$\Delta(1620)\ S_{31}$

$I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$ 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

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1600 to 1660 ($\approx$ 1630) OUR ESTIMATE				
1625 ±10	ANISOVICH	10	DPWA	Multichannel
1615.2$\pm$ 0.4	ARNDT	06	DPWA	$\pi N \to \pi N,\ \eta N$
1672 $\pm$ 7	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1620 ±20	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1610 $\pm$ 7	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1650 ±25	THOMA	08	DPWA	Multichannel
1614.1$\pm$ 1.1	ARNDT	04	DPWA	$\pi N \to \pi N,\ \eta N$
1612 $\pm$ 2	PENNER	02C	DPWA	Multichannel
1617 ±15	VRANA	00	DPWA	Multichannel
1672 $\pm$ 5	ARNDT	96	IPWA	$\gamma N \to \pi N$
1617	ARNDT	95	DPWA	$\pi N \to N\pi$
1669	LI	93	IPWA	$\gamma N \to \pi N$
1620	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
1712.8$\pm$ 6.0	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
1786.7$\pm$ 2.0	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$
1580	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1600	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Delta(1620)$ BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
135 to 150 ($\approx$ 145) OUR ESTIMATE				
148 ±15	ANISOVICH	10	DPWA	Multichannel
146.9$\pm$ 1.9	ARNDT	06	DPWA	$\pi N \to \pi N,\ \eta N$
154 ±37	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
140 ±20	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
139 ±18	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
250 ±60	THOMA	08	DPWA	Multichannel
141.0$\pm$ 6.0	ARNDT	04	DPWA	$\pi N \to \pi N,\ \eta N$
202 $\pm$ 7	PENNER	02C	DPWA	Multichannel
143 ±42	VRANA	00	DPWA	Multichannel
147 $\pm$ 8	ARNDT	96	IPWA	$\gamma N \to \pi N$
108	ARNDT	95	DPWA	$\pi N \to N\pi$

184		LI	93	IPWA $\gamma N \to \pi N$
120		BARNHAM	80	IPWA $\pi N \to N\pi\pi$
228.3±18.0	[1] CHEW	80	BPWA $\pi^+ p \to \pi^+ p$ (lower mass)
30.0± 6.4	[1] CHEW	80	BPWA $\pi^+ p \to \pi^+ p$ (higher mass)
120	[2] LONGACRE	77	IPWA $\pi N \to N\pi\pi$
150	[3] LONGACRE	75	IPWA $\pi N \to N\pi\pi$

$\Delta(1620)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1590 to 1610 ($\approx$ 1600) OUR ESTIMATE			
1596± 7	ANISOVICH	10	DPWA Multichannel
1595	ARNDT	06	DPWA $\pi N \to \pi N, \eta N$
1608	[4] HOEHLER	93	SPED $\pi N \to \pi N$
1600±15	CUTKOSKY	80	IPWA $\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
1615±25	THOMA	08	DPWA Multichannel
1594	ARNDT	04	DPWA $\pi N \to \pi N, \eta N$
1607	VRANA	00	DPWA Multichannel
1585	ARNDT	95	DPWA $\pi N \to N\pi$
1587	ARNDT	91	DPWA $\pi N \to \pi N$ Soln SM90
1583 or 1583	[5] LONGACRE	78	IPWA $\pi N \to N\pi\pi$
1575 or 1572	[2] LONGACRE	77	IPWA $\pi N \to N\pi\pi$

$-2\times$IMAGINARY PART

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
115 to 120 ($\approx$ 118) OUR ESTIMATE			
130±10	ANISOVICH	10	DPWA Multichannel
135	ARNDT	06	DPWA $\pi N \to \pi N, \eta N$
116	[4] HOEHLER	93	SPED $\pi N \to \pi N$
120±20	CUTKOSKY	80	IPWA $\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •			
180±35	THOMA	08	DPWA Multichannel
118	ARNDT	04	DPWA $\pi N \to \pi N, \eta N$
148	VRANA	00	DPWA Multichannel
104	ARNDT	95	DPWA $\pi N \to N\pi$
120	ARNDT	91	DPWA $\pi N \to \pi N$ Soln SM90
143 or 149	[5] LONGACRE	78	IPWA $\pi N \to N\pi\pi$
119 or 128	[2] LONGACRE	77	IPWA $\pi N \to N\pi\pi$

$\Delta(1620)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
15	ARNDT	06	DPWA $\pi N \to \pi N, \eta N$
19	HOEHLER	93	SPED $\pi N \to \pi N$
15±2	CUTKOSKY	80	IPWA $\pi N \to \pi N$

• • • 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 θ

VALUE (°)	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 ± 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 (Γ_i/Γ)
Γ_1	$N\pi$	20–30 %
Γ_2	$N\pi\pi$	70–80 %
Γ_3	$\Delta\pi$	30–60 %
Γ_4	$\Delta(1232)\pi$, D-wave	
Γ_5	$N\rho$	7–25 %
Γ_6	$N\rho$, $S=1/2$, S-wave	
Γ_7	$N\rho$, $S=3/2$, D-wave	
Γ_8	$N(1440)\pi$	
Γ_9	$N\gamma$	0.004–0.044 %
Γ_{10}	$N\gamma$, helicity$=1/2$	0.004–0.044 %

$\Delta(1620)$ BRANCHING RATIOS

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.2 to 0.3 OUR ESTIMATE				
0.23 ± 0.05	ANISOVICH	10	DPWA	Multichannel
0.315 ± 0.001	ARNDT	06	DPWA	$\pi N \rightarrow \pi N, \eta N$
0.09 ± 0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
0.25 ± 0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.35 ± 0.06	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

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

0.22 ± 0.12	THOMA	08	DPWA	Multichannel
0.310 ± 0.004	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
0.34 ± 0.01	PENNER	02C	DPWA	Multichannel
0.45 ± 0.05	VRANA	00	DPWA	Multichannel
0.29	ARNDT	95	DPWA	$\pi N \to N\pi$
0.60	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$ (lower mass)
0.36	[1] CHEW	80	BPWA	$\pi^+ p \to \pi^+ p$ (higher mass)

Note: Signs of couplings from $\pi N \to N\pi\pi$ 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 $N\pi \to \Delta(1620) \to \Delta(1232)\pi$, D-wave $(\Gamma_1\Gamma_4)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.36 to −0.28 OUR ESTIMATE				
-0.24 ± 0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
-0.33 ± 0.06	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
-0.39	[2,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
-0.40	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

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

VALUE	DOCUMENT ID		TECN	COMMENT
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 $N\pi \to \Delta(1620) \to N\rho$, $S=1/2$, S-wave $(\Gamma_1\Gamma_6)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.12 to +0.22 OUR ESTIMATE				
$+0.15 \pm 0.02$	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
$+0.40 \pm 0.10$	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
$+0.08$	[2,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
$+0.28$	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Gamma(N\rho, S=1/2, S\text{-wave})/\Gamma_{\text{total}}$ Γ_6/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.14 ± 0.03	VRANA	00	DPWA	Multichannel

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

VALUE	DOCUMENT ID		TECN	COMMENT
−0.15 to −0.03 OUR ESTIMATE				
-0.06 ± 0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
-0.13	[2,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$\Gamma(N\rho, S=3/2, D\text{-wave})/\Gamma_{total}$ Γ_7/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.02 ± 0.01	VRANA	00	DPWA	Multichannel

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.11 ± 0.05	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$

$\Gamma(N(1440)\pi)/\Gamma_{total}$ Γ_8/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
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 γN amplitudes predating 1981 may be found in our 2006 edition, Journal of Physics, G **33** 1 (2006).

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

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
$+0.027\pm0.011$ OUR ESTIMATE				
0.063 ± 0.012	ANISOVICH	10	DPWA	Multichannel
0.050 ± 0.002	DUGGER	07	DPWA	$\gamma N \to \pi N$
0.035 ± 0.020	ARNDT	96	IPWA	$\gamma N \to \pi N$
0.035 ± 0.010	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
0.010 ± 0.015	AWAJI	81	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.066	DRECHSEL	07	DPWA	$\gamma N \to \pi N$
-0.050	PENNER	02D	DPWA	Multichannel
0.042 ± 0.003	LI	93	IPWA	$\gamma N \to \pi N$
0.066	WADA	84	DPWA	Compton scattering

$\Delta(1620)$ FOOTNOTES

[1] 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.

[2] LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N\pi\pi$ 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.

[3] From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

[4] See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

[5] LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

[6] LONGACRE 77 considers this coupling to be well determined.

Δ(1620) REFERENCES

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

ANISOVICH	10	EPJ A44 203	A.V. Anisovich *et al.*	(BONN, PNPI)
THOMA	08	PL B659 87	U. Thoma *et al.*	(CB-ELSA Collab.)
DRECHSEL	07	EPJ A34 69	D. Drechsel, S.S. Kamalov, L. Tiator	(MAINZ, JINR)
DUGGER	07	PR C76 025211	M. Dugger *et al.*	(Jefferson Lab CLAS Collab.)
ARNDT	06	PR C74 045205	R.A. Arndt *et al.*	(GWU)
PDG	06	JPG 33 1	W.-M. Yao *et al.*	(PDG Collab.)
ARNDT	04	PR C69 035213	R.A. Arndt *et al.*	(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 *et al.*	(VPI, BRCO)
HOEHLER	93	πN Newsletter 9 1	G. Hohler	(KARL)
LI	93	PR C47 2759	Z.J. Li *et al.*	(VPI)
MANLEY	92	PR D45 4002	D.M. Manley, E.M. Saleski	(KENT) IJP
Also		PR D30 904	D.M. Manley *et al.*	(VPI)
ARNDT	91	PR D43 2131	R.A. Arndt *et al.*	(VPI, TELE) IJP
WADA	84	NP B247 313	Y. Wada *et al.*	(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 *et al.*	(HELS, CIT, CERN)
AWAJI	81	Bonn Conf. 352	N. Awaji, R. Kajikawa	(NAGO)
Also		NP B197 365	K. Fujii *et al.*	(NAGO)
BARNHAM	80	NP B168 243	K.W.J. Barnham *et al.*	(LOIC)
CHEW	80	Toronto Conf. 123	D.M. Chew	(LBL) IJP
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
LONGACRE	78	PR D17 1795	R.S. Longacre *et al.*	(LBL, SLAC)
LONGACRE	77	NP B122 493	R.S. Longacre, J. Dolbeau	(SACL) IJP
Also		NP B108 365	J. Dolbeau *et al.*	(SACL) IJP
LONGACRE	75	PL 55B 415	R.S. Longacre *et al.*	(LBL, SLAC) IJP