# $N(1650)$ $S_{11}$

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

## $N(1650)$ BREIT-WIGNER MASS

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **1640 to 1680 (≈ 1650) OUR ESTIMATE** | | | | |
| 1659± 9 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 1650±30 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 1670± 8 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 1689±12 | VRANA | 00 | | Multichannel |
| 1677± 8 | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| 1667 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 1712 | [1] ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 1669±17 | BATINIC | 95 | DPWA | $\pi N \to N\pi$, $N\eta$ |
| 1713±27 | [2] BATINIC | 95 | DPWA | $\pi N \to N\pi$, $N\eta$ |
| 1674 | LI | 93 | IPWA | $\gamma N \to \pi N$ |
| 1688 | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| 1672 | MUSETTE | 80 | IPWA | $\pi^- p \to \Lambda K^0$ |
| 1680 | SAXON | 80 | DPWA | $\pi^- p \to \Lambda K^0$ |
| 1680 | BAKER | 78 | DPWA | $\pi^- p \to \Lambda K^0$ |
| 1694 | BARBOUR | 78 | DPWA | $\gamma N \to \pi N$ |
| 1700± 5 | [3] BAKER | 77 | IPWA | $\pi^- p \to \Lambda K^0$ |
| 1680 | [3] BAKER | 77 | DPWA | $\pi^- p \to \Lambda K^0$ |
| 1700 | [4] LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |
| 1675 | KNASEL | 75 | DPWA | $\pi^- p \to \Lambda K^0$ |
| 1660 | [5] LONGACRE | 75 | IPWA | $\pi N \to N\pi\pi$ |

## $N(1650)$ BREIT-WIGNER WIDTH

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **145 to 190 (≈ 150) OUR ESTIMATE** | | | | |
| 167.9± 9.4 | GREEN | 97 | DPWA | $\pi N \to \pi N$, $\eta N$ |
| 173 ±12 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 150 ±40 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 180 ±20 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |

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

| | | | | | |
|---|---|---|---|---|---|
| 202 ±40 | | VRANA | 00 | | Multichannel |
| 160 ±12 | | ARNDT | 96 | IPWA | $\gamma N \to \pi N$ |
| 90 | | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 184 | [1] | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 215 ±32 | | BATINIC | 95 | DPWA | $\pi N \to N\pi,\ N\eta$ |
| 279 ±54 | [2] | BATINIC | 95 | DPWA | $\pi N \to N\pi,\ N\eta$ |
| 225 | | LI | 93 | IPWA | $\gamma N \to \pi N$ |
| 183 | | CRAWFORD | 80 | DPWA | $\gamma N \to \pi N$ |
| 179 | | MUSETTE | 80 | IPWA | $\pi^- p \to \Lambda K^0$ |
| 120 | | SAXON | 80 | DPWA | $\pi^- p \to \Lambda K^0$ |
| 90 | | BAKER | 78 | DPWA | $\pi^- p \to \Lambda K^0$ |
| 193 | | BARBOUR | 78 | DPWA | $\gamma N \to \pi N$ |
| 130 ±10 | [3] | BAKER | 77 | IPWA | $\pi^- p \to \Lambda K^0$ |
| 90 | [3] | BAKER | 77 | DPWA | $\pi^- p \to \Lambda K^0$ |
| 170 | [4] | LONGACRE | 77 | IPWA | $\pi N \to N\pi\pi$ |
| 170 | | KNASEL | 75 | DPWA | $\pi^- p \to \Lambda K^0$ |
| 130 | [5] | LONGACRE | 75 | IPWA | $\pi N \to N\pi\pi$ |

## *N*(1650) POLE POSITION

### REAL PART

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **1640 to 1680 (≈ 1660) OUR ESTIMATE** | | | | |
| 1660±10 | [6] | ARNDT | 98 | DPWA $\pi N \to \pi N,\ \eta N$ |
| 1673 | | ARNDT | 95 | DPWA $\pi N \to N\pi$ |
| 1689 | [1] | ARNDT | 95 | DPWA $\pi N \to N\pi$ |
| 1670 | [7] | HOEHLER | 93 | ARGD $\pi N \to \pi N$ |
| 1640±20 | | CUTKOSKY | 80 | IPWA $\pi N \to \pi N$ |

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

| | | | | |
|---|---|---|---|---|
| 1663 | | VRANA | 00 | Multichannel |
| 1657 | | ARNDT | 91 | DPWA $\pi N \to \pi N$ Soln SM90 |
| 1648 or 1651 | [8] | LONGACRE | 78 | IPWA $\pi N \to N\pi\pi$ |
| 1699 or 1698 | [4] | LONGACRE | 77 | IPWA $\pi N \to N\pi\pi$ |

### −2×IMAGINARY PART

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **150 to 170 (≈ 160) OUR ESTIMATE** | | | | |
| 140±20 | [6] | ARNDT | 98 | DPWA $\pi N \to \pi N,\ \eta N$ |
| 82 | | ARNDT | 95 | DPWA $\pi N \to N\pi$ |
| 192 | [1] | ARNDT | 95 | DPWA $\pi N \to N\pi$ |
| 163 | [7] | HOEHLER | 93 | ARGD $\pi N \to \pi N$ |
| 150±30 | | CUTKOSKY | 80 | IPWA $\pi N \to \pi N$ |

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

| | | | | |
|---|---|---|---|---|
| 240 | | VRANA | 00 | Multichannel |
| 160 | | ARNDT | 91 | DPWA $\pi N \to \pi N$ Soln SM90 |
| 117 or 119 | [8] | LONGACRE | 78 | IPWA $\pi N \to N\pi\pi$ |
| 174 or 173 | [4] | LONGACRE | 77 | IPWA $\pi N \to N\pi\pi$ |

## *N*(1650) ELASTIC POLE RESIDUE

### MODULUS $|r|$

| *VALUE* (MeV) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| 22 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 72 | [1] ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 39 | HOEHLER | 93 | ARGD | $\pi N \to \pi N$ |
| $60 \pm 10$ | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 54 | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |

### PHASE $\theta$

| *VALUE* (°) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| 29 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| $-85$ | [1] ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| $-37$ | HOEHLER | 93 | ARGD | $\pi N \to \pi N$ |
| $-75 \pm 25$ | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $-38$ | ARNDT | 91 | DPWA | $\pi N \to \pi N$ Soln SM90 |

## *N*(1650) DECAY MODES

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

| | Mode | Fraction ($\Gamma_i/\Gamma$) |
|---|---|---|
| $\Gamma_1$ | $N\pi$ | 55–90 % |
| $\Gamma_2$ | $N\eta$ | 3–10 % |
| $\Gamma_3$ | $\Lambda K$ | 3–11 % |
| $\Gamma_4$ | $\Sigma K$ | |
| $\Gamma_5$ | $N\pi\pi$ | 10–20 % |
| $\Gamma_6$ | $\Delta\pi$ | 1–7 % |
| $\Gamma_7$ | $\Delta(1232)\pi$, $D$-wave | |
| $\Gamma_8$ | $N\rho$ | 4–12 % |
| $\Gamma_9$ | $N\rho$, $S$=1/2, $S$-wave | |
| $\Gamma_{10}$ | $N\rho$, $S$=3/2, $D$-wave | |
| $\Gamma_{11}$ | $N(\pi\pi)^{I=0}_{S\text{-wave}}$ | <4 % |
| $\Gamma_{12}$ | $N(1440)\pi$ | <5 % |
| $\Gamma_{13}$ | $p\gamma$ | 0.04–0.18 % |
| $\Gamma_{14}$ | $p\gamma$, helicity=1/2 | 0.04–0.18 % |
| $\Gamma_{15}$ | $n\gamma$ | 0.003–0.17 % |
| $\Gamma_{16}$ | $n\gamma$, helicity=1/2 | 0.003–0.17 % |

## $N(1650)$ BRANCHING RATIOS

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

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **0.55 to 0.90 OUR ESTIMATE** | | | | |
| 0.735±0.011 | GREEN | 97 | DPWA | $\pi N \to \pi N, \eta N$ |
| 0.89 ±0.07 | MANLEY | 92 | IPWA | $\pi N \to \pi N$ & $N\pi\pi$ |
| 0.65 ±0.10 | CUTKOSKY | 80 | IPWA | $\pi N \to \pi N$ |
| 0.61 ±0.04 | HOEHLER | 79 | IPWA | $\pi N \to \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.74 ±0.02 | VRANA | 00 | | Multichannel |
| 0.99 | ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 0.27 | [1] ARNDT | 95 | DPWA | $\pi N \to N\pi$ |
| 0.94 ±0.07 | BATINIC | 95 | DPWA | $\pi N \to N\pi, N\eta$ |
| 0.49 ±0.21 | [2] BATINIC | 95 | DPWA | $\pi N \to N\pi, N\eta$ |

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

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.06±0.05 | BATINIC | 95 | DPWA | $\pi N \to N\pi, N\eta$ |
| 0.02±0.03 | [2] BATINIC | 95 | DPWA | $\pi N \to N\pi, N\eta$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1650) \to N\eta$ — $(\Gamma_1\Gamma_2)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.09 | [9] BAKER | 79 | DPWA | $\pi^- p \to n\eta$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1650) \to \Lambda K$ — $(\Gamma_1\Gamma_3)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **−0.27 to −0.17 OUR ESTIMATE** | | | | |
| −0.22 | BELL | 83 | DPWA | $\pi^- p \to \Lambda K^0$ |
| −0.22 | SAXON | 80 | DPWA | $\pi^- p \to \Lambda K^0$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.25 | [10] BAKER | 78 | DPWA | See SAXON 80 |
| −0.23±0.01 | [3] BAKER | 77 | IPWA | $\pi^- p \to \Lambda K^0$ |
| −0.25 | [3] BAKER | 77 | DPWA | $\pi^- p \to \Lambda K^0$ |
| 0.12 | KNASEL | 75 | DPWA | $\pi^- p \to \Lambda K^0$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \to N(1650) \to \Sigma K$ — $(\Gamma_1\Gamma_4)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.254 | LIVANOS | 80 | DPWA | $\pi p \to \Sigma K$ |
| 0.066 to 0.137 | [11] DEANS | 75 | DPWA | $\pi N \to \Sigma K$ |
| 0.20 | KNASEL | 75 | DPWA | |

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 $N\pi \rightarrow N(1650) \rightarrow \Delta(1232)\pi$, $D$-wave $(\Gamma_1\Gamma_7)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **+0.15 to 0.23 OUR ESTIMATE** | | | | |
| +0.12±0.04 | MANLEY | 92 | IPWA | $\pi N \rightarrow \pi N$ & $N\pi\pi$ |
| +0.29 | [4,12] LONGACRE | 77 | IPWA | $\pi N \rightarrow N\pi\pi$ |
| +0.15 | [5] LONGACRE | 75 | IPWA | $\pi N \rightarrow N\pi\pi$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow N(1650) \rightarrow N\rho$, $S$=1/2, $S$-wave $(\Gamma_1\Gamma_9)^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **±0.03 to ±0.19 OUR ESTIMATE** | | | | |
| −0.01±0.09 | MANLEY | 92 | IPWA | $\pi N \rightarrow \pi N$ & $N\pi\pi$ |
| +0.17 | [4,12] LONGACRE | 77 | IPWA | $\pi N \rightarrow N\pi\pi$ |
| −0.16 | [5] LONGACRE | 75 | IPWA | $\pi N \rightarrow N\pi\pi$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow N(1650) \rightarrow N\rho$, $S$=3/2, $D$-wave $(\Gamma_1\Gamma_{10})^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **+0.17 to +0.29 OUR ESTIMATE** | | | | |
| +0.16±0.06 | MANLEY | 92 | IPWA | $\pi N \rightarrow \pi N$ & $N\pi\pi$ |
| +0.29 | [4,12] LONGACRE | 77 | IPWA | $\pi N \rightarrow N\pi\pi$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow N(1650) \rightarrow N(\pi\pi)^{I=0}_{S\text{-wave}}$ $(\Gamma_1\Gamma_{11})^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **+0.04 to +0.18 OUR ESTIMATE** | | | | |
| +0.12±0.08 | MANLEY | 92 | IPWA | $\pi N \rightarrow \pi N$ & $N\pi\pi$ |
| 0.00 | [4,12] LONGACRE | 77 | IPWA | $\pi N \rightarrow N\pi\pi$ |
| +0.25 | [5] LONGACRE | 75 | IPWA | $\pi N \rightarrow N\pi\pi$ |

### $(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{total}$ in $N\pi \rightarrow N(1650) \rightarrow N(1440)\pi$ $(\Gamma_1\Gamma_{12})^{1/2}/\Gamma$

| VALUE | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| +0.11±0.06 | MANLEY | 92 | IPWA | $\pi N \rightarrow \pi N$ & $N\pi\pi$ |

## $N(1650)$ PHOTON DECAY AMPLITUDES

### $N(1650) \rightarrow p\gamma$, helicity-1/2 amplitude $A_{1/2}$

| VALUE (GeV$^{-1/2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **+0.053±0.016 OUR ESTIMATE** | | | | |
| 0.069±0.005 | ARNDT | 96 | IPWA | $\gamma N \rightarrow \pi N$ |
| 0.033±0.015 | CRAWFORD | 83 | IPWA | $\gamma N \rightarrow \pi N$ |
| 0.050±0.010 | AWAJI | 81 | DPWA | $\gamma N \rightarrow \pi N$ |
| 0.065±0.005 | ARAI | 80 | DPWA | $\gamma N \rightarrow \pi N$ (fit 1) |
| 0.061±0.005 | ARAI | 80 | DPWA | $\gamma N \rightarrow \pi N$ (fit 2) |
| 0.031±0.017 | CRAWFORD | 80 | DPWA | $\gamma N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.068±0.003 | LI | 93 | IPWA | $\gamma N \rightarrow \pi N$ |
| 0.091 | WADA | 84 | DPWA | Compton scattering |
| +0.048±0.017 | BARBOUR | 78 | DPWA | $\gamma N \rightarrow \pi N$ |
| +0.068±0.009 | FELLER | 76 | DPWA | $\gamma N \rightarrow \pi N$ |

### $N(1650) \rightarrow n\gamma$, helicity-1/2 amplitude $A_{1/2}$

| VALUE ($GeV^{-1/2}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **−0.015±0.021 OUR ESTIMATE** | | | | |
| −0.015±0.005 | ARNDT | 96 | IPWA | $\gamma N \rightarrow \pi N$ |
| −0.008±0.004 | AWAJI | 81 | DPWA | $\gamma N \rightarrow \pi N$ |
| 0.004±0.004 | FUJII | 81 | DPWA | $\gamma N \rightarrow \pi N$ |
| 0.010±0.020 | ARAI | 80 | DPWA | $\gamma N \rightarrow \pi N$ (fit 1) |
| 0.008±0.019 | ARAI | 80 | DPWA | $\gamma N \rightarrow \pi N$ (fit 2) |
| −0.068±0.040 | CRAWFORD | 80 | DPWA | $\gamma N \rightarrow \pi N$ |
| −0.011±0.011 | TAKEDA | 80 | DPWA | $\gamma N \rightarrow \pi N$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.002±0.002 | LI | 93 | IPWA | $\gamma N \rightarrow \pi N$ |
| −0.045±0.024 | BARBOUR | 78 | DPWA | $\gamma N \rightarrow \pi N$ |

## $N(1650)$ $\gamma p \rightarrow \Lambda K^+$ AMPLITUDES

### $(\Gamma_i \Gamma_f)^{1/2}/\Gamma_{total}$ in $p\gamma \rightarrow N(1650) \rightarrow \Lambda K^+$ ($E_{0+}$ amplitude)

| VALUE (units $10^{-3}$) | DOCUMENT ID | | TECN |
|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | |
| 7.8 ±0.3 | WORKMAN | 90 | DPWA |
| 8.13 | TANABE | 89 | DPWA |

### $p\gamma \rightarrow N(1650) \rightarrow \Lambda K^+$ phase angle $\theta$ ($E_{0+}$ amplitude)

| VALUE (degrees) | DOCUMENT ID | | TECN |
|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | |
| −107 ±3 | WORKMAN | 90 | DPWA |
| −107.8 | TANABE | 89 | DPWA |

## $N(1650)$ FOOTNOTES

[1] ARNDT 95 finds two distinct states.

[2] BATINIC 95 finds two distinct states. This second resonance was associated with the $N(2090)$ $S_{11}$.

[3] The two BAKER 77 entries are from an IPWA using the Barrelet-zero method and from a conventional energy-dependent analysis.

[4] 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.

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

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

[7] 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.

[8] 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.

[9] BAKER 79 fixed this coupling during fitting, but the negative sign relative to the $N(1535)$ is well determined.

[10] The overall phase of BAKER 78 couplings has been changed to agree with previous conventions. Superseded by SAXON 80.
[11] The range given for DEANS 75 is from the four best solutions.
[12] LONGACRE 77 considers this coupling to be well determined.

## *N*(1650) REFERENCES

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


| | | | | | |
|---|---|---|---|---|---|
| VRANA | 00 | PRPL 328 181 | T.P. Vrana, S.A. Dytman,, T.-S.H. Lee | | |
| ARNDT | 98 | PR C58 3636 | R.A. Arndt *et al.* | | |
| GREEN | 97 | PR C55 R2167 | A.M. Green, S. Wycech | (HELS, WINR) | |
| 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 | $\pi N$ 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 |
| WORKMAN | 90 | PR C42 781 | R.L. Workman | (VPI) | |
| TANABE | 89 | PR C39 741 | H. Tanabe, M. Kohno, C. Bennhold | (MANZ) | |
| Also | 89 | NC 102A 193 | M. Kohno, H. Tanabe, C. Bennhold | (MANZ) | |
| WADA | 84 | NP B247 313 | Y. Wada *et al.* | (INUS) | |
| BELL | 83 | NP B222 389 | K.W. Bell *et al.* | (RL) | IJP |
| 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) | |
| 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 |
| LIVANOS | 80 | Toronto Conf. 35 | P. Livanos *et al.* | (SACL) | IJP |
| MUSETTE | 80 | NC 57A 37 | M. Musette | (BRUX) | IJP |
| SAXON | 80 | NP B162 522 | D.H. Saxon *et al.* | (RHEL, BRIS) | IJP |
| 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 |
| BAKER | 78 | NP B141 29 | R.D. Baker *et al.* | (RL, CAVE) | 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) | |
| BAKER | 77 | NP B126 365 | R.D. Baker *et al.* | (RHEL) | 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 |
| DEANS | 75 | NP B96 90 | S.R. Deans *et al.* | (SFLA, ALAH) | IJP |
| KNASEL | 75 | PR D11 1 | T.M. Knasel *et al.* | (CHIC, WUSL, OSU+) | IJP |
| LONGACRE | 75 | PL 55B 415 | R.S. Longacre *et al.* | (LBL, SLAC) | IJP |