

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

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

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

$\Delta(1600)$ POLE POSITION

REAL PART

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

¹Fit to the amplitudes of HOEHLER 79.

−2×IMAGINARY PART

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

¹Fit to the amplitudes of HOEHLER 79.

$\Delta(1600)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

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

• • • 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	$\pi N \rightarrow \pi N, \eta N$

¹ Fit to the amplitudes of HOEHLER 79.

PHASE θ

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	$\pi N \rightarrow \pi N$
−150±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

• • • 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	$\pi N \rightarrow \pi N, \eta N$

¹ Fit to the amplitudes of HOEHLER 79.

$\Delta(1600)$ INELASTIC POLE RESIDUE

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

Normalized residue in $N\pi \rightarrow \Delta(1600) \rightarrow \Delta\pi$, *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 $N\pi \rightarrow \Delta(1600) \rightarrow \Delta\pi$, *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 $N\pi \rightarrow \Delta(1600) \rightarrow \Sigma K$

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 $\pi N \rightarrow \pi N$
1522 ± 13	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • 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 $\pi N \rightarrow \pi N$
220 ± 40	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • 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 (Γ_i/Γ)
Γ_1 $N\pi$	8–24%
Γ_2 $N\pi\pi$	58–84 %
Γ_3 $\Delta(1232)\pi$	58–82 %
Γ_4 $\Delta(1232)\pi$, P -wave	72–82%
Γ_5 $\Delta(1232)\pi$, F -wave	<2%
Γ_6 $N(1440)\pi$	17–27%
Γ_7 $N\gamma$	0.001–0.035 %
Γ_8 $N\gamma$, helicity=1/2	0.0–0.02 %
Γ_9 $N\gamma$, helicity=3/2	0.001–0.015 %

$\Delta(1600)$ BRANCHING RATIOS **$\Gamma(N\pi)/\Gamma_{\text{total}}$** **$\Gamma_1/\Gamma$**

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 $\pi N \rightarrow \pi N$
21 ± 6	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
• • • 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

¹Statistical error only. **$\Gamma(\Delta(1232)\pi, P\text{-wave})/\Gamma_{\text{total}}$** **$\Gamma_4/\Gamma$**

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

¹Statistical error only. **$\Gamma(\Delta(1232)\pi, F\text{-wave})/\Gamma_{\text{total}}$** **$\Gamma_5/\Gamma$**

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

 $\Gamma(N(1440)\pi)/\Gamma_{\text{total}}$ **Γ_6/Γ**

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

¹Statistical error only. **$\Delta(1600)$ PHOTON DECAY AMPLITUDES AT THE POLE** **$\Delta(1600) \rightarrow N\gamma$, helicity-1/2 amplitude $A_{1/2}$**

MODULUS ($\text{GeV}^{-1/2}$)	PHASE ($^\circ$)	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 $A_{3/2}$

<i>MODULUS</i> ($\text{GeV}^{-1/2}$)	<i>PHASE</i> ($^\circ$)	<i>DOCUMENT ID</i>	<i>TECN</i>	<i>COMMENT</i>
-0.006 ± 0.0013	62 ± 32	ROENCHEN	22	DPWA Multichannel
0.055 ± 0.010	152 ± 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 $A_{1/2}$**

<i>VALUE</i> ($\text{GeV}^{-1/2}$)	<i>DOCUMENT ID</i>	<i>TECN</i>	<i>COMMENT</i>
-0.060 to -0.030 ($\approx$ -0.045) OUR ESTIMATE			
0.0082 ± 0.0014	¹ HUNT	19	DPWA Multichannel
-0.051 ± 0.010	SOKHOYAN	15A	DPWA Multichannel
-0.018 ± 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 ± 0.009	ANISOVICH	12A	DPWA Multichannel
0.006 ± 0.005	¹ SHRESTHA	12A	DPWA Multichannel
0.0	PENNER	02D	DPWA Multichannel

¹Statistical error only. **$\Delta(1600) \rightarrow N\gamma$, helicity-3/2 amplitude $A_{3/2}$**

<i>VALUE</i> ($\text{GeV}^{-1/2}$)	<i>DOCUMENT ID</i>	<i>TECN</i>	<i>COMMENT</i>
-0.050 to -0.020 ($\approx$ -0.035) OUR ESTIMATE			
0.048 ± 0.014	¹ HUNT	19	DPWA Multichannel
-0.055 ± 0.010	SOKHOYAN	15A	DPWA Multichannel
-0.025 ± 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 ± 0.012	ANISOVICH	12A	DPWA Multichannel
0.052 ± 0.008	¹ SHRESTHA	12A	DPWA Multichannel
-0.024	PENNER	02D	DPWA Multichannel

¹Statistical error only. **$\Delta(1600)$ REFERENCES**For early references, see Physics Letters **111B** 1 (1982).

ROENCHEN	22	EPJ A58 229	D. Roenchen <i>et al.</i>	(JULI, GWU, BONN+)
HUNT	19	PR C99 055205	B.C. Hunt, D.M. Manley	
ROENCHEN	15A	EPJ A51 70	D. Roenchen <i>et al.</i>	
SOKHOYAN	15A	EPJ A51 95	V. Sokhoyan <i>et al.</i>	(CBELSA/TAPS Collab.)
PDG	14	CP C38 070001	K. Olive <i>et al.</i>	(PDG Collab.)
SVARC	14	PR C89 045205	A. Svarc <i>et al.</i>	(RBI Zagreb, UNI Tuzla)
ANISOVICH	12A	EPJ A48 15	A.V. Anisovich <i>et al.</i>	(BONN, PNPI)
SHRESTHA	12A	PR C86 055203	M. Shrestha, D.M. Manley	(KSU)
ARNDT	06	PR C74 045205	R.A. Arndt <i>et al.</i>	(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	πN Newsletter 9 1	G. Hohler	(KARL)
CUTKOSKY	80	Toronto Conf. 19	R.E. Cutkosky <i>et al.</i>	(CMU, LBL) IJP
Also		PR D20 2839	R.E. Cutkosky <i>et al.</i>	(CMU, LBL) IJP

HOEHLER	79	PDAT 12-1	G. Hohler <i>et al.</i>	(KARLT) IJP
Also		Toronto Conf. 3	R. Koch	(KARLT) IJP
