

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

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

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			
1875 ± 1	ROENCHEN 22	DPWA	Multichannel
1888 ± 4	SOKHOYAN 15A	DPWA	Multichannel
1877 ± 2 ± 1	¹ SVARC 14	L+P	π N → π N
1890 ± 15	CUTKOSKY 80	IPWA	π N → π 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	π N → π N, η N
1910	VRANA 00	DPWA	Multichannel
1878	HOEHLER 93	ARGD	π N → π N

¹Fit to the amplitudes of HOEHLER 79.

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
220 to 260 (≈ 240) OUR ESTIMATE			
166 ± 2	ROENCHEN 22	DPWA	Multichannel
245 ± 8	SOKHOYAN 15A	DPWA	Multichannel
223 ± 4 ± 1	¹ SVARC 14	L+P	π N → π N
260 ± 40	CUTKOSKY 80	IPWA	π N → π 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	π N → π N, η N
230	VRANA 00	DPWA	Multichannel
230	HOEHLER 93	ARGD	π N → π N

¹Fit 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			
27 ± 1	ROENCHEN 22	DPWA	Multichannel
58 ± 2	SOKHOYAN 15A	DPWA	Multichannel
44 ± 1	¹ SVARC 14	L+P	π N → π N
50 ± 7	CUTKOSKY 80	IPWA	π N → π 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	$\pi N \rightarrow \pi N, \eta N$
47	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$

¹ Fit to the amplitudes of HOEHLER 79.

PHASE θ

VALUE (°)	DOCUMENT ID	TECN	COMMENT
−40 to −24 (≈ −32) OUR ESTIMATE			
1.1 ± 1.0	ROENCHEN	22	DPWA Multichannel
−24 ± 3	SOKHOYAN	15A	DPWA Multichannel
−39 ± 1 ± 1	¹ SVARC	14	L+P $\pi N \rightarrow \pi N$
−33 ± 8	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$

• • • 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	$\pi N \rightarrow \pi N, \eta N$
−32	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$

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 $N\pi \rightarrow \Delta(1950) \rightarrow \Sigma K$

MODULUS	PHASE (°)	DOCUMENT ID	TECN	COMMENT
0.020 ± 0.002	−40 ± 4	ROENCHEN	22	DPWA Multichannel
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 $N\pi \rightarrow \Delta(1950) \rightarrow \Delta\pi, F\text{-wave}$

MODULUS	PHASE (°)	DOCUMENT ID	TECN	COMMENT
0.30 ± 0.27	166 ± 1	ROENCHEN	22	DPWA Multichannel
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 $N\pi \rightarrow \Delta(1950) \rightarrow \Delta\pi, H\text{-wave}$

MODULUS	PHASE (°)	DOCUMENT ID	TECN	COMMENT
0.051 ± 0.004	−11 ± 1	ROENCHEN	22	DPWA Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.033	−97	ROENCHEN	15A	DPWA Multichannel

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

<u>MODULUS</u>	<u>PHASE ($^\circ$)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.035±0.005	90 ± 25	GUTZ	14	DPWA Multichannel

$\Delta(1950)$ BREIT-WIGNER MASS

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
1915 to 1950 (\approx 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

¹Statistical error only.

$\Delta(1950)$ BREIT-WIGNER WIDTH

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
235 to 335 (\approx 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

¹Statistical error only.

$\Delta(1950)$ DECAY MODES

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

Mode	Fraction (Γ_i/Γ)
Γ_1 $N\pi$	35–45 %
Γ_2 ΣK	0.3–0.5 %
Γ_3 $N\pi\pi$	37–77 %
Γ_4 $\Delta(1232)\pi, F$ -wave	1–9 %

Γ_5	$N(1680)\pi$, P -wave	3–9 %
Γ_6	$\Delta(1232)\eta$	< 0.6 %
Γ_7	$N\gamma$	0.06–0.14 %
Γ_8	$N\gamma$, helicity=1/2	0.03–0.05 %
Γ_9	$N\gamma$, helicity=3/2	0.04–0.09 %

$\Delta(1950)$ BRANCHING RATIOS

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

VALUE (%)	DOCUMENT ID	TECN	COMMENT
35–45 % OUR ESTIMATE			
38 ± 2	¹ HUNT	19	DPWA Multichannel
46 ± 2	ANISOVICH	17	DPWA Multichannel
47.1 ± 0.1	¹ ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
39 ± 4	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
38 ± 2	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
● ● ● 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

¹Statistical error only.

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

VALUE (%)	DOCUMENT ID	TECN	COMMENT
57 ± 20	GOLOVATCH	19	DPWA $\gamma p \rightarrow \pi^+ \pi^- p$

$\Gamma(\Sigma K)/\Gamma_{\text{total}}$ Γ_2/Γ

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

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

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

¹Statistical error only.

$\Gamma(N(1680)\pi, P\text{-wave})/\Gamma_{\text{total}}$ Γ_5/Γ

VALUE (%)	DOCUMENT ID	TECN	COMMENT
6 ± 3	SOKHOYAN	15A	DPWA Multichannel

$\Gamma(\Delta(1232)\eta)/\Gamma_{\text{total}}$				Γ_6/Γ
VALUE (%)	DOCUMENT ID	TECN	COMMENT	
0.3 ± 0.3	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

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

MODULUS ($\text{GeV}^{-1/2}$)	PHASE ($^\circ$)	DOCUMENT ID	TECN	COMMENT
-0.031 ± 0.002	-81 ± 4	ROENCHEN	22	DPWA Multichannel
-0.067 ± 0.004	-10 ± 5	SOKHOYAN	15A	DPWA Multichannel
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
-0.068	-19	ROENCHEN	15A	DPWA Multichannel

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

MODULUS ($\text{GeV}^{-1/2}$)	PHASE ($^\circ$)	DOCUMENT ID	TECN	COMMENT
-0.045 ± 0.002	-89 ± 2	ROENCHEN	22	DPWA Multichannel
-0.095 ± 0.004	-10 ± 5	SOKHOYAN	15A	DPWA Multichannel
● ● ● 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

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

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID	TECN	COMMENT
-0.075 to -0.065 (≈ -0.070) OUR ESTIMATE			
-0.0698 ± 0.0141	GOLOVATCH	19	DPWA $\gamma p \rightarrow \pi^+ \pi^- p$
-0.047 ± 0.002	¹ HUNT	19	DPWA Multichannel
-0.067 ± 0.005	ANISOVICH	17	DPWA Multichannel
-0.083 ± 0.004	WORKMAN	12A	DPWA $\gamma N \rightarrow N\pi$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
-0.067 ± 0.005	SOKHOYAN	15A	DPWA Multichannel
-0.067 ± 0.005	GUTZ	14	DPWA Multichannel
-0.071 ± 0.004	ANISOVICH	12A	DPWA Multichannel
-0.065 ± 0.001	¹ SHRESTHA	12A	DPWA Multichannel
-0.094	DRECHSEL	07	DPWA $\gamma N \rightarrow \pi N$

¹Statistical error only.

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

VALUE ($\text{GeV}^{-1/2}$)	DOCUMENT ID	TECN	COMMENT
-0.100 to -0.080 (≈ -0.090) OUR ESTIMATE			
-0.1181 ± 0.0193	GOLOVATCH	19	DPWA $\gamma p \rightarrow \pi^+ \pi^- p$
-0.074 ± 0.002	¹ HUNT	19	DPWA Multichannel
-0.094 ± 0.004	ANISOVICH	17	DPWA Multichannel
-0.096 ± 0.004	WORKMAN	12A	DPWA $\gamma N \rightarrow N\pi$

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

-0.094 ±0.004	SOKHOYAN	15A	DPWA	Multichannel
-0.094 ±0.004	GUTZ	14	DPWA	Multichannel
-0.094 ±0.005	ANISOVICH	12A	DPWA	Multichannel
-0.083 ±0.001	¹ SHRESTHA	12A	DPWA	Multichannel
-0.121	DRECHSEL	07	DPWA	$\gamma N \rightarrow \pi N$

¹ Statistical error only.

Δ(1950) REFERENCES

ROENCHEN	22	EPJ A58 229	D. Roenchen <i>et al.</i>	(JULI, GWU, BONN+)
GOLOVATCH	19	PL B788 371	E. Golovatch <i>et al.</i>	(CLAS Collab.)
HUNT	19	PR C99 055205	B.C. Hunt, D.M. Manley	
ANISOVICH	17	PL B766 357	A.V. Anisovich <i>et al.</i>	
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.)
GUTZ	14	EPJ A50 74	E. Gutz <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)
WORKMAN	12A	PR C86 015202	R. Workman <i>et al.</i>	(GWU)
DRECHSEL	07	EPJ A34 69	D. Drechsel, S.S. Kamalov, L. Tiator	(MAINZ, JINR)
ARNDT	06	PR C74 045205	R.A. Arndt <i>et al.</i>	(GWU)
VRANA	00	PRPL 328 181	T.P. Vrana, S.A. Dytman, T.-S.H. Lee	(PITT, ANL)
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
