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

$I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$ 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				
1550±15	SARANTSEV	25	DPWA	Multichannel
1590± 1	ROENCHEN	22	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
1515±20	SOKHOYAN	15A	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				
260±20	SARANTSEV	25	DPWA	Multichannel
136± 1	ROENCHEN	22	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
250±30	SOKHOYAN	15A	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	$\pi N \rightarrow \pi N, \eta N$

[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				
1575±15	SARANTSEV	25	DPWA	Multichannel
1664±16	[1] HUNT	19	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. • • •

1520±20	SOKHOYAN	15A	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.

Δ(1600) BREIT-WIGNER WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
200 to 300 (≈ 250) OUR ESTIMATE				
290± 25	SARANTSEV	25	DPWA	Multichannel
322± 46	[1] HUNT	19	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. • • •

235± 30	SOKHOYAN	15A	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.

Δ(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	$N\rho$	(7 ±4) %
Γ_7	$N\rho$, S=1/2	(2.0±2.0) %
Γ_8	$N\rho$, S=3/2 , P-wave	(5.0±3.0) %
Γ_9	$N(1440)\pi$	17–27%
Γ_{10}	$N\gamma$	0.001–0.035 %
Γ_{11}	$N\gamma$, helicity=1/2	0.0–0.02 %
Γ_{12}	$N\gamma$, helicity=3/2	0.001–0.015 %

Δ(1600) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$ Γ_1/Γ

VALUE (%)	*DOCUMENT ID*		*TECN*	*COMMENT*
8–24% OUR ESTIMATE				
17 ±4	SEIFEN	25	DPWA	Multichannel
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. • • •					
8 ±2	[1]	SHRESTHA	12A	DPWA	Multichannel
13 ±1		PENNER	02C	DPWA	Multichannel
28 ±5		VRANA	00	DPWA	Multichannel

[1] Statistical error only.

$\Gamma(\Delta(1232)\pi)/\Gamma_{\text{total}}$ Γ_3/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
44±7	SARANTSEV	25	DPWA	Multichannel

$\Gamma(\Delta(1232)\pi, P\text{-wave})/\Gamma_{\text{total}}$ Γ_4/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
72–82% OUR ESTIMATE				
40± 6	SARANTSEV	25	DPWA	Multichannel
70± 6	SEIFEN	25	DPWA	Multichannel
64± 6	[1] HUNT	19	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •				
77± 5	SOKHOYAN	15A	DPWA	Multichannel
70± 3	[1] SHRESTHA	12A	DPWA	Multichannel
59±10	VRANA	00	DPWA	Multichannel

[1] Statistical error only.

$\Gamma(\Delta(1232)\pi, F\text{-wave})/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
<2% OUR ESTIMATE				
4±3	SARANTSEV	25	DPWA	Multichannel
<2	SEIFEN	25	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •				
<2	SOKHOYAN	15A	DPWA	Multichannel

$\Gamma(N\rho)/\Gamma_{\text{total}}$ Γ_6/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
7±4	SARANTSEV	25	DPWA	Multichannel

$\Gamma(N\rho, S{=}1/2)/\Gamma_{\text{total}}$ Γ_7/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
2±2	SARANTSEV	25	DPWA	Multichannel

$\Gamma(N\rho, S{=}3/2, P\text{-wave})/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
5±3	SARANTSEV	25	DPWA	Multichannel

$\Gamma(N(1440)\pi)/\Gamma_{\text{total}}$ Γ_9/Γ

VALUE (%)	DOCUMENT ID		TECN	COMMENT
17–27% OUR ESTIMATE				
< 1	SEIFEN	25	DPWA	Multichannel
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

Δ(1600) → Nγ, helicity-1/2 amplitude $A_{1/2}$

MODULUS ($GeV^{-1/2}$)	PHASE (°)	DOCUMENT ID		TECN	COMMENT
0.040±0.008	120 ± 20	SARANTSEV	25	DPWA	Multichannel
0.025±0.005	0.5 ± 3.0	ROENCHEN	22	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.230	−42	ROENCHEN	15A	DPWA	Multichannel
0.053±0.010	130 ± 15	SOKHOYAN	15A	DPWA	Multichannel

Δ(1600) → Nγ, helicity-3/2 amplitude $A_{3/2}$

MODULUS ($GeV^{-1/2}$)	PHASE (°)	DOCUMENT ID		TECN	COMMENT
0.038±0.012	155 ± 20	SARANTSEV	25	DPWA	Multichannel
−0.006±0.0013	62 ± 32	ROENCHEN	22	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.332	−71	ROENCHEN	15A	DPWA	Multichannel
0.055±0.010	152 ± 15	SOKHOYAN	15A	DPWA	Multichannel

Δ(1600) BREIT-WIGNER PHOTON DECAY AMPLITUDES

Δ(1600) → Nγ, helicity-1/2 amplitude $A_{1/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.060 to −0.030 (≈ −0.045) OUR ESTIMATE				
−0.042 ±0.010	SARANTSEV	25	DPWA	Multichannel
0.0082±0.0014	[1] HUNT	19	DPWA	Multichannel
−0.018 ±0.015	[1] ARNDT	96	IPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.051 ±0.010	SOKHOYAN	15A	DPWA	Multichannel
0.006 ±0.005	[1] SHRESTHA	12A	DPWA	Multichannel
0.0	PENNER	02D	DPWA	Multichannel

[1] Statistical error only.

Δ(1600) → Nγ, helicity-3/2 amplitude $A_{3/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.050 to −0.020 (≈ −0.035) OUR ESTIMATE				
−0.039±0.008	SARANTSEV	25	DPWA	Multichannel
0.048±0.014	[1] HUNT	19	DPWA	Multichannel
−0.025±0.015	[1] ARNDT	96	IPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.055±0.010	SOKHOYAN	15A	DPWA	Multichannel
0.052±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).

SARANTSEV	25	PR C112 015202	A.V. Sarantsev *et al.*	(Bonn-Gatchina Collab.)
SEIFEN	25	EPJ A61 173	T. Seifen *et al.*	(CBELSA/TAPS Collab.)
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	πN 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