NODE=B019

$\Delta(1600)$ P_{33}

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

NODE=B019

Most of the results published before 1975 are now obsolete and have been omitted. They may be found 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).

The various analyses are not in good agreement.

$\Delta(1600)$ BREIT-WIGNER MASS

NODE=B019205

NODE=B019M

→ NOT CHECKED ←

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1550 to 1700 (≈ 1600) OUR ESTIMATE				
1706±10	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1600±50	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1522±13	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1667± 1	PENNER	02C	DPWA	Multichannel
1687±44	VRANA	00	DPWA	Multichannel
1672±15	ARNDT	96	IPWA	$\gamma N \to \pi N$
1706	LI	93	IPWA	$\gamma N \to \pi N$
1690	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
1560	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1640	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Delta(1600)$ BREIT-WIGNER WIDTH

NODE=B019210

NODE=B019W

→ NOT CHECKED ←

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
250 to 450 (≈ 350) OUR ESTIMATE				
430± 73	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
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. • • •				
397± 10	PENNER	02C	DPWA	Multichannel
493± 75	VRANA	00	DPWA	Multichannel
315± 20	ARNDT	96	IPWA	$\gamma N \to \pi N$
215	LI	93	IPWA	$\gamma N \to \pi N$
250	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
180	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
300	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Delta(1600)$ POLE POSITION

NODE=B019215

REAL PART

NODE=B019RE

NODE=B019RE

→ NOT CHECKED ←

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1500 to 1700 (≈ 1600) OUR ESTIMATE				
1457	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
1550	[3] HOEHLER	93	SPED	$\pi N \to \pi N$
1550±40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1599	VRANA	00	DPWA	Multichannel
1675	ARNDT	95	DPWA	$\pi N \to N\pi$
1612	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
1609 or 1610	[4] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
1541 or 1542	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

−2×IMAGINARY PART

NODE=B019IM

NODE=B019IM

→ NOT CHECKED ←

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
200 to 400 (≈ 300) OUR ESTIMATE				
400	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
200±60	CUTKOSKY	80	IPWA	$\pi N \to \pi N$

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

312	VRANA	00	DPWA	Multichannel
386	ARNDT	95	DPWA	$\pi N \to N\pi$
230	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
323 or 325	[4] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
178 or 178	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

Δ(1600) ELASTIC POLE RESIDUE

NODE=B019220

MODULUS $|r|$

NODE=B019RER
NODE=B019RER

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
44	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
17±4	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
52	ARNDT	95	DPWA	$\pi N \to N\pi$
16	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

PHASE θ

NODE=B019IMR
NODE=B019IMR

VALUE (°)	DOCUMENT ID		TECN	COMMENT
+147	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
−150±30	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+ 14	ARNDT	95	DPWA	$\pi N \to N\pi$
− 73	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

Δ(1600) DECAY MODES

NODE=B019225;NODE=B019

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

NODE=B019

	Mode	Fraction (Γ_i/Γ)	
Γ_1	$N\pi$	10–25 %	DESIG=1;OUR EST
Γ_2	ΣK		DESIG=2
Γ_3	$N\pi\pi$	75–90 %	DESIG=11;OUR EST
Γ_4	$\Delta\pi$	40–70 %	DESIG=22;OUR EST
Γ_5	$\Delta(1232)\pi$, P-wave		DESIG=3
Γ_6	$\Delta(1232)\pi$, F-wave		DESIG=4
Γ_7	$N\rho$	<25 %	DESIG=23;OUR EST
Γ_8	$N\rho$, S=1/2, P-wave		DESIG=5
Γ_9	$N\rho$, S=3/2, P-wave		DESIG=6
Γ_{10}	$N\rho$, S=3/2, F-wave		DESIG=7
Γ_{11}	$N(1440)\pi$	10–35 %	DESIG=24;OUR EST
Γ_{12}	$N(1440)\pi$, P-wave		DESIG=8
Γ_{13}	$N\gamma$	0.001–0.02 %	DESIG=25;OUR EST
Γ_{14}	$N\gamma$, helicity=1/2	0.0–0.02 %	DESIG=9;OUR EST
Γ_{15}	$N\gamma$, helicity=3/2	0.001–0.005 %	DESIG=10;OUR EST

Δ(1600) BRANCHING RATIOS

NODE=B019230

$\Gamma(N\pi)/\Gamma_{total}$ Γ_1/Γ

NODE=B019R1
NODE=B019R1
→ NOT CHECKED ←

VALUE	DOCUMENT ID		TECN	COMMENT
0.10 to 0.25 OUR ESTIMATE				
0.12±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.18±0.04	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.21±0.06	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.13±0.01	PENNER	02C	DPWA	Multichannel
0.28±0.05	VRANA	00	DPWA	Multichannel

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to \Sigma K$ $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

NODE=B019R2

VALUE	DOCUMENT ID		TECN	COMMENT
−0.36 to −0.28 OUR ESTIMATE				
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.006 to 0.042	[5] DEANS	75	DPWA	$\pi N \to \Sigma K$

NODE=B019R2 → NOT CHECKED ←

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 $\Delta(1232)\pi$.

NODE=B019310

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to \Delta(1232)\pi$, P-wave $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

NODE=B019R3

VALUE	DOCUMENT ID		TECN	COMMENT
+0.27 to +0.33 OUR ESTIMATE				
+0.29±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
+0.24±0.05	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$
+0.34	[1,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
+0.30	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

NODE=B019R3 → NOT CHECKED ←

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

NODE=B019R8

VALUE	DOCUMENT ID		TECN	COMMENT
0.59±0.10	VRANA	00	DPWA	Multichannel

NODE=B019R8

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to \Delta(1232)\pi$, F-wave $(\Gamma_1\Gamma_6)^{1/2}/\Gamma$

NODE=B019R4

VALUE	DOCUMENT ID		TECN	COMMENT
−0.15 to −0.03 OUR ESTIMATE				
−0.07	[1,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

NODE=B019R4 → NOT CHECKED ←

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to N\rho$, S=1/2, P-wave $(\Gamma_1\Gamma_8)^{1/2}/\Gamma$

NODE=B019R5

VALUE	DOCUMENT ID		TECN	COMMENT
+0.10	[1,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

NODE=B019R5

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to N\rho$, S=3/2, P-wave $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$

NODE=B019R6

VALUE	DOCUMENT ID		TECN	COMMENT
+0.10	[1,6] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

NODE=B019R6

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to \Delta(1600) \to N(1440)\pi$, P-wave $(\Gamma_1\Gamma_{12})^{1/2}/\Gamma$

NODE=B019R7

VALUE	DOCUMENT ID		TECN	COMMENT
+0.15 to +0.23 OUR ESTIMATE				
+0.16±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
+0.23±0.04	BARNHAM	80	IPWA	$\pi N \to N\pi\pi$

NODE=B019R7 → NOT CHECKED ←

$\Gamma(N(1440)\pi)/\Gamma_{total}$ Γ_{11}/Γ

NODE=B019R9

VALUE	DOCUMENT ID		TECN	COMMENT
0.13±0.04	VRANA	00	DPWA	Multichannel

NODE=B019R9

$\Delta(1600)$ PHOTON DECAY AMPLITUDES

NODE=B019235

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

NODE=B019235

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

NODE=B019A1

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.023±0.020 OUR ESTIMATE				
−0.018±0.015	ARNDT	96	IPWA	$\gamma N \to \pi N$
−0.039±0.030	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
−0.046±0.013	AWAJI	81	DPWA	$\gamma N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.0	PENNER	02D	DPWA	Multichannel
−0.026±0.002	LI	93	IPWA	$\gamma N \to \pi N$
−0.200	[7] WADA	84	DPWA	Compton scattering
0.000±0.030	BARBOUR	78	DPWA	$\gamma N \to \pi N$

NODE=B019A1 → NOT CHECKED ←

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

NODE=B019A2
NODE=B019A2

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.009±0.021 OUR ESTIMATE				
−0.025±0.015	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
−0.013±0.014	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.025±0.031	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.024	PENNER	02D	DPWA	Multichannel
−0.016±0.002	LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.023	WADA	84	DPWA	Compton scattering
0.000±0.045	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

→ NOT CHECKED ←

$\Delta(1600)$ FOOTNOTES

NODE=B019

[1] 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. NODE=B019;LINKAGE=L7

[2] From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes. NODE=B019;LINKAGE=L5

[3] 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. NODE=B010;LINKAGE=H9

[4] 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. NODE=B019;LINKAGE=L8

[5] The range given is from the four best solutions. DEANS 75 disagrees with $\pi^+ p \rightarrow \Sigma^+ K^+$ data of WINNIK 77 around 1920 MeV. NODE=B019;LINKAGE=C

[6] LONGACRE 77 considers this coupling to be well determined. NODE=B019;LINKAGE=X

[7] WADA 84 is inconsistent with other analyses — see the Note on N and Δ Resonances. NODE=B019;LINKAGE=P

$\Delta(1600)$ REFERENCES

NODE=B019

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

NODE=B019

ARNDT	06	PR C74 045205	R.A. Arndt *et al.*	(GWU)	REFID=51535
PDG	06	JPG 33 1	W.-M. Yao *et al.*	(PDG Collab.)	REFID=51004
PENNER	02C	PR C66 055211	G. Penner, U. Mosel	(GIES)	REFID=49129
PENNER	02D	PR C66 055212	G. Penner, U. Mosel	(GIES)	REFID=49130
VRANA	00	PRPL 328 181	T.P. Vrana, S.A. Dytman,, T.-S.H. Lee	(PITT+)	REFID=47593
ARNDT	96	PR C53 430	R.A. Arndt, I.I. Strakovsky, R.L. Workman	(VPI)	REFID=44675
ARNDT	95	PR C52 2120	R.A. Arndt *et al.*	(VPI, BRCO)	REFID=44535
HOEHLER	93	πN Newsletter 9 1	G. Hohler	(KARL)	REFID=43821
LI	93	PR C47 2759	Z.J. Li *et al.*	(VPI)	REFID=43327
MANLEY	92	PR D45 4002	D.M. Manley, E.M. Saleski	(KENT) IJP	REFID=41535
Also		PR D30 904	D.M. Manley *et al.*	(VPI)	REFID=30071
ARNDT	91	PR D43 2131	R.A. Arndt *et al.*	(VPI, TELE) IJP	REFID=41467
WADA	84	NP B247 313	Y. Wada *et al.*	(INUS)	REFID=30072
CRAWFORD	83	NP B211 1	R.L. Crawford, W.T. Morton	(GLAS)	REFID=30070
PDG	82	PL 111B 1	M. Roos *et al.*	(HELS, CIT, CERN)	REFID=41167
AWAJI	81	Bonn Conf. 352	N. Awaji, R. Kajikawa	(NAGO)	REFID=30067
Also		NP B197 365	K. Fujii *et al.*	(NAGO)	REFID=30068
BARNHAM	80	NP B168 243	K.W.J. Barnham *et al.*	(LOIC)	REFID=31072
CUTKOSKY	80	Toronto Conf. 19	R.E. Cutkosky *et al.*	(CMU, LBL) IJP	REFID=30064
Also		PR D20 2839	R.E. Cutkosky *et al.*	(CMU, LBL) IJP	REFID=40096
HOEHLER	79	PDAT 12-1	G. Hohler *et al.*	(KARLT) IJP	REFID=30058
Also		Toronto Conf. 3	R. Koch	(KARLT) IJP	REFID=30859
BARBOUR	78	NP B141 253	I.M. Barbour, R.L. Crawford, N.H. Parsons	(GLAS)	REFID=30053
LONGACRE	78	PR D17 1795	R.S. Longacre *et al.*	(LBL, SLAC)	REFID=30054
LONGACRE	77	NP B122 493	R.S. Longacre, J. Dolbeau	(SACL) IJP	REFID=30051
Also		NP B108 365	J. Dolbeau *et al.*	(SACL) IJP	REFID=30052
WINNIK	77	NP B128 66	M. Winnik *et al.*	(HAIF) I	REFID=30378
DEANS	75	NP B96 90	S.R. Deans *et al.*	(SFLA, ALAH) IJP	REFID=30383
LONGACRE	75	PL 55B 415	R.S. Longacre *et al.*	(LBL, SLAC) IJP	REFID=30047