

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

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

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
<b>1470 to 1590 (<math>\approx</math> 1520) OUR ESTIMATE</b>			
1590 $\pm$ 1	ROENCHEN 22	DPWA	Multichannel
1515 $\pm$ 20	SOKHOYAN 15A	DPWA	Multichannel
1469 $\pm$ 10 $\pm$ 5	<sup>1</sup> 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	$\pi N \rightarrow \pi N$

<sup>1</sup> Fit to the amplitudes of HOEHLER 79.

### –2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>150 to 320 (<math>\approx</math> 280) OUR ESTIMATE</b>			
136 $\pm$ 1	ROENCHEN 22	DPWA	Multichannel
250 $\pm$ 30	SOKHOYAN 15A	DPWA	Multichannel
314 $\pm$ 18 $\pm$ 8	<sup>1</sup> 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

<sup>1</sup> Fit to the amplitudes of HOEHLER 79.

## $\Delta(1600)$ ELASTIC POLE RESIDUE

### MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>10 to 40 (<math>\approx</math> 25) OUR ESTIMATE</b>			
11 $\pm$ 1	ROENCHEN 22	DPWA	Multichannel
13 $\pm$ 3	SOKHOYAN 15A	DPWA	Multichannel
38 $\pm$ 2 $\pm$ 2	<sup>1</sup> 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	$\pi N \rightarrow \pi N, \eta N$

<sup>1</sup> 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	<sup>1</sup> 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	$\pi N \rightarrow \pi N, \eta N$

<sup>1</sup> 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

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>1500 to 1640 (<math>\approx</math> 1570) OUR ESTIMATE</b>			
1664 $\pm$ 16	<sup>1</sup> HUNT	19	DPWA Multichannel
1520 $\pm$ 20	SOKHOYAN	15A	DPWA Multichannel
1600 $\pm$ 50	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
1522 $\pm$ 13	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
1510 $\pm$ 20	ANISOVICH	12A	DPWA Multichannel
1626 $\pm$ 8	<sup>1</sup> SHRESTHA	12A	DPWA Multichannel
1667 $\pm$ 1	PENNER	02C	DPWA Multichannel
1687 $\pm$ 44	VRANA	00	DPWA Multichannel
<sup>1</sup> Statistical error only.			

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

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>200 to 300 (<math>\approx</math> 250) OUR ESTIMATE</b>			
322 $\pm$ 46	<sup>1</sup> HUNT	19	DPWA Multichannel
235 $\pm$ 30	SOKHOYAN	15A	DPWA Multichannel
300 $\pm$ 100	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
220 $\pm$ 40	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
220 $\pm$ 45	ANISOVICH	12A	DPWA Multichannel
225 $\pm$ 18	<sup>1</sup> SHRESTHA	12A	DPWA Multichannel
397 $\pm$ 10	PENNER	02C	DPWA Multichannel
493 $\pm$ 75	VRANA	00	DPWA Multichannel
<sup>1</sup> 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 %
$\Gamma_4$ $\Delta(1232)\pi$ , <i>P</i> -wave	72–82%
$\Gamma_5$ $\Delta(1232)\pi$ , <i>F</i> -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 %

## $\Delta(1600)$ BRANCHING RATIOS

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

<u>VALUE (%)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>8–24% OUR ESTIMATE</b>			
10.7 ± 1.9	<sup>1</sup> 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	<sup>1</sup> SHRESTHA	12A	DPWA Multichannel
13 ± 1	PENNER	02C	DPWA Multichannel
28 ± 5	VRANA	00	DPWA Multichannel

<sup>1</sup>Statistical error only.

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

<u>VALUE (%)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>72–82% OUR ESTIMATE</b>			
64 ± 6	<sup>1</sup> 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	<sup>1</sup> SHRESTHA	12A	DPWA Multichannel
59 ± 10	VRANA	00	DPWA Multichannel

<sup>1</sup>Statistical error only.

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

<u>VALUE (%)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>&lt;2% OUR ESTIMATE</b>			
<2	SOKHOYAN	15A	DPWA Multichannel

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

<u>VALUE (%)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>17–27% OUR ESTIMATE</b>			
22 ± 5	<sup>1</sup> HUNT	19	DPWA Multichannel
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
22 ± 3	<sup>1</sup> SHRESTHA	12A	DPWA Multichannel
13 ± 4	VRANA	00	DPWA Multichannel

<sup>1</sup>Statistical error only.

## $\Delta(1600)$ PHOTON DECAY AMPLITUDES AT THE POLE

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

<u>MODULUS (<math>\text{GeV}^{-1/2}</math>)</u>	<u>PHASE (<math>^\circ</math>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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 $A_{3/2}$

<u>MODULUS (<math>\text{GeV}^{-1/2}</math>)</u>	<u>PHASE (<math>^\circ</math>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
$-0.006 \pm 0.0013$	$62 \pm 32$	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 $A_{1/2}$

<u>VALUE (<math>\text{GeV}^{-1/2}</math>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>-0.060 to -0.030 (<math>\approx -0.045</math>) OUR ESTIMATE</b>			
$0.0082 \pm 0.0014$	<sup>1</sup> HUNT	19	DPWA Multichannel
$-0.051 \pm 0.010$	SOKHOYAN	15A	DPWA Multichannel
$-0.018 \pm 0.015$	<sup>1</sup> 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
$0.006 \pm 0.005$	<sup>1</sup> SHRESTHA	12A	DPWA Multichannel
0.0	PENNER	02D	DPWA Multichannel

<sup>1</sup>Statistical error only.

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

<u>VALUE (<math>\text{GeV}^{-1/2}</math>)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>-0.050 to -0.020 (<math>\approx -0.035</math>) OUR ESTIMATE</b>			
$0.048 \pm 0.014$	<sup>1</sup> HUNT	19	DPWA Multichannel
$-0.055 \pm 0.010$	SOKHOYAN	15A	DPWA Multichannel
$-0.025 \pm 0.015$	<sup>1</sup> 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
$0.052 \pm 0.008$	<sup>1</sup> SHRESTHA	12A	DPWA Multichannel
-0.024	PENNER	02D	DPWA Multichannel

<sup>1</sup>Statistical 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	$\pi N$ 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

---