# $N(1535)$ $S_{11}$

$I(J^P) = \frac{1}{2}(\frac{1}{2}^-)$ 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).

## $N(1535)$ BREIT-WIGNER 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. • • • | | | | |
| 1530 ±10 | BAI | 01B | BES | $J/\psi \to p\overline{p}\eta$ |
| 1522 ±11 | THOMPSON | 01 | CLAS | $\gamma^* p \to p\eta$ |
| 1542 ± 3 | VRANA | 00 | DPWA | Multichannel |
| 1532 ± 5 | ARMSTRONG | 99B | DPWA | $\gamma^* p \to p\eta$ |
| 1549.0± 2.1 | 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 | $\pi N \to N\pi\pi$ |

## $N(1535)$ BREIT-WIGNER WIDTH

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **100 to 200 (≈ 150) OUR ESTIMATE** | | | | |
| 148.2± 8.1 | GREEN | 97 | DPWA | $\pi N \to \pi N$, $\eta N$ |
| 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. • • • | | | | |
| 95 ±25 | BAI | 01B | BES | $J/\psi \to p\overline{p}\eta$ |
| 143 ±18 | THOMPSON | 01 | CLAS | $\gamma^* p \to p\eta$ |
| 112 ±19 | VRANA | 00 | DPWA | Multichannel |
| 154 ±20 | ARMSTRONG | 99B | DPWA | $\gamma^* p \to p\eta$ |
| 212 ±20 | [3] KRUSCHE | 97 | DPWA | $\gamma N \to \eta N$ |
| 168.8±11.6 | 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 | $\pi N \rightarrow N\pi$, $N\eta$ |
| 145 | | BATINIC | 95B | DPWA | $\pi N \rightarrow N\pi$, $N\eta$ |
| 200 ±40 | | KRUSCHE | 95 | DPWA | $\gamma p \rightarrow p\eta$ |
| 84 | | LI | 93 | IPWA | $\gamma N \rightarrow \pi N$ |
| 136 | | CRAWFORD | 80 | DPWA | $\gamma N \rightarrow \pi N$ |
| 180 | | BAKER | 79 | DPWA | $\pi^- p \rightarrow n\eta$ |
| 132 | | BARBOUR | 78 | DPWA | $\gamma N \rightarrow \pi N$ |
| 57 | | BERENDS | 77 | IPWA | $\gamma N \rightarrow \pi N$ |
| 139 ±33 | | BHANDARI | 77 | DPWA | Uses $N\eta$ cusp |
| 135 | [1] | LONGACRE | 77 | IPWA | $\pi N \rightarrow N\pi\pi$ |
| 100 | [2] | LONGACRE | 75 | IPWA | $\pi N \rightarrow N\pi\pi$ |

## *N*(1535) POLE POSITION

### REAL PART

| *VALUE* (MeV) | | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **1495 to 1515 (≈ 1505) OUR ESTIMATE** | | | | |
| 1510±10 | [4] | ARNDT | 98 | DPWA $\pi N \rightarrow \pi N$, $\eta N$ |
| 1501 | | ARNDT | 95 | DPWA $\pi N \rightarrow N\pi$ |
| 1487 | [5] | HOEHLER | 93 | SPED $\pi N \rightarrow \pi N$ |
| 1510±50 | | CUTKOSKY | 80 | IPWA $\pi N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1525 | | VRANA | 00 | DPWA Multichannel |
| 1499 | | ARNDT | 91 | DPWA $\pi N \rightarrow \pi N$ Soln SM90 |
| 1496 or 1499 | [6] | LONGACRE | 78 | IPWA $\pi N \rightarrow N\pi\pi$ |
| 1519± 4 | | BHANDARI | 77 | DPWA Uses $N\eta$ cusp |
| 1525 or 1527 | [1] | LONGACRE | 77 | IPWA $\pi N \rightarrow N\pi\pi$ |

### −2×IMAGINARY PART

| *VALUE* (MeV) | | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **90 to 250 (≈ 170) OUR ESTIMATE** | | | | |
| 170±30 | [4] | ARNDT | 98 | DPWA $\pi N \rightarrow \pi N$, $\eta N$ |
| 124 | | ARNDT | 95 | DPWA $\pi N \rightarrow N\pi$ |
| 260±80 | | CUTKOSKY | 80 | IPWA $\pi N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 102 | | VRANA | 00 | DPWA Multichannel |
| 110 | | ARNDT | 91 | DPWA $\pi N \rightarrow \pi N$ Soln SM90 |
| 103 or 105 | [6] | LONGACRE | 78 | IPWA $\pi N \rightarrow N\pi\pi$ |
| 140±32 | | BHANDARI | 77 | DPWA Uses $N\eta$ cusp |
| 135 or 123 | [1] | LONGACRE | 77 | IPWA $\pi N \rightarrow N\pi\pi$ |

## *N*(1535) ELASTIC POLE RESIDUE

### MODULUS $|r|$

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

### PHASE $\theta$

| VALUE (°) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| $-12$ | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| $+15 \pm 45$ | 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 ($\Gamma_i/\Gamma$) |
|---|---|---|
| $\Gamma_1$ | $N\pi$ | 35–55 % |
| $\Gamma_2$ | $N\eta$ | 30–55 % |
| $\Gamma_3$ | $N\pi\pi$ | 1–10 % |
| $\Gamma_4$ | $\Delta\pi$ | <1 % |
| $\Gamma_5$ | $\Delta(1232)\pi$, $D$-wave | |
| $\Gamma_6$ | $N\rho$ | <4 % |
| $\Gamma_7$ | $N\rho$, $S$=1/2, $S$-wave | |
| $\Gamma_8$ | $N\rho$, $S$=3/2, $D$-wave | |
| $\Gamma_9$ | $N(\pi\pi)^{I=0}_{S\text{-wave}}$ | <3 % |
| $\Gamma_{10}$ | $N(1440)\pi$ | <7 % |
| $\Gamma_{11}$ | $p\gamma$ | 0.15–0.35 % |
| $\Gamma_{12}$ | $p\gamma$, helicity=1/2 | 0.15–0.35 % |
| $\Gamma_{13}$ | $n\gamma$ | 0.004–0.29 % |
| $\Gamma_{14}$ | $n\gamma$, helicity=1/2 | 0.004–0.29 % |

## $N(1535)$ BRANCHING RATIOS

### $\Gamma(N\pi)/\Gamma_{total}$ $\Gamma_1/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.35 to 0.55 OUR ESTIMATE** | | | | |
| $0.394 \pm 0.009$ | GREEN | 97 | DPWA | $\pi N \to \pi N, \eta N$ |
| $0.51 \pm 0.05$ | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| $0.50 \pm 0.10$ | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| $0.38 \pm 0.04$ | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $0.35 \pm 0.08$ | VRANA | 00 | DPWA | Multichannel |
| $0.330 \pm 0.011$ | ABAEV | 96 | DPWA | $\pi^- p \to \eta n$ |
| 0.31 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| $0.34 \pm 0.09$ | BATINIC | 95 | DPWA | $\pi N \to N\pi, N\eta$ |
| $0.297 \pm 0.026$ | BHANDARI | 77 | DPWA | Uses $N\eta$ cusp |

## $\Gamma(N\eta)/\Gamma_{total}$ $\Gamma_2/\Gamma$

| VALUE | CL% | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **+0.30 to 0.55 OUR ESTIMATE** | | | | | |
| **0.51 ±0.05** | | VRANA | 00 | DPWA | Multichannel |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| > 0.45 | 95 | [7] ARMSTRONG | 99B | DPWA | $p\,(e,e'p)\,\eta$ |
| 0.568±0.011 | | GREEN | 97 | DPWA | $\pi N \to \pi N,\ \eta N$ |
| 0.591±0.017 | | 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 | $\pi N \to N\pi\pi$ |

## $\Gamma(\Delta(1232)\pi, D\text{-wave})/\Gamma_{total}$ $\Gamma_5/\Gamma$

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

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

## $\Gamma(N\rho, S$=1/2, $S$-wave$)/\Gamma_{total}$ $\Gamma_7/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 0.02±0.01 | VRANA | 00 | DPWA | Multichannel |

## $\Gamma(N\rho, S$=3/2, $D$-wave$)/\Gamma_{total}$ $\Gamma_8/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 0.00±0.01 | VRANA | 00 | DPWA | Multichannel |

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

### $\Gamma(N(\pi\pi)^{I=0}_{S\text{-wave}})/\Gamma_{total}$ $\Gamma_9/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 0.02±0.01 | VRANA | 00 | DPWA | Multichannel |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ 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 | $\pi N \to \pi N$ & $N\pi\pi$ |

### $\Gamma(N(1440)\pi)/\Gamma_{total}$ $\Gamma_{10}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| 0.10±0.09 | VRANA | 00 | DPWA | Multichannel |

## 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 |
|---|---|---|---|---|---|
| **+0.090 ±0.030 OUR ESTIMATE** | | | | | |
| 0.120 ±0.011 ±0.015 | [3] | KRUSCHE | 97 | DPWA | $\gamma N \to \eta N$ |
| 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 | [8] | 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 | [9] | 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 |
|---|---|---|---|---|
| **$-0.046 \pm 0.027$ OUR ESTIMATE** | | | | |
| $-0.020 \pm 0.035$ | ARNDT | 96 | IPWA | $\gamma N \rightarrow \pi N$ |
| $0.035 \pm 0.014$ | AWAJI | 81 | DPWA | $\gamma N \rightarrow \pi N$ |
| $-0.062 \pm 0.003$ | FUJII | 81 | DPWA | $\gamma N \rightarrow \pi N$ |
| $-0.075 \pm 0.019$ | ARAI | 80 | DPWA | $\gamma N \rightarrow \pi N$ (fit 1) |
| $-0.075 \pm 0.018$ | ARAI | 80 | DPWA | $\gamma N \rightarrow \pi N$ (fit 2) |
| $-0.098 \pm 0.026$ | CRAWFORD | 80 | DPWA | $\gamma N \rightarrow \pi N$ |
| $-0.011 \pm 0.017$ | TAKEDA | 80 | DPWA | $\gamma N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $-0.100 \pm 0.030$ | KRUSCHE | 95C | IPWA | $\gamma d \rightarrow \eta N(N)$ |
| $-0.046 \pm 0.005$ | LI | 93 | IPWA | $\gamma N \rightarrow \pi N$ |
| $-0.112 \pm 0.034$ | BARBOUR | 78 | DPWA | $\gamma N \rightarrow \pi N$ |
| $-0.048$ | [9] NOELLE | 78 | | $\gamma N \rightarrow \pi N$ |

### $N(1535) \rightarrow N\gamma$, 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. • • • | | | |
| $-0.84 \pm 0.15$ | 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] KRUSCHE 97 fits with the mass fixed at 1544 MeV.

[4] ARNDT 98 also lists pole residues, which display more model dependence than do the associated pole positions.

[5] See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of $N$ and $\Delta$ resonances as determined from Argand diagrams of $\pi N$ elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

[6] 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.

[7] The best value ARMSTRONG 99B obtains is $\simeq 0.55$; this assumes $S_{11}$ dominance in the reaction $p(e, e'p)\,\eta$ at $Q^2 = 4$ $(GeV/c)^2$.

[8] BENMERROUCHE 91 uses an effective Lagrangian approach to analyze $\eta$ photoproduction data.

[9] 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).


| | | | | |
|---|---|---|---|---|
| BAI | 01B | PL B510 75 | J.Z. Bai *et al.* | (BEPC BES Collab.) |
| THOMPSON | 01 | PRL 86 1702 | R. Thompson *et al.* | (Jefferson CLAS Collab.) |
| VRANA | 00 | PRPL 328 181 | T.P. Vrana, S.A. Dytman,, T.-S.H. Lee | (PITT+) |
| ARMSTRONG | 99B | PR D60 052004 | C.S. Armstrong *et al.* | |
| ARNDT | 98 | PR C58 3636 | R.A. Arndt *et al.* | |
| GREEN | 97 | PR C55 R2167 | A.M. Green, S. Wycech | (HELS, WINR) |
| KRUSCHE | 97 | PL B397 171 | B. Krusche *et al.* | (GIES, RPI, SASK) |
| ABAEV | 96 | PR C53 385 | V.V. Abaev, B.M.K. Nefkens | (UCLA) |
| 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.* | |
| BATINIC | 95B | PR C52 2188 | M. Batinic, I. Slaus, A. Svarc | (BOSK) |
| BENMERROU... | 95 | PR D51 3237 | M. Benmerrouche, N.C. Mukhopadhyay, J.F. Zhang | |
| KRUSCHE | 95 | PRL 74 3736 | B. Krusche *et al.* | (GIES, MANZ, GLAS+) |
| KRUSCHE | 95C | PL B358 40 | B. Krusche *et al.* | (GIES, MANZ, GLAS+) |
| MUKHOPAD... | 95B | PL B364 1 | N.C. Mukhopadhyay, J.F. Zhang, M. Benmerrouche | |
| HOEHLER | 93 | $\pi N$ 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 |
| BENMERROU... | 91 | PRL 67 1070 | M. Benmerrouche, N.C. Mukhopadhyay | (RPI) |
| 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 |
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| BARBOUR | 78 | NP B141 253 | I.M. Barbour, R.L. Crawford, N.H. Parsons | (GLAS) |
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| NOELLE | 78 | PTP 60 778 | P. Noelle | (NAGO) |
| BERENDS | 77 | NP B136 317 | F.A. Berends, A. Donnachie | (LEID, MCHS) IJP |
| BHANDARI | 77 | PR D15 192 | R. Bhandari, Y.A. Chao | (CMU) IJP |
| LONGACRE | 77 | NP B122 493 | R.S. Longacre, J. Dolbeau | (SACL) IJP |
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