$N(1440)\ P_{11}$

$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ∗∗∗∗

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** (1982).

N(1440) BREIT-WIGNER MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1430 to 1470 (≈ 1440) OUR ESTIMATE				
1462±10	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1440±30	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1410±12	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1463± 7	ARNDT	96	IPWA	$\gamma N \to \pi N$
1467	ARNDT	95	DPWA	$\pi N \to N\pi$
1421±18	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$
1465	LI	93	IPWA	$\gamma N \to \pi N$
1471	CUTKOSKY	90	IPWA	$\pi N \to \pi N$
1411	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
1472	[1] BAKER	79	DPWA	$\pi^- p \to n\eta$
1417	BARBOUR	78	DPWA	$\gamma N \to \pi N$
1460	BERENDS	77	IPWA	$\gamma N \to \pi N$
1380	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1390	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

N(1440) BREIT-WIGNER WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
250 to 450 (≈ 350) OUR ESTIMATE				
391± 34	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
545±170	CUTKOSKY	90	IPWA	$\pi N \to \pi N$
340± 70	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
135± 10	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
360± 20	ARNDT	96	IPWA	$\gamma N \to \pi N$
440	ARNDT	95	DPWA	$\pi N \to N\pi$
250± 63	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$
315	LI	93	IPWA	$\gamma N \to \pi N$
334	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
113	[1] BAKER	79	DPWA	$\pi^- p \to n\eta$
331	BARBOUR	78	DPWA	$\gamma N \to \pi N$
279	BERENDS	77	IPWA	$\gamma N \to \pi N$
200	[2] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
200	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$N(1440)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1345 to 1385 (≈ 1365) OUR ESTIMATE				
1346	[4] ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
1385	[5] HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1370	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
1375±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1360	[6] ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1381 or 1379	[7] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$
1360 or 1333	[2] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
160 to 260 (≈ 210) OUR ESTIMATE				
176	[4] ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
164	[5] HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
228	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
180±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
252	[6] ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
209 or 210	[7] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$
167 or 234	[2] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$

$N(1440)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
42	[4] ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
40	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
74	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
52±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
109	[6] ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−101	[4] ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
− 84	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
−100±35	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
− 93	[6] ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

$N(1440)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	60–70 %
Γ_2	$N\eta$	
Γ_3	$N\pi\pi$	30–40 %
Γ_4	$\Delta\pi$	20–30 %
Γ_5	$\Delta(1232)\pi$, P-wave	
Γ_6	$N\rho$	<8 %
Γ_7	$N\rho$, S=1/2, P-wave	
Γ_8	$N\rho$, S=3/2, P-wave	
Γ_9	$N(\pi\pi)^{I=0}_{S\text{-wave}}$	5–10 %
Γ_{10}	$p\gamma$	0.035–0.048 %
Γ_{11}	$p\gamma$, helicity=1/2	0.035–0.048 %
Γ_{12}	$n\gamma$	0.009–0.032 %
Γ_{13}	$n\gamma$, helicity=1/2	0.009–0.032 %

$N(1440)$ BRANCHING RATIOS

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.6 to 0.7 OUR ESTIMATE				
0.69±0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.68±0.04	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.51±0.05	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.68	ARNDT	95	DPWA	$\pi N \to N\pi$
0.56±0.08	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to N(1440) \to N\eta$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
seen	[1] BAKER	79	DPWA	$\pi^- p \to n\eta$
+0.328	[8] FELTESSE	75	DPWA	1488–1745 MeV

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 $N\pi \to N(1440) \to \Delta(1232)\pi$, P-wave — $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.37 to +0.41 OUR ESTIMATE				
+0.39±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
+0.41	[2,9] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
+0.37	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1440) \to N\rho$, S=1/2, P-wave $\qquad (\Gamma_1\Gamma_7)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
±0.07 to ±0.25 OUR ESTIMATE				
−0.11	[2,9] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
+0.23	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1440) \to N\rho$, S=3/2, P-wave $\qquad (\Gamma_1\Gamma_8)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.18	[2,9] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1440) \to N(\pi\pi)^{I=0}_{S\text{-wave}}$ $\qquad (\Gamma_1\Gamma_9)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
±0.17 to ±0.25 OUR ESTIMATE				
+0.24±0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
−0.18	[2,9] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
−0.23	[3] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

N(1440) PHOTON DECAY AMPLITUDES

$N(1440) \to p\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($\mathrm{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.065 ±0.004 OUR ESTIMATE				
−0.063 ±0.005	ARNDT	96	IPWA	$\gamma N \to \pi N$
−0.069 ±0.018	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
−0.063 ±0.008	AWAJI	81	DPWA	$\gamma N \to \pi N$
−0.069 ±0.004	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
−0.066 ±0.004	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
−0.079 ±0.009	BRATASHEV...	80	DPWA	$\gamma N \to \pi N$
−0.068 ±0.015	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
−0.0584±0.0148	ISHII	80	DPWA	Compton scattering
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.085 ±0.003	LI	93	IPWA	$\gamma N \to \pi N$
−0.129	[10] WADA	84	DPWA	Compton scattering
−0.075 ±0.015	BARBOUR	78	DPWA	$\gamma N \to \pi N$
−0.125	[11] NOELLE	78		$\gamma N \to \pi N$
−0.076	BERENDS	77	IPWA	$\gamma N \to \pi N$
−0.087 ±0.006	FELLER	76	DPWA	$\gamma N \to \pi N$

$N(1440) \to n\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($\mathrm{GeV}^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
+0.040±0.010 OUR ESTIMATE				
0.045±0.015	ARNDT	96	IPWA	$\gamma N \to \pi N$
0.037±0.010	AWAJI	81	DPWA	$\gamma N \to \pi N$
0.030±0.003	FUJII	81	DPWA	$\gamma N \to \pi N$
0.023±0.009	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
0.019±0.012	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
0.056±0.015	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
−0.029±0.035	TAKEDA	80	DPWA	$\gamma N \to \pi N$

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

0.085±0.006	LI	93	IPWA	$\gamma N \to \pi N$
+0.059±0.016	BARBOUR	78	DPWA	$\gamma N \to \pi N$
0.062	[11] NOELLE	78		$\gamma N \to \pi N$

N(1440) FOOTNOTES

[1] BAKER 79 finds a coupling of the $N(1440)$ to the $N\eta$ channel near (but slightly below) threshold.

[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] ARNDT 95 also finds a second-sheet pole with real part = 1383 MeV, $-2\times$imaginary part = 210 MeV, and residue with modulus 92 MeV and phase = $-54°$.

[5] 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.

[6] ARNDT 91 (Soln SM90) also finds a second-sheet pole with real part = 1413 MeV, $-2\times$ imaginary part = 256 MeV, and residue = $(78-153i)$ MeV.

[7] 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.

[8] An alternative which cannot be distinguished from this is to have a P_{13} resonance with M = 1530 MeV, Γ = 79 MeV, and elasticity = +0.271.

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

[10] WADA 84 is inconsistent with other analyses; see the Note on N and Δ Resonances.

[11] Converted to our conventions using M = 1486 MeV, Γ = 613 MeV from NOELLE 78.

N(1440) REFERENCES

For early references, see Physics Letters **111B** 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
Also	98	PR C57 1004 (erratum)	M. Batinic+	
HOEHLER	93	πN Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CUTKOSKY	90	PR D42 235	+Wang	(CMU)
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWAJI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
BRATASHEV...	80	NP B166 525	Bratashevskij, Gorbenko, Derebchinskij+	(KFTI)

CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
ISHII	80	NP B165 189	+Egawa, Kato, Miyachi+	(KYOT, INUS)
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOELLE	78	PTP 60 778		(NAGO)
BERENDS	77	NP B136 317	+Donnachie	(LEID, MCHS) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	(SACL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP