$N(1520)\ D_{13}$

$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$ 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 1980 were last included in our 2006 edition, Journal of Physics, G **33** 1 (2006).

N(1520) BREIT-WIGNER MASS

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
1515 to 1525 (≈ 1520) OUR ESTIMATE				
1514.5± 0.2	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
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. • • •				
1516.3± 0.8	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
1509 ± 1	PENNER	02C	DPWA	Multichannel
1518 ± 3	VRANA	00	DPWA	Multichannel
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	$\gamma N \to \pi N$
1510	[1] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
1520	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

N(1520) BREIT-WIGNER WIDTH

VALUE (MeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
100 to 125 (≈ 115) OUR ESTIMATE				
103.6± 0.4	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
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. • • •				
98.6± 2.6	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
100 ± 2	PENNER	02C	DPWA	Multichannel
124 ± 4	VRANA	00	DPWA	Multichannel
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	$\gamma N \to \pi N$
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
1505 to 1515 (≈ 1510) OUR ESTIMATE				
1515	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
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. • • •				
1514	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
1504	VRANA	00	DPWA	Multichannel
1515	ARNDT	95	DPWA	$\pi N \to N \pi$
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
105 to 120 (≈ 110) OUR ESTIMATE				
113	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
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. • • •				
102	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
112	VRANA	00	DPWA	Multichannel
110	ARNDT	95	DPWA	$\pi N \to N \pi$
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
38	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
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. • • •				
35	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
34	ARNDT	95	DPWA	$\pi N \to N \pi$
33	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
− 5	ARNDT	06	DPWA	$\pi N \to \pi N, \eta N$
− 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. • • •				
− 6	ARNDT	04	DPWA	$\pi N \to \pi N, \eta N$
7	ARNDT	95	DPWA	$\pi N \to N \pi$
−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	$N\pi$	0.55 to 0.65
Γ_2	$N\eta$	$(2.3 \pm 0.4) \times 10^{-3}$
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
0.55 to 0.65 OUR ESTIMATE				
0.632 ± 0.001	ARNDT	06	DPWA	$\pi N \to \pi N$, ηN
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. • • •				
0.640 ± 0.005	ARNDT	04	DPWA	$\pi N \to \pi N$, ηN
0.56 ± 0.01	PENNER	02C	DPWA	Multichannel
0.63 ± 0.02	VRANA	00	DPWA	Multichannel
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
0.0023 ± 0.0004 OUR AVERAGE				
0.0023 ± 0.0004	PENNER	02C	DPWA	Multichannel
0.00 ± 0.01	VRANA	00	DPWA	Multichannel

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

0.0008 to 0.0012	ARNDT	05	DPWA	Multichannel
0.0008±0.0001	TIATOR	99	DPWA	$\gamma p \rightarrow p\eta$
0.001 ±0.002	BATINIC	95	DPWA	$\pi N \rightarrow N\pi$, $N\eta$

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	$\pi N \rightarrow N\pi\pi$

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

VALUE	DOCUMENT ID		TECN	COMMENT
0.15±0.02	VRANA	00	DPWA	Multichannel

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ 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	$\pi N \rightarrow N\pi\pi$

$\Gamma(\Delta(1232)\pi$, D-wave$)/\Gamma_{total}$ — Γ_6/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.11±0.02	VRANA	00	DPWA	Multichannel

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ 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	$\pi N \rightarrow N\pi\pi$

$\Gamma(N\rho$, S=3/2, S-wave$)/\Gamma_{total}$ — Γ_9/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.09±0.01	VRANA	00	DPWA	Multichannel

$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ 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	$\pi N \rightarrow N\pi\pi$

$\Gamma(N(\pi\pi)^{I=0}_{S\text{-wave}})/\Gamma_{total}$ — Γ_{11}/Γ

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

N(1520) PHOTON DECAY AMPLITUDES

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

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
−0.024 ±0.009 OUR ESTIMATE				
−0.038 ±0.003	AHRENS	02	DPWA	$\gamma N \to \pi N$
−0.020 ±0.007	ARNDT	96	IPWA	$\gamma N \to \pi N$
−0.028 ±0.014	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
−0.007 ±0.004	AWAJI	81	DPWA	$\gamma N \to \pi N$
−0.032 ±0.005	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
−0.032 ±0.004	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
−0.031 ±0.009	BRATASHEV...	80	DPWA	$\gamma N \to \pi N$
−0.019 ±0.007	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
−0.0430±0.0063	ISHII	80	DPWA	Compton scattering
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−0.003	PENNER	02D	DPWA	Multichannel
−0.052 ±0.010 ±0.007	[6] MUKHOPAD...	98		$\gamma p \to \eta p$
−0.020 ±0.002	LI	93	IPWA	$\gamma N \to \pi N$
−0.012	WADA	84	DPWA	Compton scattering

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

VALUE (GeV$^{-1/2}$)	DOCUMENT ID		TECN	COMMENT
+0.166 ±0.005 OUR ESTIMATE				
0.147 ±0.010	AHRENS	02	DPWA	$\gamma N \to \pi N$
0.167 ±0.005	ARNDT	96	IPWA	$\gamma N \to \pi N$
0.156 ±0.022	CRAWFORD	83	IPWA	$\gamma N \to \pi N$
0.168 ±0.013	AWAJI	81	DPWA	$\gamma N \to \pi N$
0.178 ±0.003	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 1)
0.162 ±0.003	ARAI	80	DPWA	$\gamma N \to \pi N$ (fit 2)
0.166 ±0.005	BRATASHEV...	80	DPWA	$\gamma N \to \pi N$
0.167 ±0.010	CRAWFORD	80	DPWA	$\gamma N \to \pi N$
0.1695±0.0014	ISHII	80	DPWA	Compton scattering
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.151	PENNER	02D	DPWA	Multichannel
0.130 ±0.020 ±0.015	[6] MUKHOPAD...	98		$\gamma p \to \eta p$
0.167 ±0.002	LI	93	IPWA	$\gamma N \to \pi N$
0.168	WADA	84	DPWA	Compton scattering

N(1520) → $n\gamma$, 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	$\gamma N \to \pi N$
−0.066±0.013	AWAJI	81	DPWA	$\gamma N \to \pi N$
−0.067±0.004	FUJII	81	DPWA	$\gamma N \to \pi N$
−0.076±0.006	ARAI	80	DPWA	$\gamma N \to \pi N$ (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. • • •				
-0.084	PENNER	02D	DPWA	Multichannel
-0.058 ± 0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$

$N(1520) \rightarrow n\gamma$, 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. • • •				
-0.159	PENNER	02D	DPWA	Multichannel
-0.131 ± 0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$

$N(1520)$ 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] MUKHOPADHYAY 98 uses an effective Lagrangian approach to analyze η photoproduction data. The *ratio* of the $A_{3/2}$ and $A_{1/2}$ amplitudes is determined, with less model dependence than the amplitudes themselves, to be $A_{3/2}/A_{1/2} = -2.5 \pm 0.5 \pm 0.4$.

$N(1520)$ REFERENCES

For early references, see Physics Letters **111B** 1 (1982). For very early references, see Reviews of Modern Physics **37** 633 (1965).

ARNDT	06	PR C74 045205	R.A. Arndt *et al.*	(GWU)
PDG	06	JPG 33 1	W.-M. Yao *et al.*	(PDG Collab.)
ARNDT	05	PR C72 045202	R.A. Arndt *et al.*	(GWU, PNPI)
ARNDT	04	PR C69 035213	R.A. Arndt *et al.*	(GWU, TRIU)
AHRENS	02	PRL 88 232002	J. Ahrens *et al.*	(Mainz MAMI GDH/A2 Collab.)
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+)
TIATOR	99	PR C60 035210	L. Tiator *et al.*	
MUKHOPAD...	98	PL B444 7	N.C. Mukhopadhyay, N. Mathur	

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)
BATINIC	95	PR C51 2310	M. Batinic *et al.*	(BOSK, UCLA)
Also		PR C57 1004 (erratum)	M. Batinic *et al.*	
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)
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)
FUJII	81	NP B187 53	K. Fujii *et al.*	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93	I. Arai	(INUS)
Also		NP B194 251	I. Arai, H. Fujii	(INUS)
BRATASHEV...	80	NP B166 525	A.S. Bratashevsky *et al.*	(KFTI)
CRAWFORD	80	Toronto Conf. 107	R.L. Crawford	(GLAS)
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
ISHII	80	NP B165 189	T. Ishii *et al.*	(KYOT, INUS)
TAKEDA	80	NP B168 17	H. Takeda *et al.*	(TOKY, INUS)
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