# $\Delta(1905)\ F_{35}$

$I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$ Status: ∗∗∗∗

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters **111B** (1982).

## $\Delta$(1905) BREIT-WIGNER MASS

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1870 to 1920 (≈ 1905) OUR ESTIMATE** | | | | |
| 1881 ±18 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 1910 ±30 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 1905 ±20 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1873 ±77 | VRANA | 00 | | Multichannel |
| 1895 ± 8 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| 1850 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 1960 ±40 | CANDLIN | 84 | DPWA | $\pi^+ p \to \Sigma^+ K^+$ |
| $1787.0^{+6.0}_{-5.7}$ | CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |
| 1880 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| 1892 | BARBOUR | 78 | DPWA | $\gamma N \to \pi N$ |
| 1830 | [1] LONGACRE | 75 | IPWA | $\pi N \to N\pi\pi$ |

## $\Delta$(1905) BREIT-WIGNER WIDTH

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **280 to 440 (≈ 350) OUR ESTIMATE** | | | | |
| 327 ± 51 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 400 ±100 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 260 ± 20 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 461 ±111 | VRANA | 00 | | Multichannel |
| 354 ± 10 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| 294 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 270 ± 40 | CANDLIN | 84 | DPWA | $\pi^+ p \to \Sigma^+ K^+$ |
| $66.0^{+24.0}_{-16.0}$ | CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |
| 193 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| 159 | BARBOUR | 78 | DPWA | $\gamma N \to \pi N$ |
| 220 | [1] LONGACRE | 75 | IPWA | $\pi N \to N\pi\pi$ |

## $\Delta$(1905) POLE POSITION

### REAL PART

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1800 to 1860 (≈ 1830) OUR ESTIMATE** | | | | |
| 1832 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 1829 | [2] HOEHLER | 93 | SPED | $\pi N \to \pi N$ |
| 1830±40 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |

• • • We do not use the following data for averages, fits, limits, etc. • • •

| | | | | |
|---|---|---|---|---|
| 1793 | VRANA | 00 | | Multichannel |
| 1794 | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |
| 1813 or 1808 | [3] LONGACRE | 78 | IPWA | $\pi N \to N\pi\pi$ |

## −2×IMAGINARY PART

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **230 to 330 (≈ 280) OUR ESTIMATE** | | | | |
| 254 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 303 | [2] HOEHLER | 93 | SPED | $\pi N \to \pi N$ |
| 280±60 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 302 | VRANA | 00 | | Multichannel |
| 230 | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |
| 193 or 187 | [3] LONGACRE | 78 | IPWA | $\pi N \to N\pi\pi$ |

# Δ(1905) ELASTIC POLE RESIDUE

## MODULUS |r|

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 12 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 25 | HOEHLER | 93 | SPED | $\pi N \to \pi N$ |
| 25±8 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 14 | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |

## PHASE θ

| VALUE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| − 4 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| −50±20 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −40 | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |

# Δ(1905) DECAY MODES

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

| | Mode | Fraction ($\Gamma_i/\Gamma$) |
|---|---|---|
| $\Gamma_1$ | $N\pi$ | 5–15 % |
| $\Gamma_2$ | $\Sigma K$ | |
| $\Gamma_3$ | $N\pi\pi$ | 85–95 % |
| $\Gamma_4$ | $\Delta\pi$ | <25 % |
| $\Gamma_5$ | $\Delta(1232)\pi$, $P$-wave | |
| $\Gamma_6$ | $\Delta(1232)\pi$, $F$-wave | |

| | | |
|---|---|---|
| $\Gamma_7$ | $N\rho$ | >60 % |
| $\Gamma_8$ | $N\rho$, $S$=3/2, $P$-wave | |
| $\Gamma_9$ | $N\rho$, $S$=3/2, $F$-wave | |
| $\Gamma_{10}$ | $N\rho$, $S$=1/2, $F$-wave | |
| $\Gamma_{11}$ | $N\gamma$ | 0.01–0.03 % |
| $\Gamma_{12}$ | $N\gamma$, helicity=1/2 | 0.0–0.1 % |
| $\Gamma_{13}$ | $N\gamma$, helicity=3/2 | 0.004–0.03 % |

## $\Delta$(1905) BRANCHING RATIOS

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

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.05 to 0.15 OUR ESTIMATE** | | | | |
| 0.12±0.03 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 0.08±0.03 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 0.15±0.02 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.09±0.01 | VRANA | 00 | | Multichannel |
| 0.12 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 0.11 | CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1905) \to \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| −0.015±0.003 | CANDLIN | 84 | DPWA | $\pi^+ p \to \Sigma^+ K^+$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.013 | LIVANOS | 80 | DPWA | $\pi p \to \Sigma K$ |
| 0.021 to 0.054 | [4] DEANS | 75 | DPWA | $\pi N \to \Sigma K$ |

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 $N\pi \to \Delta(1905) \to \Delta(1232)\pi$, $P$-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| −0.04±0.05 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1905) \to \Delta(1232)\pi$, $F$-wave — $(\Gamma_1\Gamma_6)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| +0.02±0.03 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| +0.20 | [1] LONGACRE | 75 | IPWA | $\pi N \to N\pi\pi$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| +0.17 | [5] NOVOSELLER | 78 | IPWA | $\pi N \to N\pi\pi$ |
| +0.06 | [6] NOVOSELLER | 78 | IPWA | $\pi N \to N\pi\pi$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1905) \to N\rho$, $S$=3/2, $P$-wave $(\Gamma_1\Gamma_8)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **+0.030 to +0.36 OUR ESTIMATE** | | | | |
| +0.33 ±0.03 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| +0.33 | [1] LONGACRE | 75 | IPWA | $\pi N \to N\pi\pi$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| +0.26 | [5] NOVOSELLER | 78 | IPWA | $\pi N \to N\pi\pi$ |
| +0.11 to +0.33 | [7] NOVOSELLER | 78 | IPWA | $\pi N \to N\pi\pi$ |

## $\Delta(1905)$ PHOTON DECAY AMPLITUDES

### $\Delta(1905) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

| VALUE (GeV$^{-1/2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **+0.026±0.011 OUR ESTIMATE** | | | | |
| 0.022±0.005 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| 0.021±0.010 | CRAWFORD | 83 | IPWA | $\gamma N \to \pi N$ |
| 0.043±0.020 | AWAJI | 81 | DPWA | $\gamma N \to \pi N$ |
| 0.022±0.010 | ARAI | 80 | DPWA | $\gamma N \to \pi N$ (fit 1) |
| 0.031±0.009 | ARAI | 80 | DPWA | $\gamma N \to \pi N$ (fit 2) |
| 0.024±0.014 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.055±0.004 | LI | 93 | IPWA | $\gamma N \to \pi N$ |
| +0.033±0.018 | BARBOUR | 78 | DPWA | $\gamma N \to \pi N$ |

### $\Delta(1905) \to N\gamma$, helicity-3/2 amplitude $A_{3/2}$

| VALUE (GeV$^{-1/2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **−0.045±0.020 OUR ESTIMATE** | | | | |
| −0.045±0.005 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| −0.056±0.028 | CRAWFORD | 83 | IPWA | $\gamma N \to \pi N$ |
| −0.025±0.023 | AWAJI | 81 | DPWA | $\gamma N \to \pi N$ |
| −0.029±0.007 | ARAI | 80 | DPWA | $\gamma N \to \pi N$ (fit 1) |
| −0.045±0.006 | ARAI | 80 | DPWA | $\gamma N \to \pi N$ (fit 2) |
| −0.072±0.035 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.002±0.003 | LI | 93 | IPWA | $\gamma N \to \pi N$ |
| −0.055±0.019 | BARBOUR | 78 | DPWA | $\gamma N \to \pi N$ |

## $\Delta(1905)$ 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.

[4] The range given for DEANS 75 is from the four best solutions.

[5] A Breit-Wigner fit to the HERNDON 75 IPWA.

[6] A Breit-Wigner fit to the NOVOSELLER 78B IPWA.

[7] A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near 90°.

# Δ(1905) REFERENCES

For early references, see Physics Letters **111B** 70 (1982).


| | | | | |
|---|---|---|---|---|
| VRANA | 00 | PRPL 328 181 | T.P. Vrana, S.A. Dytman,, T.-S.H. Lee | |
| 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 |
| Also | 84 | 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) |
| CRAWFORD | 83 | NP B211 1 | R.L. Crawford, W.T. Morton | (GLAS) |
| PDG | 82 | PL 111B | M. Roos *et al.* | (HELS, CIT, CERN) |
| AWAJI | 81 | Bonn Conf. 352 | N. Awaji, R. Kajikawa | (NAGO) |
| Also | 82 | NP B197 365 | K. Fujii *et al.* | (NAGO) |
| ARAI | 80 | Toronto Conf. 93 | I. Arai | (INUS) |
| Also | 82 | NP B194 251 | I. Arai, H. Fujii | (INUS) |
| CHEW | 80 | Toronto Conf. 123 | D.M. Chew | (LBL) IJP |
| CRAWFORD | 80 | Toronto Conf. 107 | R.L. Crawford | (GLAS) |
| CUTKOSKY | 80 | Toronto Conf. 19 | R.E. Cutkosky *et al.* | (CMU, LBL) IJP |
| Also | 79 | PR D20 2839 | R.E. Cutkosky *et al.* | (CMU, LBL) IJP |
| LIVANOS | 80 | Toronto Conf. 35 | P. Livanos *et al.* | (SACL) IJP |
| HOEHLER | 79 | PDAT 12-1 | G. Hohler *et al.* | (KARLT) IJP |
| Also | 80 | Toronto Conf. 3 | R. Koch | (KARLT) IJP |
| BARBOUR | 78 | NP B141 253 | I.M. Barbour, R.L. Crawford, N.H. Parsons | (GLAS) |
| LONGACRE | 78 | PR D17 1795 | R.S. Longacre *et al.* | (LBL, SLAC) |
| NOVOSELLER | 78 | NP B137 509 | D.E. Novoseller | (CIT) IJP |
| NOVOSELLER | 78B | NP B137 445 | D.E. Novoseller | (CIT) IJP |
| DEANS | 75 | NP B96 90 | S.R. Deans *et al.* | (SFLA, ALAH) IJP |
| HERNDON | 75 | PR D11 3183 | D. Herndon *et al.* | (LBL, SLAC) |
| LONGACRE | 75 | PL 55B 415 | R.S. Longacre *et al.* | (LBL, SLAC) IJP |