$N(1520)\ D_{13}$

$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$ 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) BREIT-WIGNER 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. • • •				
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	$\gamma N \to \pi N$
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) BREIT-WIGNER 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. • • •				
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	$\gamma N \to \pi N$
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
1505 to 1515 (≈ 1510) OUR ESTIMATE				
1515	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
1510	[3] HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1510±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1504	VRANA	00	DPWA	Multichannel
1511	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1514 or 1511	[4] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$
1508 or 1505	[1] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$

−2×IMAGINARY PART

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
110 to 120 (≈ 115) OUR ESTIMATE				
110	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
120	[3] HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
114±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
112	VRANA	00	DPWA	Multichannel
108	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
146 or 137	[4] LONGACRE	78	IPWA	$\pi N \rightarrow N\pi\pi$
109 or 107	[1] LONGACRE	77	IPWA	$\pi N \rightarrow N\pi\pi$

$N(1520)$ ELASTIC POLE RESIDUE

MODULUS $|r|$

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

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMMENT
7	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
− 8	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
−12±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
−10	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ 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	$N\eta$	$(2.3\pm0.4)\times10^{-3}$
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
0.5 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. • • •				
0.56 ± 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 NEW AVERAGE [0.000 ± 0.010 OUR 2002 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 ± 0.0001	TIATOR	99	DPWA	$\gamma p \to p\eta$
0.001 ± 0.002	BATINIC	95	DPWA	$\pi N \to N\pi$, $N\eta$

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

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

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 $N\pi \to N(1520) \to \Delta(1232)\pi$, 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	$\pi N \to \pi N$ & $N\pi\pi$
−0.26	[1,5] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
−0.24	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Gamma(\Delta(1232)\pi$, 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 $N\pi \to N(1520) \to \Delta(1232)\pi$, 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	$\pi N \to \pi N$ & $N\pi\pi$
−0.21	[1,5] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
−0.30	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Gamma(\Delta(1232)\pi$, 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 $N\pi \to N(1520) \to N\rho$, 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	$\pi N \to \pi N$ & $N\pi\pi$
−0.35	[1,5] LONGACRE	77	IPWA	$\pi N \to N\pi\pi$
−0.24	[2] LONGACRE	75	IPWA	$\pi N \to N\pi\pi$

$\Gamma(N\rho$, 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 $N\pi \to N(1520) \to N(\pi\pi)^{I=0}_{S\text{-wave}}$ — $(\Gamma_1\Gamma_{11})^{1/2}/\Gamma$

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

$\Gamma(N(\pi\pi)^{I=0}_{S\text{-wave}})/\Gamma_{total}$ 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
−0.016 ±0.008	BARBOUR	78	DPWA	$\gamma N \to \pi N$
−0.008	[7] NOELLE	78		$\gamma N \to \pi N$
−0.021	BERENDS	77	IPWA	$\gamma N \to \pi N$
−0.005 ±0.005	FELLER	76	DPWA	$\gamma N \to \pi N$

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
+0.157 ±0.007	BARBOUR	78	DPWA	$\gamma N \to \pi N$
0.206	[7] NOELLE	78		$\gamma N \to \pi N$
+0.075	BERENDS	77	IPWA	$\gamma N \to \pi N$
+0.164 ±0.008	FELLER	76	DPWA	$\gamma N \to \pi N$

$N(1520) \rightarrow n\gamma$, 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. • • •				
−0.084	PENNER	02D	DPWA	Multichannel
−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	[7] 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. • • •				
−0.159	PENNER	02D	DPWA	Multichannel
−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	[7] 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] 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 $A_{3/2}/A_{1/2} = -2.5 \pm 0.5 \pm 0.4$.

[7] 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).

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	98	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	84	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	M. Roos *et al.*	(HELS, CIT, CERN)
AWAJI	81	Bonn Conf. 352	N. Awaji, R. Kajikawa	(NAGO)
Also	82	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	82	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	79	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)
BAKER	79	NP B156 93	R.D. Baker *et al.*	(RHEL) IJP
HOEHLER	79	PDAT 12-1	G. Hohler *et al.*	(KARLT) IJP
Also	80	Toronto Conf. 3	R. Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	I.M. Barbour, R.L. Crawford, N.H. Parsons	(GLAS)
LONGACRE	78	PR D17 1795	R.S. Longacre *et al.*	(LBL, SLAC)
NOELLE	78	PTP 60 778	P. Noelle	(NAGO)
BERENDS	77	NP B136 317	F.A. Berends, A. Donnachie	(LEID, MCHS) IJP
LONGACRE	77	NP B122 493	R.S. Longacre, J. Dolbeau	(SACL) IJP
Also	76	NP B108 365	J. Dolbeau *et al.*	(SACL) IJP
FELLER	76	NP B104 219	P. Feller *et al.*	(NAGO, OSAK) IJP
FELTESSE	75	NP B93 242	J. Feltesse *et al.*	(SACL) IJP
LONGACRE	75	PL 55B 415	R.S. Longacre *et al.*	(LBL, SLAC) IJP