$N(1520)$ D_{13}

$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$ 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(1520) MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1515 to 1530 (≈ 1520) OUR ESTIMATE				
1524± 4	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
1525±10	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
1519± 4	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1516±10	ARNDT	96	IPWA	$\gamma N \to \pi N$
1515	ARNDT	95	DPWA	$\pi N \to N\pi$
1526±18	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$
1510	LI	93	IPWA	$\gamma N \to \pi N$
1504	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
1503	BARBOUR	78	DPWA	$\gamma N \to \pi N$
1510	BERENDS	77	IPWA	$\gamma N \to \pi N$
1510	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1520	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

N(1520) WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
110 to 135 (≈ 120) OUR ESTIMATE				
124± 8	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
120±15	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
114± 7	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
106± 4	ARNDT	96	IPWA	$\gamma N \to \pi N$
106	ARNDT	95	DPWA	$\pi N \to N\pi$
143±32	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$
120	LI	93	IPWA	$\gamma N \to \pi N$
124	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
183	BAKER	79	DPWA	$\pi^- p \to n\eta$
135	BARBOUR	78	DPWA	$\gamma N \to \pi N$
105	BERENDS	77	IPWA	$\gamma N \to \pi N$
110	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
150	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

N(1520) POLE POSITION

REAL PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1515	ARNDT	95	DPWA	$\pi N \to N\pi$
1510	[3] HOEHLER	93	ARGD	$\pi N \to \pi N$
1510±5	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1511	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
1514 or 1511	[4] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
1508 or 1505	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
110	ARNDT	95	DPWA	$\pi N \to N\pi$
120	[3] HOEHLER	93	ARGD	$\pi N \to \pi N$
114±10	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
108	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90
146 or 137	[4] LONGACRE	78	IPWA	$\pi N \to N\pi\pi$
109 or 107	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$

N(1520) ELASTIC POLE RESIDUE

MODULUS $|r|$

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
34	ARNDT	95	DPWA	$\pi N \to N\pi$
32	HOEHLER	93	ARGD	$\pi N \to \pi N$
35±2	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
33	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

PHASE θ

VALUE (°)	*DOCUMENT ID*		*TECN*	*COMMENT*
7	ARNDT	95	DPWA	$\pi N \to N\pi$
− 8	HOEHLER	93	ARGD	$\pi N \to \pi N$
−12±5	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−10	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

$N(1520)$ DECAY MODES

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

	Mode	Fraction (Γ_i/Γ)
Γ_1	$N\pi$	50–60 %
Γ_2	$N\eta$	
Γ_3	$N\pi\pi$	40–50 %
Γ_4	$\Delta\pi$	15–25 %
Γ_5	$\Delta(1232)\pi$, S-wave	5–12 %
Γ_6	$\Delta(1232)\pi$, D-wave	10–14 %
Γ_7	$N\rho$	15–25 %
Γ_8	$N\rho$, S=1/2, D-wave	
Γ_9	$N\rho$, S=3/2, S-wave	
Γ_{10}	$N\rho$, S=3/2, D-wave	
Γ_{11}	$N(\pi\pi)^{I=0}_{S\text{-wave}}$	<8 %
Γ_{12}	$p\gamma$	0.46–0.56 %
Γ_{13}	$p\gamma$, helicity=1/2	0.001–0.034 %
Γ_{14}	$p\gamma$, helicity=3/2	0.44–0.53 %
Γ_{15}	$n\gamma$	0.30–0.53 %
Γ_{16}	$n\gamma$, helicity=1/2	0.04–0.10 %
Γ_{17}	$n\gamma$, helicity=3/2	0.25–0.45 %

$N(1520)$ BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{total}$ Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.5 to 0.6 OUR ESTIMATE				
0.59±0.03	MANLEY	92	IPWA	$\pi N \to \pi N$ & $N\pi\pi$
0.58±0.03	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
0.54±0.03	HOEHLER	79	IPWA	$\pi N \to \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.61	ARNDT	95	DPWA	$\pi N \to N\pi$
0.46±0.06	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$

$\Gamma(N\eta)/\Gamma_{total}$ Γ_2/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.001±0.002	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow N(1520) \rightarrow N\eta$ $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.02	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
+0.011	FELTESSE	75	DPWA	Soln A; see BAKER 79

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 $\Delta(1232)\pi$.

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow N(1520) \rightarrow \Delta(1232)\pi$, S-wave $(\Gamma_1\Gamma_5)^{1/2}/\Gamma$

VALUE		DOCUMENT ID		TECN	COMMENT
−0.26 to −0.20 OUR ESTIMATE					
−0.18 ± 0.05		MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
−0.26	[1,5]	LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
−0.24	[2]	LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow N(1520) \rightarrow \Delta(1232)\pi$, D-wave $(\Gamma_1\Gamma_6)^{1/2}/\Gamma$

VALUE		DOCUMENT ID		TECN	COMMENT
−0.28 to −0.24 OUR ESTIMATE					
−0.29 ± 0.03		MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
−0.21	[1,5]	LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
−0.30	[2]	LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow N(1520) \rightarrow N\rho$, S=3/2, S-wave $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$

VALUE		DOCUMENT ID		TECN	COMMENT
−0.35 to −0.31 OUR ESTIMATE					
−0.35 ± 0.03		MANLEY	92	IPWA	$\pi N \rightarrow \pi N$ & $N\pi\pi$
−0.35	[1,5]	LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
−0.24	[2]	LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow N(1520) \rightarrow N(\pi\pi)^{I=0}_{S\text{-wave}}$ $(\Gamma_1\Gamma_{11})^{1/2}/\Gamma$

VALUE		DOCUMENT ID		TECN	COMMENT
−0.22 to −0.06 OUR ESTIMATE					
−0.13	[1,5]	LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$
−0.17	[2]	LONGACRE	75	IPWA	$\pi N \rightarrow N\pi\pi$

N(1520) PHOTON DECAY AMPLITUDES

N(1520) → pγ, helicity-1/2 amplitude $A_{1/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.024 ±0.009 OUR ESTIMATE				
−0.020 ±0.007	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
−0.028 ±0.014	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
−0.007 ±0.004	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
−0.032 ±0.005	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
−0.032 ±0.004	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
−0.031 ±0.009	BRATASHEV...	80	DPWA	$\gamma N \rightarrow \pi N$
−0.019 ±0.007	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
−0.0430 ± 0.0063	ISHII	80	DPWA	Compton scattering

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

−0.020 ±0.002		LI	93	IPWA	$\gamma N \rightarrow \pi N$
−0.012		WADA	84	DPWA	Compton scattering
−0.016 ±0.008		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
−0.008	[6]	NOELLE	78		$\gamma N \rightarrow \pi N$
−0.021		BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
−0.005 ±0.005		FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

$N(1520) \rightarrow p\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE ($GeV^{-1/2}$)	*DOCUMENT ID*		*TECN*	*COMMENT*
+0.166 ±0.005 OUR ESTIMATE				
0.167 ±0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.156 ±0.022	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.168 ±0.013	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
0.178 ±0.003	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
0.162 ±0.003	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
0.166 ±0.005	BRATASHEV...	80	DPWA	$\gamma N \rightarrow \pi N$
0.167 ±0.010	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
0.1695±0.0014	ISHII	80	DPWA	Compton scattering

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

0.167 ±0.002		LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.168		WADA	84	DPWA	Compton scattering
+0.157 ±0.007		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
0.206	[6]	NOELLE	78		$\gamma N \rightarrow \pi N$
+0.075		BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
+0.164 ±0.008		FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

$N(1520) \rightarrow n\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE ($GeV^{-1/2}$)	*DOCUMENT ID*		*TECN*	*COMMENT*
−0.059±0.009 OUR ESTIMATE				
−0.048±0.008	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
−0.066±0.013	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
−0.067±0.004	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
−0.076±0.006	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
−0.071±0.011	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
−0.056±0.011	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
−0.050±0.014	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$

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

−0.058±0.003		LI	93	IPWA	$\gamma N \rightarrow \pi N$
−0.055±0.014		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
−0.060	[6]	NOELLE	78		$\gamma N \rightarrow \pi N$

$N(1520) \rightarrow n\gamma$, helicity-3/2 amplitude $A_{3/2}$

VALUE ($GeV^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
-0.139 ± 0.011 OUR ESTIMATE				
-0.140 ± 0.010	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.124 ± 0.009	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
-0.158 ± 0.003	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
-0.147 ± 0.008	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 1)
-0.148 ± 0.009	ARAI	80	DPWA	$\gamma N \rightarrow \pi N$ (fit 2)
-0.144 ± 0.015	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
-0.118 ± 0.011	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
-0.131 ± 0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.141 ± 0.015	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
-0.127	[6] NOELLE	78		$\gamma N \rightarrow \pi N$

$N(1520)$ 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] LONGACRE 77 considers this coupling to be well determined.

[6] Converted to our conventions using $M = 1528$ MeV, $\Gamma = 187$ MeV from NOELLE 78.

$N(1520)$ REFERENCES

For early references, see Physics Letters **111B** 70 (1982). For very early references, see Reviews of Modern Physics **37** 633 (1965).

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)
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
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