# $\Lambda$

$I(J^P) = 0(\frac{1}{2}^+)$ Status: ****

We have omitted some results that have been superseded by later experiments. See our earlier editions.

## $\Lambda$ MASS

The fit uses $\Lambda$, $\Sigma^+$, $\Sigma^0$, $\Sigma^-$ mass and mass-difference measurements.

| *VALUE* (MeV) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **1115.683±0.006 OUR FIT** | | | | | |
| **1115.683±0.006 OUR AVERAGE** | | | | | |
| 1115.678±0.006±0.006 | 20k | HARTOUNI | 94 | SPEC | $pp$ 27.5 GeV/$c$ |
| 1115.690±0.008±0.006 | 18k | [1] HARTOUNI | 94 | SPEC | $pp$ 27.5 GeV/$c$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 1115.59 ±0.08 | 935 | HYMAN | 72 | HEBC | |
| 1115.39 ±0.12 | 195 | MAYEUR | 67 | EMUL | |
| 1115.6 ±0.4 | | LONDON | 66 | HBC | |
| 1115.65 ±0.07 | 488 | [2] SCHMIDT | 65 | HBC | |
| 1115.44 ±0.12 | | [3] BHOWMIK | 63 | RVUE | |

[1] We assume *CPT* invariance: this is the $\overline{\Lambda}$ mass as measured by HARTOUNI 94. See below for the fractional mass difference, testing *CPT*.

[2] The SCHMIDT 65 masses have been reevaluated using our April 1973 proton and $K^\pm$ and $\pi^\pm$ masses. P. Schmidt, private communication (1974).

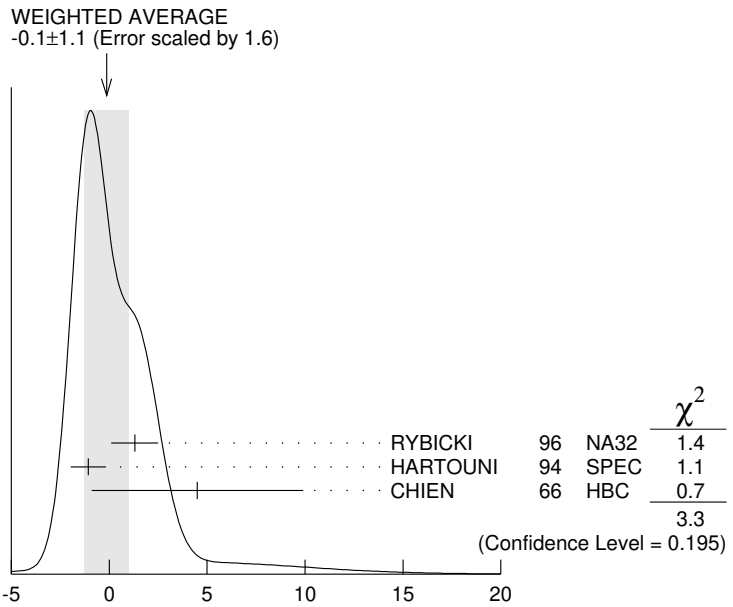
[3] The mass has been raised 35 keV to take into account a 46 keV increase in the proton mass and an 11 keV decrease in the $\pi^\pm$ mass (note added Reviews of Modern Physics **39** 1 (1967)).

## $(m_\Lambda - m_{\overline{\Lambda}}) / m_\Lambda$

A test of *CPT* invariance.

| *VALUE* (units $10^{-5}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **− 0.1 ± 1.1 OUR AVERAGE** | | Error includes scale factor of 1.6. See the ideogram below. | | | |
| + 1.3 ± 1.2 | 31k | [4] RYBICKI | 96 | NA32 | $\pi^-$ Cu, 230 GeV |
| − 1.08± 0.90 | | HARTOUNI | 94 | SPEC | $pp$ 27.5 GeV/$c$ |
| 4.5 ± 5.4 | | CHIEN | 66 | HBC | 6.9 GeV/$c$ $\overline{p}p$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| −26 ±13 | | BADIER | 67 | HBC | 2.4 GeV/$c$ $\overline{p}p$ |

[4] RYBICKI 96 is an analysis of old ACCMOR (NA32) data.

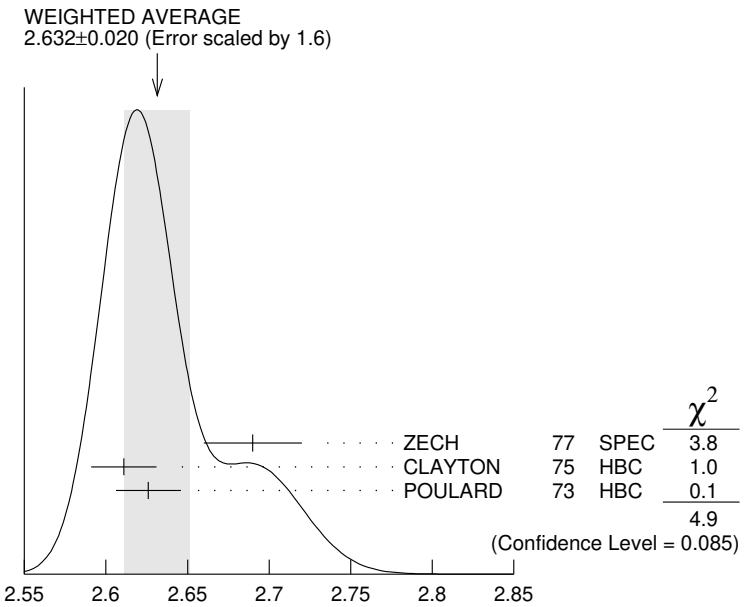



$(m_\Lambda - m_{\overline{\Lambda}}) \Big/ m_\Lambda$

## Λ MEAN LIFE

Measurements with an error $\geq 0.1 \times 10^{-10}$ s have been omitted altogether, and only the latest high-statistics measurements are used for the average.

| *VALUE* ($10^{-10}$ s) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **2.632±0.020 OUR AVERAGE** | | Error includes scale factor of 1.6. See the ideogram below. | | | |
| 2.69 ±0.03 | 53k | ZECH | 77 | SPEC | Neutral hyperon beam |
| 2.611±0.020 | 34k | CLAYTON | 75 | HBC | 0.96–1.4 GeV/$c$ $K^-p$ |
| 2.626±0.020 | 36k | POULARD | 73 | HBC | 0.4–2.3 GeV/$c$ $K^-p$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 2.69 ±0.05 | 6582 | ALTHOFF | 73B | OSPK | $\pi^+ n \rightarrow \Lambda K^+$ |
| 2.54 ±0.04 | 4572 | BALTAY | 71B | HBC | $K^-p$ at rest |
| 2.535±0.035 | 8342 | GRIMM | 68 | HBC | |
| 2.47 ±0.08 | 2600 | HEPP | 68 | HBC | |
| 2.35 ±0.09 | 916 | BURAN | 66 | HLBC | |
| $2.452^{+0.056}_{-0.054}$ | 2213 | ENGELMANN | 66 | HBC | |
| 2.59 ±0.09 | 794 | HUBBARD | 64 | HBC | |
| 2.59 ±0.07 | 1378 | SCHWARTZ | 64 | HBC | |
| 2.36 ±0.06 | 2239 | BLOCK | 63 | HEBC | |




$\Lambda$ mean life ($10^{-10}$ s)

## $(\tau_\Lambda - \tau_{\overline{\Lambda}}) / \tau_\Lambda$

A test of $CPT$ invariance.

| *VALUE* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **−0.001 ±0.009 OUR AVERAGE** | | | | |
| −0.0018±0.0066±0.0056 | BARNES | 96 | CNTR | LEAR $\overline{p}p \rightarrow \overline{\Lambda}\Lambda$ |
| 0.044 ±0.085 | BADIER | 67 | HBC | 2.4 GeV/$c$ $\overline{p}p$ |

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## $\Lambda$ MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" above. Measurements with an error $\geq 0.15\ \mu_N$ have been omitted.

| *VALUE* ($\mu_N$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **−0.613 ±0.004 OUR AVERAGE** | | | | | |
| −0.606 ±0.015 | 200k | COX | 81 | SPEC | |
| −0.6138±0.0047 | 3M | SCHACHIN... | 78 | SPEC | |
| −0.59 ±0.07 | 350k | HELLER | 77 | SPEC | |
| −0.57 ±0.05 | 1.2M | BUNCE | 76 | SPEC | |
| −0.66 ±0.07 | 1300 | DAHL-JENSEN | 71 | EMUL | 200 kG field |

## Λ ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both $T$ invariance and $P$ invariance.

| *VALUE* ($10^{-16}$ $e$ cm) | *CL%* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **< 1.5** | 95 | [5] PONDROM | 81 | SPEC |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| <100 | 95 | [6] BARONI | 71 | EMUL |
| <500 | 95 | GIBSON | 66 | EMUL |

[5] PONDROM 81 measures $(-3.0 \pm 7.4) \times 10^{-17}$ $e$-cm.
[6] BARONI 71 measures $(-5.9 \pm 2.9) \times 10^{-15}$ $e$-cm.

## Λ DECAY MODES

| | Mode | Fraction ($\Gamma_i/\Gamma$) |
|---|---|---|
| $\Gamma_1$ | $p\pi^-$ | (63.9 ±0.5 ) % |
| $\Gamma_2$ | $n\pi^0$ | (35.8 ±0.5 ) % |
| $\Gamma_3$ | $n\gamma$ | ( 1.75±0.15) $\times 10^{-3}$ |
| $\Gamma_4$ | $p\pi^-\gamma$ | [a] ( 8.4 ±1.4 ) $\times 10^{-4}$ |
| $\Gamma_5$ | $pe^-\overline{\nu}_e$ | ( 8.32±0.14) $\times 10^{-4}$ |
| $\Gamma_6$ | $p\mu^-\overline{\nu}_\mu$ | ( 1.57±0.35) $\times 10^{-4}$ |

[a] See the Listings below for the pion momentum range used in this measurement.

## CONSTRAINED FIT INFORMATION

An overall fit to 5 branching ratios uses 20 measurements and one constraint to determine 5 parameters. The overall fit has a $\chi^2 = 10.5$ for 16 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the $x_i$ whose labels appear in this array to sum to one.

| | | | | |
|---|---|---|---|---|
| $x_2$ | −100 | | | |
| $x_3$ | −2 | −1 | | |
| $x_5$ | 46 | −46 | −1 | |
| $x_6$ | 0 | 0 | 0 | 0 |
| | $x_1$ | $x_2$ | $x_3$ | $x_5$ |

## Λ BRANCHING RATIOS

### $\Gamma(p\pi^-)/\Gamma(N\pi)$ $\Gamma_1/(\Gamma_1+\Gamma_2)$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.641±0.005 OUR FIT** | | | | | |
| **0.640±0.005 OUR AVERAGE** | | | | | |
| 0.646±0.008 | 4572 | BALTAY | 71B | HBC | $K^-p$ at rest |
| 0.635±0.007 | 6736 | DOYLE | 69 | HBC | $\pi^-p \rightarrow \Lambda K^0$ |
| 0.643±0.016 | 903 | HUMPHREY | 62 | HBC | |
| 0.624±0.030 | | CRAWFORD | 59B | HBC | $\pi^-p \rightarrow \Lambda K^0$ |

### $\Gamma(n\pi^0)/\Gamma(N\pi)$ $\Gamma_2/(\Gamma_1+\Gamma_2)$

| VALUE | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.359±0.005 OUR FIT** | | | | |
| **0.310±0.028 OUR AVERAGE** | | | | |
| 0.35 ±0.05 | | BROWN | 63 | HLBC |
| 0.291±0.034 | 75 | CHRETIEN | 63 | HLBC |

### $\Gamma(n\gamma)/\Gamma_{total}$ $\Gamma_3/\Gamma$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.75±0.15 OUR FIT** | | | | | |
| **1.75±0.15** | 1816 | LARSON | 93 | SPEC | $K^-p$ at rest |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $1.78\pm0.24^{+0.14}_{-0.16}$ | 287 | NOBLE | 92 | SPEC | See LARSON 93 |

### $\Gamma(n\gamma)/\Gamma(n\pi^0)$ $\Gamma_3/\Gamma_2$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 2.86±0.74±0.57 | 24 | BIAGI | 86 | SPEC | SPS hyperon beam |

### $\Gamma(p\pi^-\gamma)/\Gamma(p\pi^-)$ $\Gamma_4/\Gamma_1$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.32±0.22** | 72 | BAGGETT | 72C | HBC | $\pi^-$ $< 95$ MeV/$c$ |

### $\Gamma(pe^-\overline{\nu}_e)/\Gamma(p\pi^-)$ $\Gamma_5/\Gamma_1$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.301±0.019 OUR FIT** | | | | | |
| **1.301±0.019 OUR AVERAGE** | | | | | |
| 1.335±0.056 | 7111 | BOURQUIN | 83 | SPEC | SPS hyperon beam |
| 1.313±0.024 | 10k | WISE | 80 | SPEC | |
| 1.23 ±0.11 | 544 | LINDQUIST | 77 | SPEC | $\pi^-p \rightarrow K^0\Lambda$ |
| 1.27 ±0.07 | 1089 | KATZ | 73 | HBC | |
| 1.31 ±0.06 | 1078 | ALTHOFF | 71 | OSPK | |
| 1.17 ±0.13 | 86 | [7] CANTER | 71 | HBC | $K^-p$ at rest |
| 1.20 ±0.12 | 143 | [8] MALONEY | 69 | HBC | |
| 1.17 ±0.18 | 120 | [8] BAGLIN | 64 | FBC | $K^-$ freon 1.45 GeV/$c$ |
| 1.23 ±0.20 | 150 | [8] ELY | 63 | FBC | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 1.32 ±0.15 | 218 | [7] LINDQUIST | 71 | OSPK | See LINDQUIST 77 |

[7] Changed by us from $\Gamma(p e^- \overline{\nu}_e)/\Gamma(N\pi)$ assuming the authors used $\Gamma(p\pi^-)/\Gamma_{\text{total}} = 2/3$.

[8] Changed by us from $\Gamma(p e^- \overline{\nu}_e)/\Gamma(N\pi)$ because $\Gamma(p e^- \nu)/\Gamma(p\pi^-)$ is the directly measured quantity.

### $\Gamma(p\mu^-\overline{\nu}_\mu)/\Gamma(N\pi)$ $\Gamma_6/(\Gamma_1+\Gamma_2)$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.57±0.35 OUR FIT** | | | | | |
| **1.57±0.35 OUR AVERAGE** | | | | | |
| 1.4 ±0.5 | 14 | BAGGETT | 72B | HBC | $K^-p$ at rest |
| 2.4 ±0.8 | 9 | CANTER | 71B | HBC | $K^-p$ at rest |
| 1.3 ±0.7 | 3 | LIND | 64 | RVUE | |
| 1.5 ±1.2 | 2 | RONNE | 64 | FBC | |

## $\Lambda$ DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings. Some early results have been omitted.

### $\alpha_-$ FOR $\Lambda \to p\pi^-$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.642±0.013 OUR AVERAGE** | | | | | |
| 0.584±0.046 | 8500 | ASTBURY | 75 | SPEC | |
| 0.649±0.023 | 10325 | CLELAND | 72 | OSPK | |
| 0.67 ±0.06 | 3520 | DAUBER | 69 | HBC | From $\Xi$ decay |
| 0.645±0.017 | 10130 | OVERSETH | 67 | OSPK | $\Lambda$ from $\pi^- p$ |
| 0.62 ±0.07 | 1156 | CRONIN | 63 | CNTR | $\Lambda$ from $\pi^- p$ |

### $\phi$ ANGLE FOR $\Lambda \to p\pi^-$ $(\tan\phi = \beta\,/\,\gamma)$

| VALUE (°) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **− 6.5± 3.5 OUR AVERAGE** | | | | | |
| − 7.0± 4.5 | 10325 | CLELAND | 72 | OSPK | $\Lambda$ from $\pi^- p$ |
| − 8.0± 6.0 | 10130 | OVERSETH | 67 | OSPK | $\Lambda$ from $\pi^- p$ |
| 13.0±17.0 | 1156 | CRONIN | 63 | OSPK | $\Lambda$ from $\pi^- p$ |

### $\alpha_0\,/\,\alpha_- = \alpha(\Lambda \to n\pi^0)\,/\,\alpha(\Lambda \to p\pi^-)$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.01 ±0.07 OUR AVERAGE** | | | | | |
| 1.000±0.068 | 4760 | [9] OLSEN | 70 | OSPK | $\pi^+ n \to \Lambda K^+$ |
| 1.10 ±0.27 | | CORK | 60 | CNTR | |

[9] OLSEN 70 compares proton and neutron distributions from $\Lambda$ decay.

### $[\alpha_-(\Lambda) + \alpha_+(\overline{\Lambda})]$ / $[\alpha_-(\Lambda) - \alpha_+(\overline{\Lambda})]$

Zero if *CP* is conserved; $\alpha_-$ and $\alpha_+$ are the asymmetry parameters for $\Lambda \to p\pi^-$ and $\overline{\Lambda} \to \overline{p}\pi^+$ decay. See also the $\Xi^-$ for a similar test involving the decay chain $\Xi^- \to \Lambda\pi^-$, $\Lambda \to p\pi^-$ and the corresponding antiparticle chain.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.012±0.021 OUR AVERAGE** | | | | | |
| +0.013±0.022 | 96k | BARNES | 96 | CNTR | LEAR $\overline{p}p \to \overline{\Lambda}\Lambda$ |
| +0.01 ±0.10 | 770 | TIXIER | 88 | DM2 | $J/\psi \to \Lambda\overline{\Lambda}$ |
| −0.02 ±0.14 | 10k | [10] CHAUVAT | 85 | CNTR | $pp$, $\overline{p}p$ ISR |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| −0.07 ±0.09 | 4063 | BARNES | 87 | CNTR | See BARNES 96 |

[10] CHAUVAT 85 actually gives $\alpha_+(\overline{\Lambda})/\alpha_-(\Lambda) = -1.04 \pm 0.29$. Assumes polarization is same in $\overline{p}p \to \overline{\Lambda}X$ and $pp \to \Lambda X$. Tests of this assumption, based on *C*-invariance and fragmentation, are satisfied by the data.

### $g_A$ / $g_V$ FOR $\Lambda \to p e^- \overline{\nu}_e$

Measurements with fewer than 500 events have been omitted. Where necessary, signs have been changed to agree with our conventions, which are given in the "Note on Baryon Decay Parameters" in the neutron Listings. The measurements all assume that the form factor $g_2 = 0$. See also the footnote on DWORKIN 90.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **=0.718±0.015 OUR AVERAGE** | | | | | |
| −0.719±0.016±0.012 | 37k | [11] DWORKIN | 90 | SPEC | $e\nu$ angular corr. |
| −0.70 ±0.03 | 7111 | BOURQUIN | 83 | SPEC | $\Xi \to \Lambda\pi^-$ |
| −0.734±0.031 | 10k | [12] WISE | 81 | SPEC | $e\nu$ angular correl. |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| −0.63 ±0.06 | 817 | ALTHOFF | 73 | OSPK | Polarized $\Lambda$ |

[11] The tabulated result assumes the weak-magnetism coupling $w \equiv g_W(0)/g_V(0)$ to be 0.97, as given by the CVC hypothesis and as assumed by the other listed measurements. However, DWORKIN 90 *measures* $w$ to be 0.15 ± 0.30, and then $g_A/g_V = -0.731 \pm 0.016$.

[12] This experiment measures only the absolute value of $g_A/g_V$.

## $\Lambda$ REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.


| | | | | |
|---|---|---|---|---|
| BARNES | 96 | PR C54 1877 | P.D. Barnes *et al.* | (CERN PS-185 Collab.) |
| RYBICKI | 96 | APP B27 2155 | K. Rybicki | |
| HARTOUNI | 94 | PRL 72 1322 | E.P. Hartouni *et al.* | (BNL E766 Collab.) |
| Also | 94B | PRL 72 2821 (erratum) | E.P. Hartouni *et al.* | (BNL E766 Collab.) |
| LARSON | 93 | PR D47 799 | K.D. Larson *et al.* | (BNL-811 Collab.) |
| NOBLE | 92 | PRL 69 414 | A.J. Noble *et al.* | (BIRM, BOST, BRCO+) |
| DWORKIN | 90 | PR D41 780 | J. Dworkin *et al.* | (MICH, WISC, RUTG+) |
| TIXIER | 88 | PL B212 523 | M.H. Tixier *et al.* | (DM2 Collab.) |
| BARNES | 87 | PL B199 147 | P.D. Barnes *et al.* | (CMU, SACL, LANL+) |
| BIAGI | 86 | ZPHY C30 201 | S.F. Biagi *et al.* | (BRIS, CERN, GEVA+) |
| CHAUVAT | 85 | PL 163B 273 | P. Chauvat *et al.* | (CERN, CLER, UCLA+) |
| BOURQUIN | 83 | ZPHY C21 1 | M.H. Bourquin *et al.* | (BRIS, GEVA, HEIDP+) |
| COX | 81 | PRL 46 877 | P.T. Cox *et al.* | (MICH, WISC, RUTG, MINN+) |
| PONDROM | 81 | PR D23 814 | L. Pondrom *et al.* | (WISC, MICH, RUTG+) |
| WISE | 81 | PL 98B 123 | J.E. Wise *et al.* | (MASA, BNL) |
| WISE | 80 | PL 91B 165 | J.E. Wise *et al.* | (MASA, BNL) |
| SCHACHIN... | 78 | PRL 41 1348 | L. Schachinger *et al.* | (MICH, RUTG, WISC) |
| HELLER | 77 | PL 68B 480 | K. Heller *et al.* | (MICH, WISC, HEIDH) |

| | | | | |
|---|---|---|---|---|
| LINDQUIST | 77 | PR D16 2104 | J. Lindquist *et al.* | (EFI, OSU, ANL) |
| Also | 76 | JPG 2 L211 | J. Lindquist *et al.* | (EFI, WUSL, OSU+) |
| ZECH | 77 | NP B124 413 | G. Zech *et al.* | (SIEG, CERN, DORT, HEIDH) |
| BUNCE | 76 | PRL 36 1113 | G.R.M. Bunce *et al.* | (WISC, MICH, RUTG) |
| ASTBURY | 75 | NP B99 30 | P. Astbury *et al.* | (LOIC, CERN, ETH+) |
| CLAYTON | 75 | NP B95 130 | E.F. Clayton *et al.* | (LOIC, RHEL) |
| ALTHOFF | 73 | PL 43B 237 | K.H. Althoff *et al.* | (CERN, HEID) |
| ALTHOFF | 73B | NP B66 29 | K.H. Althoff *et al.* | (CERN, HEID) |
| KATZ | 73 | Thesis MDDP-TR-74-044 | C.N. Katz | (UMD) |
| POULARD | 73 | PL 46B 135 | G. Poulard, A. Givernaud, A.C. Borg | (SACL) |
| BAGGETT | 72B | ZPHY 252 362 | M.J. Baggett *et al.* | (HEID) |
| BAGGETT | 72C | PL 42B 379 | M.J. Baggett *et al.* | (HEID) |
| CLELAND | 72 | NP B40 221 | W.E. Cleland *et al.* | (CERN, GEVA, LUND) |
| HYMAN | 72 | PR D5 1063 | L.G. Hyman *et al.* | (ANL, CMU) |
| ALTHOFF | 71 | PL 37B 531 | K.H. Althoff *et al.* | (CERN, HEID) |
| BALTAY | 71B | PR D4 670 | C. Baltay *et al.* | (COLU, BING) |
| BARONI | 71 | LNC 2 1256 | G. Baroni, S. Petrera, G. Romano | (ROMA) |
| CANTER | 71 | PRL 26 868 | J. Canter *et al.* | (STON, COLU) |
| CANTER | 71B | PRL 27 59 | J. Canter *et al.* | (STON, COLU) |
| DAHL-JENSEN | 71 | NC 3A 1 | E. Dahl-Jensen *et al.* | (CERN, ANKA, LAUS+) |
| LINDQUIST | 71 | PRL 27 612 | J. Lindquist *et al.* | (EFI, WUSL, OSU+) |
| OLSEN | 70 | PRL 24 843 | S.L. Olsen *et al.* | (WISC, MICH) |
| DAUBER | 69 | PR 179 1262 | P.M. Dauber *et al.* | (LRL) |
| DOYLE | 69 | Thesis UCRL 18139 | J.C. Doyle | (LRL) |
| MALONEY | 69 | PRL 23 425 | J.E. Maloney, B. Sechi-Zorn | (UMD) |
| GRIMM | 68 | NC 54A 187 | H.J. Grimm | (HEID) |
| HEPP | 68 | ZPHY 214 71 | V. Hepp, H. Schleich | (HEID) |
| BADIER | 67 | PL 25B 152 | J. Badier *et al.* | (EPOL) |
| MAYEUR | 67 | U.Libr.Brux.Bul. 32 | C. Mayeur, E. Tompa, J.H. Wickens | (BELG, LOUC) |
| OVERSETH | 67 | PRL 19 391 | O.E. Overseth, R.F. Roth | (MICH, PRIN) |
| PDG | 67 | RMP 39 1 | A.H. Rosenfeld *et al.* | (LRL, CERN, YALE) |
| BURAN | 66 | PL 20 318 | T. Buran *et al.* | (OSLO) |
| CHIEN | 66 | PR 152 1171 | C.Y. Chien *et al.* | (YALE, BNL) |
| ENGELMANN | 66 | NC 45A 1038 | R. Engelmann *et al.* | (HEID, REHO) |
| GIBSON | 66 | NC 45A 882 | W.M. Gibson, K. Green | (BRIS) |
| LONDON | 66 | PR 143 1034 | G.W. London *et al.* | (BNL, SYRA) |
| SCHMIDT | 65 | PR 140B 1328 | P. Schmidt | (COLU) |
| BAGLIN | 64 | NC 35 977 | C. Baglin *et al.* | (EPOL, CERN, LOUC, RHEL+) |
| HUBBARD | 64 | PR 135B 183 | J.R. Hubbard *et al.* | (LRL) |
| LIND | 64 | PR 135B 1483 | V.G. Lind *et al.* | (WISC) |
| RONNE | 64 | PL 11 357 | B.E. Ronne *et al.* | (CERN, EPOL, LOUC+) |
| SCHWARTZ | 64 | Thesis UCRL 11360 | J.A. Schwartz | (LRL) |
| BHOWMIK | 63 | NC 28 1494 | B. Bhowmik, D.P. Goyal | (DELH) |
| BLOCK | 63 | PR 130 766 | M.M. Block *et al.* | (NWES, BGNA, SYRA+) |
| BROWN | 63 | PR 130 769 | J.L. Brown *et al.* | (LRL, MICH) |
| CHRETIEN | 63 | PR 131 2208 | M. Chretien *et al.* | (BRAN, BROW, HARV+) |
| CRONIN | 63 | PR 129 1795 | J.W. Cronin, O.E. Overseth | (PRIN) |
| ELY | 63 | PR 131 868 | R.P. Ely *et al.* | (LRL) |
| HUMPHREY | 62 | PR 127 1305 | W.E. Humphrey, R.R. Ross | (LRL) |
| CORK | 60 | PR 120 1000 | B. Cork *et al.* | (LRL, PRIN, BNL) |
| CRAWFORD | 59B | PRL 2 266 | F.S. Crawford *et al.* | (LRL) |