

$\Delta(1620) S_{31}$  $I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$  Status: \*\*\*\*

Most of the results published before 1975 were last included in our 1982 edition, Physics Letters **111B** 1 (1982). Some further obsolete results published before 1984 were last included in our 2006 edition, Journal of Physics, G **33** 1 (2006).

 **$\Delta(1620)$  BREIT-WIGNER MASS**

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>1600 to 1660 (<math>\approx</math> 1630) OUR ESTIMATE</b>			
1615.2 $\pm$ 0.4	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
1672 $\pm$ 7	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$
1620 $\pm$ 20	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
1610 $\pm$ 7	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
1650 $\pm$ 25	THOMA	08	DPWA Multichannel
1614.1 $\pm$ 1.1	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
1612 $\pm$ 2	PENNER	02C	DPWA Multichannel
1617 $\pm$ 15	VRANA	00	DPWA Multichannel
1672 $\pm$ 5	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
1617	ARNDT	95	DPWA $\pi N \rightarrow N\pi$
1669	LI	93	IPWA $\gamma N \rightarrow \pi N$
1620	BARNHAM	80	IPWA $\pi N \rightarrow N\pi\pi$
1712.8 $\pm$ 6.0	<sup>1</sup> CHEW	80	BPWA $\pi^+ p \rightarrow \pi^+ p$
1786.7 $\pm$ 2.0	<sup>1</sup> CHEW	80	BPWA $\pi^+ p \rightarrow \pi^+ p$
1580	<sup>2</sup> LONGACRE	77	IPWA $\pi N \rightarrow N\pi\pi$
1600	<sup>3</sup> LONGACRE	75	IPWA $\pi N \rightarrow N\pi\pi$

 **$\Delta(1620)$  BREIT-WIGNER WIDTH**

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>135 to 150 (<math>\approx</math> 145) OUR ESTIMATE</b>			
146.9 $\pm$ 1.9	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
154 $\pm$ 37	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$
140 $\pm$ 20	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
139 $\pm$ 18	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
250 $\pm$ 60	THOMA	08	DPWA Multichannel
141.0 $\pm$ 6.0	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
202 $\pm$ 7	PENNER	02C	DPWA Multichannel
143 $\pm$ 42	VRANA	00	DPWA Multichannel
147 $\pm$ 8	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
108	ARNDT	95	DPWA $\pi N \rightarrow N\pi$
184	LI	93	IPWA $\gamma N \rightarrow \pi N$

120	BARNHAM	80	IPWA	$\pi N \rightarrow N\pi\pi$
228.3 ± 18.0	<sup>1</sup> CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$ (lower mass)
30.0 ± 6.4	<sup>1</sup> CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$ (higher mass)
120	<sup>2</sup> LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
150	<sup>3</sup> LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

## Δ(1620) POLE POSITION

### REAL PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>1590 to 1610 (≈ 1600) OUR ESTIMATE</b>			
1595	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
1608	<sup>4</sup> HOEHLER	93	SPED $\pi N \rightarrow \pi N$
1600 ± 15	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
1615 ± 25	THOMA	08	DPWA Multichannel
1594	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
1607	VRANA	00	DPWA Multichannel
1585	ARNDT	95	DPWA $\pi N \rightarrow N\pi$
1587	ARNDT	91	DPWA $\pi N \rightarrow \pi N$ Soln SM90
1583 or 1583	<sup>5</sup> LONGACRE	78	IPWA $\pi N \rightarrow N\pi\pi$
1575 or 1572	<sup>2</sup> LONGACRE	77	IPWA $\pi N \rightarrow N\pi\pi$

### −2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>115 to 120 (≈ 118) OUR ESTIMATE</b>			
135	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
116	<sup>4</sup> HOEHLER	93	SPED $\pi N \rightarrow \pi N$
120 ± 20	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
180 ± 35	THOMA	08	DPWA Multichannel
118	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
148	VRANA	00	DPWA Multichannel
104	ARNDT	95	DPWA $\pi N \rightarrow N\pi$
120	ARNDT	91	DPWA $\pi N \rightarrow \pi N$ Soln SM90
143 or 149	<sup>5</sup> LONGACRE	78	IPWA $\pi N \rightarrow N\pi\pi$
119 or 128	<sup>2</sup> LONGACRE	77	IPWA $\pi N \rightarrow N\pi\pi$

## Δ(1620) ELASTIC POLE RESIDUE

### MODULUS |r|

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
15	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
19	HOEHLER	93	SPED $\pi N \rightarrow \pi N$
15 ± 2	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
17	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
14	ARNDT	95	DPWA $\pi N \rightarrow N\pi$
15	ARNDT	91	DPWA $\pi N \rightarrow \pi N$ Soln SM90

## PHASE $\theta$

VALUE ( $^\circ$ )	DOCUMENT ID	TECN	COMMENT
– 92	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$
– 95	HOEHLER	93	SPED $\pi N \rightarrow \pi N$
–110 $\pm$ 20	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
–104	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$
–121	ARNDT	95	DPWA $\pi N \rightarrow N\pi$
–125	ARNDT	91	DPWA $\pi N \rightarrow \pi N$ Soln SM90

## $\Delta(1620)$ DECAY MODES

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

Mode	Fraction ( $\Gamma_j/\Gamma$ )
$\Gamma_1$ $N\pi$	20–30 %
$\Gamma_2$ $N\pi\pi$	70–80 %
$\Gamma_3$ $\Delta\pi$	30–60 %
$\Gamma_4$ $\Delta(1232)\pi, D$ -wave	
$\Gamma_5$ $N\rho$	7–25 %
$\Gamma_6$ $N\rho, S=1/2, S$ -wave	
$\Gamma_7$ $N\rho, S=3/2, D$ -wave	
$\Gamma_8$ $N(1440)\pi$	
$\Gamma_9$ $N\gamma$	0.004–0.044 %
$\Gamma_{10}$ $N\gamma, \text{helicity}=1/2$	0.004–0.044 %

## $\Delta(1620)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$	DOCUMENT ID	TECN	COMMENT	$\Gamma_1/\Gamma$
<b>0.2 to 0.3 OUR ESTIMATE</b>				
0.315 $\pm$ 0.001	ARNDT	06	DPWA $\pi N \rightarrow \pi N, \eta N$	
0.09 $\pm$ 0.02	MANLEY	92	IPWA $\pi N \rightarrow \pi N \& N\pi\pi$	
0.25 $\pm$ 0.03	CUTKOSKY	80	IPWA $\pi N \rightarrow \pi N$	
0.35 $\pm$ 0.06	HOEHLER	79	IPWA $\pi N \rightarrow \pi N$	
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●				
0.22 $\pm$ 0.12	THOMA	08	DPWA Multichannel	
0.310 $\pm$ 0.004	ARNDT	04	DPWA $\pi N \rightarrow \pi N, \eta N$	
0.34 $\pm$ 0.01	PENNER	02C	DPWA Multichannel	
0.45 $\pm$ 0.05	VRANA	00	DPWA Multichannel	
0.29	ARNDT	95	DPWA $\pi N \rightarrow N\pi$	
0.60	<sup>1</sup> CHEW	80	BPWA $\pi^+ p \rightarrow \pi^+ p$ (lower mass)	
0.36	<sup>1</sup> CHEW	80	BPWA $\pi^+ p \rightarrow \pi^+ p$ (higher mass)	

Note: Signs of couplings from  $\pi N \rightarrow N\pi\pi$  analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase

ambiguity is resolved by choosing a negative sign for the  $\Delta(1620) S_{31}$  coupling to  $\Delta(1232)\pi$ .

**$(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}}$  in  $N\pi \rightarrow \Delta(1620) \rightarrow \Delta(1232)\pi$ , D-wave**  **$(\Gamma_1 \Gamma_4)^{1/2} / \Gamma$**

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>−0.36 to −0.28 OUR ESTIMATE</b>			
−0.24 ± 0.03	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N\pi\pi$
−0.33 ± 0.06	BARNHAM 80	IPWA	$\pi N \rightarrow N\pi\pi$
−0.39	<sup>2,6</sup> LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$
−0.40	<sup>3</sup> LONGACRE 75	IPWA	$\pi N \rightarrow N\pi\pi$

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

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.39 ± 0.02	VRANA 00	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.48 ± 0.25	THOMA 08	DPWA	Multichannel

**$(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}}$  in  $N\pi \rightarrow \Delta(1620) \rightarrow N\rho, S=1/2$ , S-wave**  **$(\Gamma_1 \Gamma_6)^{1/2} / \Gamma$**

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>+0.12 to +0.22 OUR ESTIMATE</b>			
+0.15 ± 0.02	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N\pi\pi$
+0.40 ± 0.10	BARNHAM 80	IPWA	$\pi N \rightarrow N\pi\pi$
+0.08	<sup>2,6</sup> LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$
+0.28	<sup>3</sup> LONGACRE 75	IPWA	$\pi N \rightarrow N\pi\pi$

**$\Gamma(N\rho, S=1/2, S\text{-wave}) / \Gamma_{\text{total}}$**   **$\Gamma_6 / \Gamma$**

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.14 ± 0.03	VRANA 00	DPWA	Multichannel

**$(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}}$  in  $N\pi \rightarrow \Delta(1620) \rightarrow N\rho, S=3/2$ , D-wave**  **$(\Gamma_1 \Gamma_7)^{1/2} / \Gamma$**

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>−0.15 to −0.03 OUR ESTIMATE</b>			
−0.06 ± 0.02	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N\pi\pi$
−0.13	<sup>2,6</sup> LONGACRE 77	IPWA	$\pi N \rightarrow N\pi\pi$

**$\Gamma(N\rho, S=3/2, D\text{-wave}) / \Gamma_{\text{total}}$**   **$\Gamma_7 / \Gamma$**

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.02 ± 0.01	VRANA 00	DPWA	Multichannel

**$(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}}$  in  $N\pi \rightarrow \Delta(1620) \rightarrow N(1440)\pi$**   **$(\Gamma_1 \Gamma_8)^{1/2} / \Gamma$**

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.11 ± 0.05	BARNHAM 80	IPWA	$\pi N \rightarrow N\pi\pi$

**$\Gamma(N(1440)\pi) / \Gamma_{\text{total}}$**   **$\Gamma_8 / \Gamma$**

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
0.00 ± 0.01	VRANA 00	DPWA	Multichannel
• • • We do not use the following data for averages, fits, limits, etc. • • •			
0.19 ± 0.12	THOMA 08	DPWA	Multichannel

## $\Delta(1620)$ PHOTON DECAY AMPLITUDES

Papers on  $\gamma N$  amplitudes predating 1981 may be found in our 2006 edition, Journal of Physics, G **33** 1 (2006).

### $\Delta(1620) \rightarrow N\gamma$ , helicity-1/2 amplitude $A_{1/2}$

VALUE ( $\text{GeV}^{-1/2}$ )	DOCUMENT ID	TECN	COMMENT
<b>+0.027 ± 0.011 OUR ESTIMATE</b>			
0.050 ± 0.002	DUGGER	07	DPWA $\gamma N \rightarrow \pi N$
0.035 ± 0.020	ARNDT	96	IPWA $\gamma N \rightarrow \pi N$
0.035 ± 0.010	CRAWFORD	83	IPWA $\gamma N \rightarrow \pi N$
0.010 ± 0.015	AWAJI	81	DPWA $\gamma N \rightarrow \pi N$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
0.066	DRECHSEL	07	DPWA $\gamma N \rightarrow \pi N$
-0.050	PENNER	02D	DPWA Multichannel
0.042 ± 0.003	LI	93	IPWA $\gamma N \rightarrow \pi N$
0.066	WADA	84	DPWA Compton scattering

### $\Delta(1620)$ FOOTNOTES

- <sup>1</sup> CHEW 80 reports two  $S_{31}$  resonances at somewhat higher masses than other analyses. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.
- <sup>2</sup> LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to  $\pi N \rightarrow N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- <sup>3</sup> From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- <sup>4</sup> See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of  $N$  and  $\Delta$  resonances as determined from Argand diagrams of  $\pi N$  elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- <sup>5</sup> LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to  $\pi N \rightarrow N\pi\pi$  data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- <sup>6</sup> LONGACRE 77 considers this coupling to be well determined.

### $\Delta(1620)$ REFERENCES

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

THOMA	08	PL B659 87	U. Thoma <i>et al.</i>	(CB-ELSA Collab.)
DRECHSEL	07	EPJ A34 69	D. Drechsel, S.S. Kamalov, L. Tiator	(MAINZ, JINR)
DUGGER	07	PR C76 025211	M. Dugger <i>et al.</i>	(Jefferson Lab CLAS Collab.)
ARNDT	06	PR C74 045205	R.A. Arndt <i>et al.</i>	(GWU)
PDG	06	JPG 33 1	W.-M. Yao <i>et al.</i>	(PDG Collab.)
ARNDT	04	PR C69 035213	R.A. Arndt <i>et al.</i>	(GWU, TRIU)
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+)
ARNDT	96	PR C53 430	R.A. Arndt, I.I. Strakovsky, R.L. Workman	(VPI)
ARNDT	95	PR C52 2120	R.A. Arndt <i>et al.</i>	(VPI, BRCO)
HOEHLER	93	$\pi N$ Newsletter 9 1	G. Hohler	(KARL)
LI	93	PR C47 2759	Z.J. Li <i>et al.</i>	(VPI)
MANLEY	92	PR D45 4002	D.M. Manley, E.M. Saleski	(KENT) IJP
Also		PR D30 904	D.M. Manley <i>et al.</i>	(VPI)

ARNDT	91	PR D43 2131	R.A. Arndt <i>et al.</i>	(VPI, TELE) IJP
WADA	84	NP B247 313	Y. Wada <i>et al.</i>	(INUS)
CRAWFORD	83	NP B211 1	R.L. Crawford, W.T. Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/9B2	G. Hohler	(KARLT)
PDG	82	PL 111B 1	M. Roos <i>et al.</i>	(HELSE, CIT, CERN)
AWAJI	81	Bonn Conf. 352	N. Awaji, R. Kajikawa	(NAGO)
Also		NP B197 365	K. Fujii <i>et al.</i>	(NAGO)
BARNHAM	80	NP B168 243	K.W.J. Barnham <i>et al.</i>	(LOIC)
CHEW	80	Toronto Conf. 123	D.M. Chew	(LBL) IJP
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
LONGACRE	78	PR D17 1795	R.S. Longacre <i>et al.</i>	(LBL, SLAC)
LONGACRE	77	NP B122 493	R.S. Longacre, J. Dolbeau	(SACL) IJP
Also		NP B108 365	J. Dolbeau <i>et al.</i>	(SACL) IJP
LONGACRE	75	PL 55B 415	R.S. Longacre <i>et al.</i>	(LBL, SLAC) IJP

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