# $\Delta(1910)\ P_{31}$

$I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$ 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).

## $\Delta(1910)$ BREIT-WIGNER MASS

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1870 to 1920 (≈ 1910) OUR ESTIMATE** | | | | |
| 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. • • • | | | | |
| 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 | $\pi^+ p \to \pi^+ p$ |
| 1921 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| 1899 | BARBOUR | 78 | DPWA | $\gamma N \to \pi N$ |
| 1790 | [2] LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |

## $\Delta(1910)$ BREIT-WIGNER WIDTH

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **190 to 270 (≈ 250) OUR ESTIMATE** | | | | |
| 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. • • • | | | | |
| 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 | $\pi^+ p \to \pi^+ p$ |
| 351 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| 230 | BARBOUR | 78 | DPWA | $\gamma N \to \pi N$ |
| 170 | [2] LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |

## $\Delta(1910)$ POLE POSITION

### REAL PART

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **1830 to 1880 (≈ 1855) OUR ESTIMATE** | | | | |
| 1810 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 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. • • • | | | | |
| 1950 | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |
| 1792 or 1801 | [2] LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |

### $-2\times$IMAGINARY PART

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **200 to 500 ($\approx$ 350) OUR ESTIMATE** | | | | |
| 494 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 283 | [3] HOEHLER | 93 | SPED | $\pi N \to \pi N$ |
| 200$\pm$40 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 398 | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |
| 172 or 165 | [2] LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |

## $\Delta$(1910) ELASTIC POLE RESIDUE

### MODULUS $|r|$

| VALUE (MeV) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 53 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 38 | HOEHLER | 93 | SPED | $\pi N \to \pi N$ |
| 20$\pm$4 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 37 | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |

### PHASE $\theta$

| VALUE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| $-$176 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| $-$ 90$\pm$30 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $-$ 91 | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |

## $\Delta$(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 % |
| $\Gamma_2$ | $\Sigma K$ | |
| $\Gamma_3$ | $N\pi\pi$ | |
| $\Gamma_4$ | $\Delta\pi$ | |
| $\Gamma_5$ | $\Delta(1232)\pi$, $P$-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 | |
| $\Gamma_{10}$ | $N\gamma$ | 0.0–0.2 % |
| $\Gamma_{11}$ | $N\gamma$, helicity=1/2 | 0.0–0.2 % |

# $\Delta(1910)$ BRANCHING RATIOS

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

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.15 to 0.3 OUR ESTIMATE** | | | | |
| 0.23±0.08 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 0.19±0.03 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 0.24±0.06 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.26 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 0.17 | [1] CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |
| 0.40 | [1] CHEW | 80 | BPWA | $\pi^+ p \to \pi^+ p$ |

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

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| < 0.03 | CANDLIN | 84 | DPWA | $\pi^+ p \to \Sigma^+ K^+$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.019 | LIVANOS | 80 | DPWA | $\pi p \to \Sigma K$ |
| 0.082 to 0.184 | [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 $N\pi \to \Delta(1910) \to \Delta(1232)\pi$, $P$-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

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

## $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ 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 | $\pi N \to N\pi\pi$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| +0.17 | [5] NOVOSELLER | 78 | 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 | $\pi N \to \pi N$ & $N\pi\pi$ |

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

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

| VALUE (GeV$^{-1/2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **+0.003±0.014 OUR ESTIMATE** | | | | |
| −0.002±0.008 | ARNDT | 96 | IPWA | $\gamma N \rightarrow \pi N$ |
| 0.014±0.030 | CRAWFORD | 83 | IPWA | $\gamma N \rightarrow \pi N$ |
| 0.025±0.011 | AWAJI | 81 | DPWA | $\gamma N \rightarrow \pi N$ |
| −0.012±0.005 | ARAI | 80 | DPWA | $\gamma N \rightarrow \pi N$ (fit 1) |
| −0.031±0.004 | ARAI | 80 | DPWA | $\gamma N \rightarrow \pi N$ (fit 2) |
| −0.005±0.030 | CRAWFORD | 80 | DPWA | $\gamma N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.032±0.003 | LI | 93 | IPWA | $\gamma N \rightarrow \pi N$ |
| −0.035±0.021 | BARBOUR | 78 | DPWA | $\gamma N \rightarrow \pi N$ |

## $\Delta(1910)$ FOOTNOTES

[1] CHEW 80 reports four resonances in the $P_{31}$ wave — see also the $\Delta(1750)$. 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 $\Delta$ 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.

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

[5] Evidence for this coupling is weak; see NOVOSELLER 78. This coupling assumes the mass is near 1820 MeV.

## $\Delta(1910)$ REFERENCES

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


| | | | | |
|---|---|---|---|---|
| ARNDT | 96 | PR C53 430 | +Strakovsky, Workman | (VPI) |
| ARNDT | 95 | PR C52 2120 | +Strakovsky, Workman, Pavan | (VPI, BRCO) |
| HOEHLER | 93 | $\pi N$ Newsletter 9 1 | | (KARL) |
| LI | 93 | PR C47 2759 | +Arndt, Roper, Workman | (VPI) |
| MANLEY | 92 | PR D45 4002 | +Saleski | (KENT) IJP |
| Also | 84 | PR D30 904 | Manley, Arndt, Goradia, Teplitz | (VPI) |
| ARNDT | 91 | PR D43 2131 | +Li, Roper, Workman, Ford | (VPI, TELE) IJP |
| CANDLIN | 84 | NP B238 477 | +Lowe, Peach, Scotland+ | (EDIN, RAL, LOWC) |
| CRAWFORD | 83 | NP B211 1 | +Morton | (GLAS) |
| HOEHLER | 83 | Landolt-Boernstein 1/9B2 | | (KARLT) |
| PDG | 82 | PL 111B | Roos, Porter, Aguilar-Benitez+ | (HELS, CIT, CERN) |
| AWAJI | 81 | Bonn Conf. 352 | +Kajikawa | (NAGO) |
| Also | 82 | NP B197 365 | Fujii, Hayashii, Iwata, Kajikawa+ | (NAGO) |
| ARAI | 80 | Toronto Conf. 93 | | (INUS) |
| Also | 82 | NP B194 251 | Arai, Fujii | (INUS) |

| | | | | |
|---|---|---|---|---|
| CHEW | 80 | Toronto Conf. 123 | | (LBL) IJP |
| CRAWFORD | 80 | Toronto Conf. 107 | | (GLAS) |
| CUTKOSKY | 80 | Toronto Conf. 19 | +Forsyth, Babcock, Kelly, Hendrick | (CMU, LBL) IJP |
| Also | 79 | PR D20 2839 | Cutkosky, Forsyth, Hendrick, Kelly | (CMU, LBL) IJP |
| LIVANOS | 80 | Toronto Conf. 35 | +Baton, Coutures, Kochowski, Neveu | (SACL) IJP |
| HOEHLER | 79 | PDAT 12-1 | +Kaiser, Koch, Pietarinen | (KARLT) IJP |
| Also | 80 | Toronto Conf. 3 | Koch | (KARLT) IJP |
| BARBOUR | 78 | NP B141 253 | +Crawford, Parsons | (GLAS) |
| NOVOSELLER | 78 | NP B137 509 | | (CIT) IJP |
| Also | 78B | NP B137 445 | Novoseller | (CIT) IJP |
| LONGACRE | 77 | NP B122 493 | +Dolbeau | (SACL) IJP |
| Also | 76 | NP B108 365 | Dolbeau, Triantis, Neveu, Cadiet | (SACL) IJP |
| DEANS | 75 | NP B96 90 | +Mitchell, Montgomery+ | (SFLA, ALAH) IJP |