# $\Delta(1910)\ 1/2^+$

$I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$ 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, G **33** 1 (2006).

## Δ(1910) BREIT-WIGNER MASS

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1860 to 1910 (≈ 1890) OUR ESTIMATE** | | | | |
| 1860 ±40 | ANISOVICH | 12A | DPWA | Multichannel |
| 2067.9± 1.7 | ARNDT | 06 | DPWA | $\pi N \to \pi N$, $\eta N$ |
| 1882 ±10 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 1910 ±40 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 1888 ±20 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1995 ±12 | VRANA | 00 | DPWA | Multichannel |
| 2152 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 1960.1±21.0 | [1] CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |
| $2121.4^{+13.0}_{-14.3}$ | [1] CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |
| 1790 | [2] LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |

## Δ(1910) BREIT-WIGNER WIDTH

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **220 to 340 (≈ 280) OUR ESTIMATE** | | | | |
| 350 ± 55 | ANISOVICH | 12A | DPWA | Multichannel |
| 543 ± 10 | ARNDT | 06 | DPWA | $\pi N \to \pi N$, $\eta N$ |
| 239 ± 25 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 225 ± 50 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 280 ± 50 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 713 ±465 | VRANA | 00 | DPWA | Multichannel |
| 760 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 152.9± 60.0 | [1] CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |
| 172.2± 37.0 | [1] CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |
| 170 | [2] LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |

## Δ(1910) POLE POSITION

### REAL PART

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1830 to 1880 (≈ 1855) OUR ESTIMATE** | | | | |
| 1850±40 | ANISOVICH | 12A | DPWA | Multichannel |
| 1771 | ARNDT | 06 | DPWA | $\pi N \to \pi N$, $\eta N$ |
| 1874 | [3] HOEHLER | 93 | SPED | $\pi N \to \pi N$ |
| 1880±30 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |

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

| | | | | |
|---|---|---|---|---|
| 1880 | VRANA | 00 | DPWA | Multichannel |
| 1810 | ARNDT | 95 | DPWA | $\pi N \rightarrow N\pi$ |
| 1950 | ARNDT | 91 | DPWA | $\pi N \rightarrow \pi N$ Soln SM90 |
| 1792 or 1801 | [2] LONGACRE | 77 | IPWA | $\pi N \rightarrow N\pi\pi$ |

## −2×IMAGINARY PART

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **200 to 500 (≈ 350) OUR ESTIMATE** | | | | |
| 350±45 | ANISOVICH | 12A | DPWA | Multichannel |
| 479 | ARNDT | 06 | DPWA | $\pi N \rightarrow \pi N, \eta N$ |
| 283 | [3] HOEHLER | 93 | SPED | $\pi N \rightarrow \pi N$ |
| 200±40 | CUTKOSKY | 80 | IPWA | $\pi N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 496 | VRANA | 00 | DPWA | Multichannel |
| 494 | ARNDT | 95 | DPWA | $\pi N \rightarrow N\pi$ |
| 398 | ARNDT | 91 | DPWA | $\pi N \rightarrow \pi N$ Soln SM90 |
| 172 or 165 | [2] LONGACRE | 77 | IPWA | $\pi N \rightarrow N\pi\pi$ |

# Δ(1910) ELASTIC POLE RESIDUE

## MODULUS |r|

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 24±6 | ANISOVICH | 12A | DPWA | Multichannel |
| 45 | ARNDT | 06 | DPWA | $\pi N \rightarrow \pi N, \eta N$ |
| 38 | HOEHLER | 93 | SPED | $\pi N \rightarrow \pi N$ |
| 20±4 | CUTKOSKY | 80 | IPWA | $\pi N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 53 | ARNDT | 95 | DPWA | $\pi N \rightarrow N\pi$ |
| 37 | ARNDT | 91 | DPWA | $\pi N \rightarrow \pi N$ Soln SM90 |

## PHASE θ

| VALUE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| −145±30 | ANISOVICH | 12A | DPWA | Multichannel |
| +172 | ARNDT | 06 | DPWA | $\pi N \rightarrow \pi N, \eta N$ |
| − 90±30 | CUTKOSKY | 80 | IPWA | $\pi N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −176 | ARNDT | 95 | DPWA | $\pi N \rightarrow N\pi$ |
| − 91 | ARNDT | 91 | DPWA | $\pi N \rightarrow \pi N$ Soln SM90 |

# Δ(1910) INELASTIC POLE RESIDUE

The "normalized residue" is the residue divided by $\Gamma_{pole}$.

## Normalized residue in $N\pi \rightarrow \Delta(1910) \rightarrow \Sigma K$

| MODULUS (%) | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **7±2** | **−110 ± 30** | ANISOVICH | 12A | DPWA | Multichannel |

### Normalized residue in $N\pi \rightarrow \Delta(1910) \rightarrow \Delta\pi$, P-wave

| MODULUS (%) | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **16±9** | **95 ± 40** | ANISOVICH | 12A | DPWA | Multichannel |

## $\Delta$(1910) DECAY MODES

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

| | Mode | Fraction ($\Gamma_i/\Gamma$) |
|---|---|---|
| $\Gamma_1$ | $N\pi$ | 15–30 % |
| $\Gamma_2$ | $\Sigma K$ | ( 9± 5) % |
| $\Gamma_3$ | $N\pi\pi$ | |
| $\Gamma_4$ | $\Delta\pi$ | (60±28) % |
| $\Gamma_5$ | $\Delta(1232)\pi$, P-wave | |
| $\Gamma_6$ | $N\rho$ | |
| $\Gamma_7$ | $N\rho$, $S$=3/2, P-wave | |
| $\Gamma_8$ | $N(1440)\pi$ | |
| $\Gamma_9$ | $N(1440)\pi$, P-wave | |
| $\Gamma_{10}$ | $N\gamma$ | 0.0–0.02 % |
| $\Gamma_{11}$ | $N\gamma$, helicity=1/2 | 0.0–0.02 % |

## $\Delta$(1910) BRANCHING RATIOS

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

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **15 to 30 OUR ESTIMATE** | | | | |
| 12 ± 3 | ANISOVICH | 12A | DPWA | Multichannel |
| 23.9± 0.1 | ARNDT | 06 | DPWA | $\pi N \rightarrow \pi N, \eta N$ |
| 23 ± 8 | MANLEY | 92 | IPWA | $\pi N \rightarrow \pi N$ & $N\pi\pi$ |
| 19 ± 3 | CUTKOSKY | 80 | IPWA | $\pi N \rightarrow \pi N$ |
| 24 ± 6 | HOEHLER | 79 | IPWA | $\pi N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 29 ±21 | VRANA | 00 | DPWA | Multichannel |
| 26 | ARNDT | 95 | DPWA | $\pi N \rightarrow N\pi$ |
| 17 | [1] CHEW | 80 | BPWA | $\pi^+ p \rightarrow \pi^+ p$ |
| 40 | [1] CHEW | 80 | BPWA | $\pi^+ p \rightarrow \pi^+ p$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow \Delta(1910) \rightarrow \Sigma K$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| < 0.03 | CANDLIN | 84 | DPWA | $\pi^+ p \rightarrow \Sigma^+ K^+$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.019 | LIVANOS | 80 | DPWA | $\pi p \rightarrow \Sigma K$ |

### $\Gamma(\Sigma K)/\Gamma_{total}$ — $\Gamma_2/\Gamma$

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **9±5** | ANISOVICH | 12A | DPWA | Multichannel |

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 $N\pi \to \Delta(1910) \to \Delta(1232)\pi$, $P$-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| +0.06 | [2] LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |

### $\Gamma(\Delta\pi)/\Gamma_{total}$ — $\Gamma_4/\Gamma$

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **60±28** | ANISOVICH | 12A | DPWA | Multichannel |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1910) \to N\rho$, $S$=3/2, $P$-wave — $(\Gamma_1\Gamma_7)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| +0.29 | [2] LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1910) \to N(1440)\pi$, $P$-wave — $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| −0.39±0.04 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |

### $\Gamma(N(1440)\pi)/\Gamma_{total}$ — $\Gamma_8/\Gamma$

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 56±7 | VRANA | 00 | DPWA | Multichannel |

## $\Delta(1910)$ PHOTON DECAY AMPLITUDES

Papers on $\gamma N$ amplitudes predating 1981 may be found in our 2006 edition, Journal of Physics, G **33** 1 (2006).

### $\Delta(1910) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

| VALUE (GeV$^{-1/2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **+0.003±0.014 OUR ESTIMATE** | | | | |
| 0.022±0.009 | ANISOVICH | 12A | DPWA | Multichannel |
| −0.002±0.008 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| 0.014±0.030 | CRAWFORD | 83 | IPWA | $\gamma N \to \pi N$ |
| 0.025±0.011 | AWAJI | 81 | DPWA | $\gamma N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.032±0.003 | LI | 93 | IPWA | $\gamma N \to \pi N$ |

## Δ(1910) FOOTNOTES

[1] CHEW 80 reports four resonances in the $P_{31}$ wave — see also the Δ(1750). Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

[2] LONGACRE 77 pole positions 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. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

[3] 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 $\pi N$ elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

## Δ(1910) REFERENCES

For early references, see Physics Letters **111B** 1 (1982).


| | | | | |
|---|---|---|---|---|
| ANISOVICH | 12A | EPJ A48 15 | A.V. Anisovich *et al.* | (BONN, PNPI) |
| ARNDT | 06 | PR C74 045205 | R.A. Arndt *et al.* | (GWU) |
| PDG | 06 | JPG 33 1 | W.-M. Yao *et al.* | (PDG Collab.) |
| 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 |
| Also | | 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) |
| HOEHLER | 83 | Landolt-Boernstein 1/9B2 | G. Hohler | (KARLT) |
| PDG | 82 | PL 111B 1 | M. Roos *et al.* | (HELS, CIT, CERN) |
| AWAJI | 81 | Bonn Conf. 352 | N. Awaji, R. Kajikawa | (NAGO) |
| Also | | NP B197 365 | K. Fujii *et al.* | (NAGO) |
| CHEW | 80 | Toronto Conf. 123 | D.M. Chew | (LBL) IJP |
| CUTKOSKY | 80 | Toronto Conf. 19 | R.E. Cutkosky *et al.* | (CMU, LBL) IJP |
| Also | | 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 | | Toronto Conf. 3 | R. Koch | (KARLT) IJP |
| LONGACRE | 77 | NP B122 493 | R.S. Longacre, J. Dolbeau | (SACL) IJP |
| Also | | NP B108 365 | J. Dolbeau *et al.* | (SACL) IJP |