈ 1880) OUR ESTIMATE** | | | | |
| 1876 | ARNDT | 06 | DPWA | $\pi N \rightarrow \pi N, \eta N$ |
| 1878 | [2] 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. • • • | | | | |
| 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

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **220 to 260 (≈ 240) OUR ESTIMATE** | | | | |
| 227 | ARNDT | 06 | DPWA | $\pi N \rightarrow \pi N, \eta N$ |
| 230 | [2] 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. • • • | | | | |
| 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 $|r|$

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 53 | ARNDT | 06 | DPWA | $\pi N \rightarrow \pi N, \eta N$ |
| 47 | HOEHLER | 93 | ARGD | $\pi N \rightarrow \pi N$ |
| 50±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 $\theta$

| VALUE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| −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 |

## $\Delta(1950)$ 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 % |
| $\Gamma_5$ | $\Delta(1232)\pi$, $F$-wave | |
| $\Gamma_6$ | $\Delta(1232)\pi$, $H$-wave | |
| $\Gamma_7$ | $N\rho$ | <10 % |
| $\Gamma_8$ | $N\rho$, $S$=1/2, $F$-wave | |
| $\Gamma_9$ | $N\rho$, $S$=3/2, $F$-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

### $\Gamma(N\pi)/\Gamma_{total}$ — $\Gamma_1/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.35 to 0.45 OUR ESTIMATE** | | | | |
| 0.471±0.001 | ARNDT | 06 | DPWA | $\pi N \to \pi N$, $\eta N$ |
| 0.38 ±0.01 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 0.39 ±0.04 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 0.38 ±0.02 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.480±0.002 | ARNDT | 04 | DPWA | $\pi N \to \pi N$, $\eta N$ |
| 0.44 ±0.01 | VRANA | 00 | DPWA | Multichannel |
| 0.49 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 0.44 | 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 | $\pi^+ p \to \Sigma^+ K^+$ |

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

### $\Gamma(\Delta(1232)\pi, F\text{-wave})/\Gamma_{total}$ — $\Gamma_5/\Gamma$

| *VALUE* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| 0.36±0.01 | 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 | $\pi N \to N\pi\pi$ |

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

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

| *VALUE* ($GeV^{-1/2}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **−0.076±0.012 OUR ESTIMATE** | | | | |
| −0.079±0.006 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| −0.068±0.007 | AWAJI | 81 | DPWA | $\gamma N \to \pi N$ |
| −0.091±0.005 | ARAI | 80 | DPWA | $\gamma N \to \pi N$ (fit 1) |
| −0.083±0.005 | ARAI | 80 | DPWA | $\gamma N \to \pi N$ (fit 2) |
| −0.067±0.014 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.102±0.003 | LI | 93 | IPWA | $\gamma N \to \pi N$ |

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

| *VALUE* ($GeV^{-1/2}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **−0.097±0.010 OUR ESTIMATE** | | | | |
| −0.103±0.006 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| −0.094±0.016 | AWAJI | 81 | DPWA | $\gamma N \to \pi N$ |
| −0.101±0.005 | ARAI | 80 | DPWA | $\gamma N \to \pi N$ (fit 1) |
| −0.100±0.005 | ARAI | 80 | DPWA | $\gamma N \to \pi N$ (fit 2) |
| −0.082±0.017 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.115±0.003 | LI | 93 | IPWA | $\gamma N \to \pi N$ |

## $\Delta(1950)$ 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 $\Delta$ 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.

[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


| | | | | |
|---|---|---|---|---|
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| 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 | $\pi N$ 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 |
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| 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) |
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