$N(1535)$ S_{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).

$N(1535)$ MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1520 to 1555 (≈ 1535) OUR ESTIMATE				
1534± 7	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1550±40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1526± 7	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1549± 2	ABAEV	96	DPWA	$\pi^- p \to \eta n$
1525±10	ARNDT	96	IPWA	$\gamma N \to \pi N$
1535	ARNDT	95	DPWA	$\pi N \to N\pi$
1542± 6	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$
1537	BATINIC	95B	DPWA	$\pi N \to N\pi$, $N\eta$
1544±13	KRUSCHE	95	DPWA	$\gamma p \to p\eta$
1518	LI	93	IPWA	$\gamma N \to \pi N$
1513	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
1511	BARBOUR	78	DPWA	$\gamma N \to \pi N$
1500	BERENDS	77	IPWA	$\gamma N \to \pi N$
1547± 6	BHANDARI	77	DPWA	Uses $N\eta$ cusp
1520	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1510	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$N(1535)$ WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
100 to 250 (≈ 150) OUR ESTIMATE				
151±27	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
240±80	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
120±20	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
169±12	ABAEV	96	DPWA	$\pi^- p \to \eta n$
103± 5	ARNDT	96	IPWA	$\gamma N \to \pi N$
66	ARNDT	95	DPWA	$\pi N \to N\pi$
150±15	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$
145	BATINIC	95B	DPWA	$\pi N \to N\pi$, $N\eta$
200±40	KRUSCHE	95	DPWA	$\gamma p \to p\eta$
84	LI	93	IPWA	$\gamma N \to \pi N$
136	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
180	BAKER	79	DPWA	$\pi^- p \to n\eta$
132	BARBOUR	78	DPWA	$\gamma N \to \pi N$
57	BERENDS	77	IPWA	$\gamma N \to \pi N$
139±33	BHANDARI	77	DPWA	Uses $N\eta$ cusp
135	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
100	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$N(1535)$ POLE POSITION

REAL PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1501	ARNDT	95	DPWA	$\pi N \to N\pi$
1487	[3] HOEHLER	93	SPED	$\pi N \to \pi N$
1510±50	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1499	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
1496 or 1499	[4] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
1519± 4	BHANDARI	77	DPWA	Uses $N\eta$ cusp
1525 or 1527	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
124	ARNDT	95	DPWA	$\pi N \to N\pi$
260±80	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
110	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
103 or 105	[4] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
140±32	BHANDARI	77	DPWA	Uses $N\eta$ cusp
135 or 123	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

N(1535) ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
31	ARNDT	95	DPWA	$\pi N \to N\pi$
120±40	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
23	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
−12	ARNDT	95	DPWA	$\pi N \to N\pi$
+15±45	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−13	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

N(1535) DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	35–55 %
Γ_2	$N\eta$	30–55 %
Γ_3	$N\pi\pi$	1–10 %
Γ_4	$\Delta\pi$	<1 %
Γ_5	$\Delta(1232)\pi$, *D*-wave	
Γ_6	$N\rho$	<4 %
Γ_7	$N\rho$, *S*=1/2, *S*-wave	
Γ_8	$N\rho$, *S*=3/2, *D*-wave	
Γ_9	$N(\pi\pi)^{I=0}_{S\text{-wave}}$	<3 %
Γ_{10}	$N(1440)\pi$	<7 %
Γ_{11}	$p\gamma$	0.08–0.27 %
Γ_{12}	$p\gamma$, helicity=1/2	0.08–0.27 %
Γ_{13}	$n\gamma$	0.004–0.29 %
Γ_{14}	$n\gamma$, helicity=1/2	0.004–0.29 %

N(1535) BRANCHING RATIOS

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.35 to 0.55 OUR ESTIMATE				
0.51 ±0.05	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.50 ±0.10	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.38 ±0.04	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.31	ARNDT	95	DPWA	$\pi N \to N\pi$
0.34 ±0.09	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$
0.297±0.026	BHANDARI	77	DPWA	Uses $N\eta$ cusp

$\Gamma(N\eta)/\Gamma_{\text{total}}$ Γ_2/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.59±0.02	ABAEV	96	DPWA	$\pi^- p \to \eta n$
0.63±0.07	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1535) \to N\eta$ $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.44 to +0.50 OUR ESTIMATE				
+0.47±0.02	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
+0.33	BAKER	79	DPWA	$\pi^- p \to n\eta$
+0.48	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 $\Delta(1232)\pi$.

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1535) \to \Delta(1232)\pi$, D-wave $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.04 to +0.06 OUR ESTIMATE				
+0.00±0.04	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.00	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
+0.06	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1535) \to N\rho$, $S=1/2$, S-wave $(\Gamma_1\Gamma_7)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
−0.14 to −0.06 OUR ESTIMATE				
−0.10±0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
−0.10	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
−0.09	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1535) \to N(\pi\pi)^{I=0}_{S\text{-wave}}$ $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.03 to +0.13 OUR ESTIMATE				
+0.07±0.04	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
+0.08	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
+0.09	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1535) \to N(1440)\pi$ $(\Gamma_1\Gamma_{10})^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
+0.10±0.05	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$

$N(1535)$ PHOTON DECAY AMPLITUDES

$N(1535) \to p\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
+0.070 ±0.012 OUR ESTIMATE				
0.060 ±0.015	ARNDT	96	IPWA	$\gamma N \to \pi N$
0.097 ±0.006	BENMERROU..	95	DPWA	$\gamma N \to N\eta$
0.095 ±0.011	[5] BENMERROU..	91		$\gamma p \to p\eta$
0.053 ±0.015	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
0.077 ±0.021	AWAJI	81	DPWA	$\gamma N \to \pi N$
0.083 ±0.007	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
0.080 ±0.007	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
0.029 ±0.007	BRATASHEV...	80	DPWA	$\gamma N \to \pi N$
0.065 ±0.016	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
0.0704±0.0091	ISHII	80	DPWA	Compton scattering
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.110 to 0.140	KRUSCHE	95	DPWA	$\gamma p \to p\eta$
0.125 ±0.025	KRUSCHE	95C	IPWA	$\gamma d \to \eta N(N)$
0.061 ±0.003	LI	93	IPWA	$\gamma N \to \pi N$
0.055	WADA	84	DPWA	Compton scattering
+0.082 ±0.019	BARBOUR	78	DPWA	$\gamma N \to \pi N$
0.046	[6] NOELLE	78		$\gamma N \to \pi N$
+0.034	BERENDS	77	IPWA	$\gamma N \to \pi N$
+0.070 ±0.004	FELLER	76	DPWA	$\gamma N \to \pi N$

$N(1535) \rightarrow n\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
-0.046 ± 0.027 OUR ESTIMATE				
-0.020 ± 0.035	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.035 ± 0.014	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
-0.062 ± 0.003	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
-0.075 ± 0.019	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
-0.075 ± 0.018	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
-0.098 ± 0.026	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
-0.011 ± 0.017	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
-0.100 ± 0.030	KRUSCHE	95C	IPWA	$\gamma d \rightarrow \eta N(N)$
-0.046 ± 0.005	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.112 ± 0.034	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
-0.048	[6] NOELLE	78		$\gamma N \rightarrow \pi N$

$N(1535) \rightarrow N\gamma_{\parallel}$ ratio $A^n_{1/2}/A^p_{1/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •			
-0.84 ± 0.15	MUKHOPAD...	95B	IPWA

$N(1535)$ FOOTNOTES

[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.

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

[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.

[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.

[5] BENMERROUCHE 91 uses an effective Lagrangian approach to analyze η photoproduction data.

[6] Converted to our conventions using $M = 1548$ MeV, $\Gamma = 73$ MeV from NOELLE 78.

$N(1535)$ REFERENCES

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

ABAEV	96	PR C53 385	+Nefkens	(UCLA)
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)
BATINIC	95B	PR C52 2188	+Slaus, Svarc	(BOSK)
BENMERROU...	95	PR D51 3237	Benmerrouche, Mukhopadhyay, Zhang	(RPI, SASK)
KRUSCHE	95	PRL 74 3736	+Ahrens, Anton+	(GIES, MANZ, GLAS, BONN, DARM)
KRUSCHE	95C	PL B358 40	+Ahrens+	(GIES, MANZ, GLAS, BONN, DARM)
MUKHOPAD...	95B	PL B364 1	Mukhopadhyay, Zhang, Benmerrouche	(RPI, SASK)
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
BENMERROU...	91	PRL 67 1070	Benmerrouche, Mukhopadhyay	(RPI)
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
BHANDARI	77	PR D15 192	+Chao	(CMU) 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