# $\Delta(1600)\ 3/2^+$

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

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

## Δ(1600) POLE POSITION

### REAL PART

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **1470 to 1590 (≈ 1520) OUR ESTIMATE** | | | | |
| 1590± 1 | ROENCHEN | 22 | DPWA | Multichannel |
| 1515±20 | SOKHOYAN | 15A | DPWA | Multichannel |
| 1469±10±5 | [1] SVARC | 14 | L+P | $\pi N \to \pi N$ |
| 1550±40 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1619 | HUNT | 19 | DPWA | Multichannel |
| 1552 | ROENCHEN | 15A | DPWA | Multichannel |
| 1498±25 | ANISOVICH | 12A | DPWA | Multichannel |
| 1457 | ARNDT | 06 | DPWA | $\pi N \to \pi N, \eta N$ |
| 1599 | VRANA | 00 | DPWA | Multichannel |
| 1550 | HOEHLER | 93 | SPED | $\pi N \to \pi N$ |

[1] Fit to the amplitudes of HOEHLER 79.

### −2×IMAGINARY PART

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **150 to 320 (≈ 280) OUR ESTIMATE** | | | | |
| 136± 1 | ROENCHEN | 22 | DPWA | Multichannel |
| 250±30 | SOKHOYAN | 15A | DPWA | Multichannel |
| 314±18±8 | [1] SVARC | 14 | L+P | $\pi N \to \pi N$ |
| 200±60 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 295 | HUNT | 19 | DPWA | Multichannel |
| 350 | ROENCHEN | 15A | DPWA | Multichannel |
| 230±50 | ANISOVICH | 12A | DPWA | Multichannel |
| 400 | ARNDT | 06 | DPWA | $\pi N \to \pi N, \eta N$ |
| 312 | VRANA | 00 | DPWA | Multichannel |

[1] Fit to the amplitudes of HOEHLER 79.

## Δ(1600) ELASTIC POLE RESIDUE

### MODULUS $|r|$

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **10 to 40 (≈ 25) OUR ESTIMATE** | | | | |
| 11±1 | ROENCHEN | 22 | DPWA | Multichannel |
| 13±3 | SOKHOYAN | 15A | DPWA | Multichannel |
| 38±2±2 | [1] SVARC | 14 | L+P | $\pi N \to \pi N$ |
| 17±4 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |

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

| | | | | |
|---|---|---|---|---|
| 23 | ROENCHEN | 15A | DPWA | Multichannel |
| 11±6 | ANISOVICH | 12A | DPWA | Multichannel |
| 44 | ARNDT | 06 | DPWA | $\pi N \to \pi N$, $\eta N$ |

[1] Fit to the amplitudes of HOEHLER 79.

### PHASE $\theta$

| VALUE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **180 to 250 (≈ 210) OUR ESTIMATE** | | | | |
| −106± 1 | ROENCHEN | 22 | DPWA | Multichannel |
| −155±20 | SOKHOYAN | 15A | DPWA | Multichannel |
| 173± 5±5 | [1] SVARC | 14 | L+P | $\pi N \to \pi N$ |
| −150±30 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |

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

| | | | | |
|---|---|---|---|---|
| −155 | ROENCHEN | 15A | DPWA | Multichannel |
| −160±33 | ANISOVICH | 12A | DPWA | Multichannel |
| +147 | ARNDT | 06 | DPWA | $\pi N \to \pi N$, $\eta N$ |

[1] Fit to the amplitudes of HOEHLER 79.

## Δ(1600) INELASTIC POLE RESIDUE

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

### Normalized residue in $N\pi \to \Delta(1600) \to \Delta\pi$, P-wave

| MODULUS | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| 0.30±0.02 | 87 ± 2 | ROENCHEN | 22 | DPWA | Multichannel |
| 0.15±0.04 | 30 ± 35 | SOKHOYAN | 15A | DPWA | Multichannel |

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

| | | | | | |
|---|---|---|---|---|---|
| 0.31 | 31 | ROENCHEN | 15A | DPWA | Multichannel |
| 0.14±0.10 | 154 ± 40 | ANISOVICH | 12A | DPWA | Multichannel |

### Normalized residue in $N\pi \to \Delta(1600) \to \Delta\pi$, F-wave

| MODULUS | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| 0.004±0.0002 | −62 ± 5 | ROENCHEN | 22 | DPWA | Multichannel |
| 0.010±0.005 | | SOKHOYAN | 15A | DPWA | Multichannel |

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

| | | | | | |
|---|---|---|---|---|---|
| 0.013 | 29 | ROENCHEN | 15A | DPWA | Multichannel |
| 0.010±0.005 | | ANISOVICH | 12A | DPWA | Multichannel |

### Normalized residue in $N\pi \to \Delta(1600) \to \Sigma K$

| MODULUS | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| 0.14±0.01 | 14 ± 1 | ROENCHEN | 22 | DPWA | Multichannel |

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

| | | | | | |
|---|---|---|---|---|---|
| 0.13 | −5.6 | ROENCHEN | 15A | DPWA | Multichannel |

## $\Delta(1600)$ BREIT-WIGNER MASS

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **1500 to 1640 (≈ 1570) OUR ESTIMATE** | | | | |
| 1664±16 | [1] HUNT | 19 | DPWA | Multichannel |
| 1520±20 | SOKHOYAN | 15A | DPWA | Multichannel |
| 1600±50 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 1522±13 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1510±20 | ANISOVICH | 12A | DPWA | Multichannel |
| 1626± 8 | [1] SHRESTHA | 12A | DPWA | Multichannel |
| 1667± 1 | PENNER | 02C | DPWA | Multichannel |
| 1687±44 | VRANA | 00 | DPWA | Multichannel |

[1] Statistical error only.

## $\Delta(1600)$ BREIT-WIGNER WIDTH

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **200 to 300 (≈ 250) OUR ESTIMATE** | | | | |
| 322± 46 | [1] HUNT | 19 | DPWA | Multichannel |
| 235± 30 | SOKHOYAN | 15A | DPWA | Multichannel |
| 300±100 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 220± 40 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 220± 45 | ANISOVICH | 12A | DPWA | Multichannel |
| 225± 18 | [1] SHRESTHA | 12A | DPWA | Multichannel |
| 397± 10 | PENNER | 02C | DPWA | Multichannel |
| 493± 75 | VRANA | 00 | DPWA | Multichannel |

[1] Statistical error only.

## $\Delta(1600)$ DECAY MODES

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

| | Mode | Fraction ($\Gamma_i/\Gamma$) |
|---|---|---|
| $\Gamma_1$ | $N\pi$ | 8–24% |
| $\Gamma_2$ | $N\pi\pi$ | 58–84 % |
| $\Gamma_3$ | $\Delta(1232)\pi$ | 58–82 % |
| $\Gamma_4$ | $\Delta(1232)\pi$, $P$-wave | 72–82% |
| $\Gamma_5$ | $\Delta(1232)\pi$, $F$-wave | <2% |
| $\Gamma_6$ | $N(1440)\pi$ | 17–27% |
| $\Gamma_7$ | $N\gamma$ | 0.001–0.035 % |
| $\Gamma_8$ | $N\gamma$, helicity=1/2 | 0.0–0.02 % |
| $\Gamma_9$ | $N\gamma$, helicity=3/2 | 0.001–0.015 % |

## Δ(1600) BRANCHING RATIOS

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

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **8–24% OUR ESTIMATE** | | | | |
| 10.7±1.9 | [1] HUNT | 19 | DPWA | Multichannel |
| 14 ±4 | SOKHOYAN | 15A | DPWA | Multichannel |
| 18 ±4 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 21 ±6 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 12 ±5 | ANISOVICH | 12A | DPWA | Multichannel |
| 8 ±2 | [1] SHRESTHA | 12A | DPWA | Multichannel |
| 13 ±1 | PENNER | 02C | DPWA | Multichannel |
| 28 ±5 | VRANA | 00 | DPWA | Multichannel |

[1] Statistical error only.

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

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **72–82% OUR ESTIMATE** | | | | |
| 64± 6 | [1] HUNT | 19 | DPWA | Multichannel |
| 77± 5 | SOKHOYAN | 15A | DPWA | Multichannel |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 78± 6 | ANISOVICH | 12A | DPWA | Multichannel |
| 70± 3 | [1] SHRESTHA | 12A | DPWA | Multichannel |
| 59±10 | VRANA | 00 | DPWA | Multichannel |

[1] Statistical error only.

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

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **<2% OUR ESTIMATE** | | | | |
| <2 | SOKHOYAN | 15A | DPWA | Multichannel |

### $\Gamma(N(1440)\pi)/\Gamma_{total}$ $\Gamma_6/\Gamma$

| VALUE (%) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **17–27% OUR ESTIMATE** | | | | |
| 22±5 | [1] HUNT | 19 | DPWA | Multichannel |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 22±3 | [1] SHRESTHA | 12A | DPWA | Multichannel |
| 13±4 | VRANA | 00 | DPWA | Multichannel |

[1] Statistical error only.

## Δ(1600) PHOTON DECAY AMPLITUDES AT THE POLE

### $\Delta(1600) \to N\gamma$, helicity-1/2 amplitude $A_{1/2}$

| MODULUS ($GeV^{-1/2}$) | PHASE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| 0.025±0.005 | 0.5 ± 3.0 | ROENCHEN | 22 | DPWA | Multichannel |
| 0.053±0.010 | 130 ± 15 | SOKHOYAN | 15A | DPWA | Multichannel |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| −0.230 | −42 | ROENCHEN | 15A | DPWA | Multichannel |

### $\Delta(1600) \rightarrow N\gamma$, helicity-3/2 amplitude $A_{3/2}$

| *MODULUS* ($GeV^{-1/2}$) | *PHASE* (°) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| $-0.006 \pm 0.0013$ | $62 \pm 32$ | ROENCHEN | 22 | DPWA | Multichannel |
| $0.055 \pm 0.010$ | $152 \pm 15$ | SOKHOYAN | 15A | DPWA | Multichannel |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.332 | $-71$ | ROENCHEN | 15A | DPWA | Multichannel |

## $\Delta(1600)$ BREIT-WIGNER PHOTON DECAY AMPLITUDES

### $\Delta(1600) \rightarrow N\gamma$, helicity-1/2 amplitude $A_{1/2}$

| *VALUE* ($GeV^{-1/2}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **$-0.060$ to $-0.030$ ($\approx -0.045$) OUR ESTIMATE** | | | | |
| $0.0082 \pm 0.0014$ | [1] HUNT | 19 | DPWA | Multichannel |
| $-0.051 \pm 0.010$ | SOKHOYAN | 15A | DPWA | Multichannel |
| $-0.018 \pm 0.015$ | [1] ARNDT | 96 | IPWA | $\gamma N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $-0.050 \pm 0.009$ | ANISOVICH | 12A | DPWA | Multichannel |
| $0.006 \pm 0.005$ | [1] SHRESTHA | 12A | DPWA | Multichannel |
| 0.0 | PENNER | 02D | DPWA | Multichannel |

[1] Statistical error only.

### $\Delta(1600) \rightarrow N\gamma$, helicity-3/2 amplitude $A_{3/2}$

| *VALUE* ($GeV^{-1/2}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **$-0.050$ to $-0.020$ ($\approx -0.035$) OUR ESTIMATE** | | | | |
| $0.048 \pm 0.014$ | [1] HUNT | 19 | DPWA | Multichannel |
| $-0.055 \pm 0.010$ | SOKHOYAN | 15A | DPWA | Multichannel |
| $-0.025 \pm 0.015$ | [1] ARNDT | 96 | IPWA | $\gamma N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $-0.040 \pm 0.012$ | ANISOVICH | 12A | DPWA | Multichannel |
| $0.052 \pm 0.008$ | [1] SHRESTHA | 12A | DPWA | Multichannel |
| $-0.024$ | PENNER | 02D | DPWA | Multichannel |

[1] Statistical error only.

## $\Delta(1600)$ REFERENCES

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


| | | | | |
|---|---|---|---|---|
| ROENCHEN | 22 | EPJ A58 229 | D. Roenchen *et al.* | (JULI, GWU, BONN+) |
| HUNT | 19 | PR C99 055205 | B.C. Hunt, D.M. Manley | |
| ROENCHEN | 15A | EPJ A51 70 | D. Roenchen *et al.* | |
| SOKHOYAN | 15A | EPJ A51 95 | V. Sokhoyan *et al.* | (CBELSA/TAPS Collab.) |
| PDG | 14 | CP C38 070001 | K. Olive *et al.* | (PDG Collab.) |
| 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) |
| ARNDT | 06 | PR C74 045205 | R.A. Arndt *et al.* | (GWU) |
| PENNER | 02C | PR C66 055211 | G. Penner, U. Mosel | (GIES) |
| PENNER | 02D | PR C66 055212 | G. Penner, U. Mosel | (GIES) |
| VRANA | 00 | PRPL 328 181 | T.P. Vrana, S.A. Dytman, T.-S.H. Lee | (PITT, ANL) |
| ARNDT | 96 | PR C53 430 | R.A. Arndt, I.I. Strakovsky, R.L. Workman | (VPI) |

| | | | | |
|---|---|---|---|---|
| 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 |