# $\Delta(1950)\ 7/2^+$

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

Older and obsolete values are listed and referenced in the 2014 edition, Chinese Physics **C38** 070001 (2014).

## Δ(1950) POLE POSITION

### REAL PART

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **1870 to 1890 (≈ 1880) OUR ESTIMATE** | | | | |
| 1888± 4 | SOKHOYAN | 15A | DPWA | Multichannel |
| 1877± 2±1 | [1] SVARC | 14 | L+P | $\pi N \to \pi N$ |
| 1890±15 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1871 | HUNT | 19 | DPWA | Multichannel |
| 1874 | ROENCHEN | 15A | DPWA | Multichannel |
| 1888± 4 | GUTZ | 14 | DPWA | Multichannel |
| 1890± 4 | ANISOVICH | 12A | DPWA | Multichannel |
| 1876 | ARNDT | 06 | DPWA | $\pi N \to \pi N, \eta N$ |
| 1910 | VRANA | 00 | DPWA | Multichannel |
| 1878 | HOEHLER | 93 | ARGD | $\pi N \to \pi N$ |

[1] Fit to the amplitudes of HOEHLER 79.

### −2×IMAGINARY PART

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **220 to 260 (≈ 240) OUR ESTIMATE** | | | | |
| 245± 8 | SOKHOYAN | 15A | DPWA | Multichannel |
| 223± 4±1 | [1] SVARC | 14 | L+P | $\pi N \to \pi N$ |
| 260±40 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 206 | HUNT | 19 | DPWA | Multichannel |
| 239 | ROENCHEN | 15A | DPWA | Multichannel |
| 245± 8 | GUTZ | 14 | DPWA | Multichannel |
| 243± 8 | ANISOVICH | 12A | DPWA | Multichannel |
| 227 | ARNDT | 06 | DPWA | $\pi N \to \pi N, \eta N$ |
| 230 | VRANA | 00 | DPWA | Multichannel |
| 230 | HOEHLER | 93 | ARGD | $\pi N \to \pi N$ |

[1] Fit to the amplitudes of HOEHLER 79.

## Δ(1950) ELASTIC POLE RESIDUE

### MODULUS $|r|$

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **44 to 60 (≈ 52) OUR ESTIMATE** | | | | |
| 58±2 | SOKHOYAN | 15A | DPWA | Multichannel |
| 44±1 | [1] SVARC | 14 | L+P | $\pi N \to \pi N$ |
| 50±7 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |

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

| | | | | |
|---|---|---|---|---|
| 56 | ROENCHEN | 15A | DPWA | Multichannel |
| 58±2 | GUTZ | 14 | DPWA | Multichannel |
| 58±2 | ANISOVICH | 12A | DPWA | Multichannel |
| 53 | ARNDT | 06 | DPWA | $\pi N \to \pi N, \eta N$ |
| 47 | HOEHLER | 93 | ARGD | $\pi N \to \pi N$ |

[1] Fit to the amplitudes of HOEHLER 79.

### PHASE $\theta$

| VALUE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **−40 to −24 (≈ −32) OUR ESTIMATE** | | | | |
| −24±3 | SOKHOYAN | 15A | DPWA | Multichannel |
| −39±1±1 | [1] SVARC | 14 | L+P | $\pi N \to \pi N$ |
| −33±8 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |

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

| | | | | |
|---|---|---|---|---|
| −33 | ROENCHEN | 15A | DPWA | Multichannel |
| −24±3 | GUTZ | 14 | DPWA | Multichannel |
| −24±3 | ANISOVICH | 12A | DPWA | Multichannel |
| −31 | ARNDT | 06 | DPWA | $\pi N \to \pi N, \eta N$ |
| −32 | HOEHLER | 93 | ARGD | $\pi N \to \pi N$ |

[1] Fit to the amplitudes of HOEHLER 79.

## $\Delta(1950)$ INELASTIC POLE RESIDUE

The "normalized residue" is the residue divided by $\Gamma_{pole}/2$.

### Normalized residue in $N\pi \to \Delta(1950) \to \Sigma K$

| MODULUS | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| 0.05 ±0.01 | −65 ± 25 | ANISOVICH | 12A | DPWA | Multichannel |

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

| | | | | | |
|---|---|---|---|---|---|
| 0.031 | −87 | ROENCHEN | 15A | DPWA | Multichannel |

### Normalized residue in $N\pi \to \Delta(1950) \to \Delta\pi$, $F$-wave

| MODULUS | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| 0.12±0.04 | undefined | SOKHOYAN | 15A | DPWA | Multichannel |

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

| | | | | | |
|---|---|---|---|---|---|
| 0.54 | 131 | ROENCHEN | 15A | DPWA | Multichannel |
| 0.12±0.04 | 12 ± 10 | ANISOVICH | 12A | DPWA | Multichannel |

### Normalized residue in $N\pi \to \Delta(1950) \to \Delta\pi$, $H$-wave

| MODULUS | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|

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

| | | | | | |
|---|---|---|---|---|---|
| 0.033 | −97 | ROENCHEN | 15A | DPWA | Multichannel |

### Normalized residue in $N\pi \rightarrow \Delta(1950) \rightarrow \Delta(1232)\eta$

| *MODULUS* | *PHASE* (°) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| 0.035±0.005 | 90 ± 25 | GUTZ | 14 | DPWA | Multichannel |

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

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **1915 to 1950 (≈ 1930) OUR ESTIMATE** | | | | |
| 1943 ±18 | GOLOVATCH | 19 | DPWA | $\gamma p \rightarrow \pi^+\pi^- p$ |
| 1913 ± 4 | [1] HUNT | 19 | DPWA | Multichannel |
| 1917 ± 4 | ANISOVICH | 17 | DPWA | Multichannel |
| 1921.3± 0.2 | [1] ARNDT | 06 | DPWA | $\pi N \rightarrow \pi N, \eta N$ |
| 1950 ±15 | CUTKOSKY | 80 | IPWA | $\pi N \rightarrow \pi N$ |
| 1913 ± 8 | HOEHLER | 79 | IPWA | $\pi N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1917 ± 4 | SOKHOYAN | 15A | DPWA | Multichannel |
| 1917 ± 4 | GUTZ | 14 | DPWA | Multichannel |
| 1915 ± 6 | ANISOVICH | 12A | DPWA | Multichannel |
| 1918 ± 1 | [1] SHRESTHA | 12A | DPWA | Multichannel |
| 1936 ± 5 | VRANA | 00 | DPWA | Multichannel |

[1] Statistical error only.

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

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **235 to 335 (≈ 285) OUR ESTIMATE** | | | | |
| 230 ±88 | GOLOVATCH | 19 | DPWA | $\gamma p \rightarrow \pi^+\pi^- p$ |
| 241 ±10 | [1] HUNT | 19 | DPWA | Multichannel |
| 251 ± 8 | ANISOVICH | 17 | DPWA | Multichannel |
| 271.1± 1.1 | [1] ARNDT | 06 | DPWA | $\pi N \rightarrow \pi N, \eta N$ |
| 340 ±50 | CUTKOSKY | 80 | IPWA | $\pi N \rightarrow \pi N$ |
| 224 ±10 | HOEHLER | 79 | IPWA | $\pi N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 251 ± 8 | SOKHOYAN | 15A | DPWA | Multichannel |
| 251 ± 8 | GUTZ | 14 | DPWA | Multichannel |
| 246 ±10 | ANISOVICH | 12A | DPWA | Multichannel |
| 259 ± 4 | [1] SHRESTHA | 12A | DPWA | Multichannel |
| 245 ±12 | VRANA | 00 | DPWA | Multichannel |

[1] Statistical error only.

## Δ(1950) DECAY MODES

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

| | Mode | Fraction ($\Gamma_i/\Gamma$) |
|---|---|---|
| $\Gamma_1$ | $N\pi$ | 35–45 % |
| $\Gamma_2$ | $\Sigma K$ | 0.3–0.5 % |
| $\Gamma_3$ | $N\pi\pi$ | |
| $\Gamma_4$ | $\Delta(1232)\pi$, *F*-wave | 1–9 % |
| $\Gamma_5$ | $N(1680)\pi$, *P*-wave | 3–9 % |
| $\Gamma_6$ | $\Delta(1232)\eta$ | $< 0.6$ % |

## Δ(1950) BRANCHING RATIOS

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

| *VALUE* (%) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **35 to 45 (≈ 40) OUR ESTIMATE** | | | | |
| 38 ±2 | [1] HUNT | 19 | DPWA | Multichannel |
| 46 ±2 | ANISOVICH | 17 | DPWA | Multichannel |
| 47.1 ±0.1 | [1] ARNDT | 06 | DPWA | $\pi N \to \pi N$, $\eta N$ |
| 39 ±4 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 38 ±2 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.046±0.002 | SOKHOYAN | 15A | DPWA | Multichannel |
| 46 ±2 | GUTZ | 14 | DPWA | Multichannel |
| 45 ±2 | ANISOVICH | 12A | DPWA | Multichannel |
| 45.6 ±0.4 | [1] SHRESTHA | 12A | DPWA | Multichannel |
| 44 ±1 | VRANA | 00 | DPWA | Multichannel |

[1] Statistical error only.

### $\Gamma(N\pi\pi)/\Gamma_{total}$ $\Gamma_3/\Gamma$

| *VALUE* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **0.57±0.20** | GOLOVATCH | 19 | DPWA | $\gamma p \to \pi^+\pi^- p$ |

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

| *VALUE* (%) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| 0.6±0.2 | ANISOVICH | 17 | DPWA | Multichannel |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.4±0.1 | ANISOVICH | 12A | DPWA | Multichannel |

### $\Gamma(\Delta(1232)\pi$, *F*-wave$)/\Gamma_{total}$ $\Gamma_4/\Gamma$

| *VALUE* (%) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| 5 ±3 | ANISOVICH | 17 | DPWA | Multichannel |
| 8 ±1 | [1] SHRESTHA | 12A | DPWA | Multichannel |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 5 ±4 | SOKHOYAN | 15A | DPWA | Multichannel |
| 2.8±1.4 | ANISOVICH | 12A | DPWA | Multichannel |
| 36 ±1 | VRANA | 00 | DPWA | Multichannel |

[1] Statistical error only.

### $\Gamma(N(1680)\pi, P\text{-wave})/\Gamma_{total}$ $\Gamma_5/\Gamma$

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| $6\pm3$ | SOKHOYAN | 15A | DPWA | Multichannel |

### $\Gamma(\Delta(1232)\eta)/\Gamma_{total}$ $\Gamma_6/\Gamma$

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| $0.3\pm0.3$ | ANISOVICH | 17 | DPWA | Multichannel |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $<1$ | GUTZ | 14 | DPWA | Multichannel |

## $\Delta(1950)$ PHOTON DECAY AMPLITUDES AT THE POLE

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

| MODULUS ($GeV^{-1/2}$) | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| $-0.067\pm0.004$ | $-10\pm5$ | SOKHOYAN | 15A | DPWA | Multichannel |
| $-0.071\pm0.004$ | $-14^{+2}_{-4}$ | ROENCHEN | 14 | DPWA | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $-0.068$ | $-19$ | ROENCHEN | 15A | DPWA | Multichannel |

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

| MODULUS ($GeV^{-1/2}$) | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| $-0.095\pm0.004$ | $-10\pm5$ | SOKHOYAN | 15A | DPWA | Multichannel |
| $-0.089^{+0.008}_{-0.007}$ | $-10^{+3}_{-1}$ | ROENCHEN | 14 | DPWA | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $-0.084$ | $-19$ | ROENCHEN | 15A | DPWA | Multichannel |

## $\Delta(1950)$ BREIT-WIGNER PHOTON DECAY AMPLITUDES

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

| VALUE ($GeV^{-1/2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **$-0.075$ to $-0.065$ ($\approx -0.070$) OUR ESTIMATE** | | | | |
| $-0.0698\pm0.0141$ | GOLOVATCH | 19 | DPWA | $\gamma p \to \pi^+\pi^- p$ |
| $-0.047\ \pm0.002$ | [1] HUNT | 19 | DPWA | Multichannel |
| $-0.067\ \pm0.005$ | ANISOVICH | 17 | DPWA | Multichannel |
| $-0.083\ \pm0.004$ | WORKMAN | 12A | DPWA | $\gamma N \to N\pi$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $-0.067\ \pm0.005$ | SOKHOYAN | 15A | DPWA | Multichannel |
| $-0.067\ \pm0.005$ | GUTZ | 14 | DPWA | Multichannel |
| $-0.071\ \pm0.004$ | ANISOVICH | 12A | DPWA | Multichannel |
| $-0.065\ \pm0.001$ | [1] SHRESTHA | 12A | DPWA | Multichannel |
| $-0.094$ | DRECHSEL | 07 | DPWA | $\gamma N \to \pi N$ |

[1] Statistical error only.

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

| *VALUE* ($GeV^{-1/2}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **$-0.100$ to $-0.080$ ($\approx -0.090$) OUR ESTIMATE** | | | | |
| $-0.1181 \pm 0.0193$ | GOLOVATCH | 19 | DPWA | $\gamma p \rightarrow \pi^+ \pi^- p$ |
| $-0.074 \pm 0.002$ | [1] HUNT | 19 | DPWA | Multichannel |
| $-0.094 \pm 0.004$ | ANISOVICH | 17 | DPWA | Multichannel |
| $-0.096 \pm 0.004$ | WORKMAN | 12A | DPWA | $\gamma N \rightarrow N\pi$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $-0.094 \pm 0.004$ | SOKHOYAN | 15A | DPWA | Multichannel |
| $-0.094 \pm 0.004$ | GUTZ | 14 | DPWA | Multichannel |
| $-0.094 \pm 0.005$ | ANISOVICH | 12A | DPWA | Multichannel |
| $-0.083 \pm 0.001$ | [1] SHRESTHA | 12A | DPWA | Multichannel |
| $-0.121$ | DRECHSEL | 07 | DPWA | $\gamma N \rightarrow \pi N$ |

[1] Statistical error only.

## $\Delta(1950)$ REFERENCES


| | | | | |
|---|---|---|---|---|
| GOLOVATCH | 19 | PL B788 371 | E. Golovatch *et al.* | (CLAS Collab.) |
| HUNT | 19 | PR C99 055205 | B.C. Hunt, D.M. Manley | |
| ANISOVICH | 17 | PL B766 357 | A.V. Anisovich *et al.* | |
| ROENCHEN | 15A | EPJ A51 70 | D. Roenchen *et al.* | |
| SOKHOYAN | 15A | EPJ A51 95 | V. Sokhoyan *et al.* | (CBELSA/TAPS Collab.) |
| GUTZ | 14 | EPJ A50 74 | E. Gutz *et al.* | (CBELSA/TAPS Collab.) |
| PDG | 14 | CP C38 070001 | K. Olive *et al.* | (PDG Collab.) |
| ROENCHEN | 14 | EPJ A50 101 | D. Roenchen *et al.* | |
| Also | | EPJ A51 63 (errat.) | D. Roenchen *et al.* | |
| SVARC | 14 | PR C89 045205 | A. Svarc *et al.* | (RBI Zagreb, UNI Tuzla) |
| ANISOVICH | 12A | EPJ A48 15 | A.V. Anisovich *et al.* | (BONN, PNPI) |
| SHRESTHA | 12A | PR C86 055203 | M. Shrestha, D.M. Manley | (KSU) |
| WORKMAN | 12A | PR C86 015202 | R. Workman *et al.* | (GWU) |
| DRECHSEL | 07 | EPJ A34 69 | D. Drechsel, S.S. Kamalov, L. Tiator | (MAINZ, JINR) |
| ARNDT | 06 | PR C74 045205 | R.A. Arndt *et al.* | (GWU) |
| VRANA | 00 | PRPL 328 181 | T.P. Vrana, S.A. Dytman, T.-S.H. Lee | (PITT, ANL) |
| HOEHLER | 93 | $\pi N$ Newsletter 9 1 | G. Hohler | (KARL) |
| 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 |
| HOEHLER | 79 | PDAT 12-1 | G. Hohler *et al.* | (KARLT) IJP |
| Also | | Toronto Conf. 3 | R. Koch | (KARLT) IJP |