# $\Sigma^+$

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

We have omitted some results that have been superseded by later experiments.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

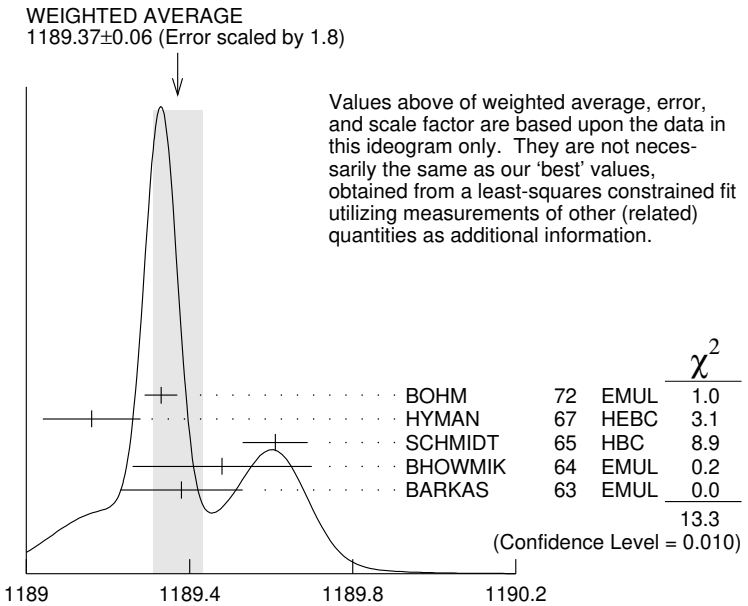
## $\Sigma^+$ MASS

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

| *VALUE* (MeV) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **1189.37±0.07 OUR FIT** | Error includes scale factor of 2.2. | | | | |
| **1189.37±0.06 OUR AVERAGE** | Error includes scale factor of 1.8. See the ideogram below. | | | | |
| 1189.33±0.04 | 607 | [1] BOHM | 72 | EMUL | |
| 1189.16±0.12 | | HYMAN | 67 | HEBC | |
| 1189.61±0.08 | 4205 | SCHMIDT | 65 | HBC | See note with $\Lambda$ mass |
| 1189.48±0.22 | 58 | [2] BHOWMIK | 64 | EMUL | |
| 1189.38±0.15 | 144 | [2] BARKAS | 63 | EMUL | |

[1] BOHM 72 is updated with our 1973 $K^-$, $\pi^-$, and $\pi^0$ masses (Reviews of Modern Physics **45** No. 2 Pt. II (1973)).

[2] These masses have been raised 30 keV to take into account a 46 keV increase in the proton mass and a 21 keV decrease in the $\pi^0$ mass (note added 1967 edition, Reviews of Modern Physics **39** 1 (1967)).



## $\Sigma^+$ MEAN LIFE

Measurements with fewer than 1000 events have been omitted.

| *VALUE* ($10^{-10}$ s) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **0.8018±0.0026 OUR AVERAGE** | | | | | |
| 0.8038±0.0040±0.0014 | | BARBOSA | 00 | E761 | hyperons, 375 GeV |
| 0.8043±0.0080±0.0014 | | [3] BARBOSA | 00 | E761 | hyperons, 375 GeV |
| 0.798 ±0.005 | 30k | MARRAFFINO | 80 | HBC | $K^-p$ 0.42–0.5 GeV/$c$ |
| 0.807 ±0.013 | 5719 | CONFORTO | 76 | HBC | $K^-p$ 1–1.4 GeV/$c$ |
| 0.795 ±0.010 | 20k | EISELE | 70 | HBC | $K^-p$ at rest |
| 0.803 ±0.008 | 10664 | BARLOUTAUD | 69 | HBC | $K^-p$ 0.4–1.2 GeV/$c$ |
| 0.83 ±0.032 | 1300 | [4] CHANG | 66 | HBC | |

[3] This is a measurement of the $\overline{\Sigma}^-$ lifetime. Here we assume *CPT* invariance; see below for the fractional $\Sigma^+$-$\overline{\Sigma}^-$ lifetime difference obtained by BARBOSA 00.

[4] We have increased the CHANG 66 error of 0.018; see our 1970 edition, Reviews of Modern Physics **42** No. 1 (1970).

## $(\tau_{\Sigma^+} - \tau_{\overline{\Sigma}^-}) / \tau_{\Sigma^+}$

A test of *CPT* invariance.

| *VALUE* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| $(-6 \pm 12) \times 10^{-4}$ | BARBOSA | 00 | E761 | hyperons, 375 GeV |

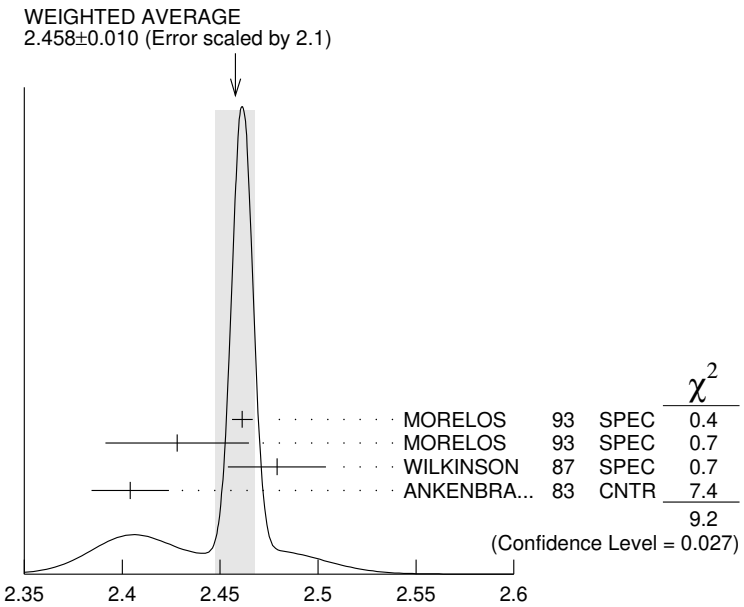
## $\Sigma^+$ MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the $\Lambda$ Listings. Measurements with an error $\geq$ 0.1 $\mu_N$ have been omitted.

| *VALUE* ($\mu_N$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **2.458 ±0.010 OUR AVERAGE** | | Error includes scale factor of 2.1. See the ideogram below. | | | |
| 2.4613±0.0034±0.0040 | 250k | MORELOS | 93 | SPEC | $p$Cu 800 GeV |
| 2.428 ±0.036 ±0.007 | 12k | [5] MORELOS | 93 | SPEC | $p$Cu 800 GeV |
| 2.479 ±0.012 ±0.022 | 137k | WILKINSON | 87 | SPEC | $p$Be 400 GeV |
| 2.4040±0.0198 | 44k | [6] ANKENBRA... | 83 | CNTR | $p$Cu 400 GeV |

[5] We assume *CPT* invariance: this is (minus) the $\overline{\Sigma}^-$ magnetic moment as measured by MORELOS 93. See below for the moment difference testing *CPT*.

[6] ANKENBRANDT 83 gives the value 2.38 ± 0.02$\mu_N$. MORELOS 93 uses the same hyperon magnet and channel and claims to determine the field integral better, leading to the revised value given here.




$\Sigma^+$ magnetic moment ($\mu_N$)

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## $(\mu_{\Sigma^+} + \mu_{\overline{\Sigma}^-}) / \mu_{\Sigma^+}$

A test of *CPT* invariance.

| *VALUE* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **0.014±0.015** | [7] MORELOS | 93 | SPEC | $p$ Cu 800 GeV |

[7] This is our calculation from the MORELOS 93 measurements of the $\Sigma^+$ and $\overline{\Sigma}^-$ magnetic moments given above. The statistical error on $\mu_{\overline{\Sigma}^-}$ dominates the error here.

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## $\Sigma^+$ DECAY MODES

| | Mode | | Fraction ($\Gamma_i/\Gamma$) | Confidence level |
|---|---|---|---|---|
| $\Gamma_1$ | $p\pi^0$ | | (51.57±0.30) % | |
| $\Gamma_2$ | $n\pi^+$ | | (48.31±0.30) % | |
| $\Gamma_3$ | $p\gamma$ | | ( 1.23±0.05) $\times 10^{-3}$ | |
| $\Gamma_4$ | $n\pi^+\gamma$ | [a] | ( 4.5 ±0.5 ) $\times 10^{-4}$ | |
| $\Gamma_5$ | $\Lambda e^+\nu_e$ | | ( 2.0 ±0.5 ) $\times 10^{-5}$ | |

### $\Delta S = \Delta Q$ ($SQ$) violating modes or $\Delta S = 1$ weak neutral current ($S1$) modes

| | | | | | |
|---|---|---|---|---|---|
| $\Gamma_6$ | $ne^+\nu_e$ | $SQ$ | < 5 | $\times 10^{-6}$ | 90% |
| $\Gamma_7$ | $n\mu^+\nu_\mu$ | $SQ$ | < 3.0 | $\times 10^{-5}$ | 90% |
| $\Gamma_8$ | $pe^+e^-$ | $S1$ | < 7 | $\times 10^{-6}$ | |

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

## CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 14 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2 = 7.7$ for 12 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 | | |
| $x_3$ | 12 | −14 | |
| | $x_1$ | $x_2$ | |

## $\Sigma^+$ BRANCHING RATIOS

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

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.4836±0.0030 OUR FIT** | | | | | |
| **0.4836±0.0030 OUR AVERAGE** | | | | | |
| 0.4828±0.0036 | 10k | [8] MARRAFFINO | 80 | HBC | $K^-p$ 0.42–0.5 GeV/$c$ |
| 0.488 ±0.008 | 1861 | NOWAK | 78 | HBC | |
| 0.484 ±0.015 | 537 | TOVEE | 71 | EMUL | |
| 0.488 ±0.010 | 1331 | BARLOUTAUD | 69 | HBC | $K^-p$ 0.4–1.2 GeV/$c$ |
| 0.46 ±0.02 | 534 | CHANG | 66 | HBC | |
| 0.490 ±0.024 | 308 | HUMPHREY | 62 | HBC | |

[8] MARRAFFINO 80 actually gives $\Gamma(p\pi^0)/\Gamma(\text{total}) = 0.5172 \pm 0.0036$.

### $\Gamma(p\gamma)/\Gamma(p\pi^0)$ $\Gamma_3/\Gamma_1$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **2.38±0.10 OUR FIT** | | | | | |
| **2.38±0.10 OUR AVERAGE** | | | | | |
| 2.32±0.11±0.10 | 32k | TIMM | 95 | E761 | $\Sigma^+$ 375 GeV |
| $2.81 \pm 0.39^{+0.21}_{-0.43}$ | 408 | HESSEY | 89 | CNTR | $K^-p \rightarrow \Sigma^+\pi^-$ at rest |
| 2.52±0.28 | 190 | [9] KOBAYASHI | 87 | CNTR | $\pi^+p \rightarrow \Sigma^+K^+$ |
| $2.46^{+0.30}_{-0.35}$ | 155 | BIAGI | 85 | CNTR | CERN hyperon beam |
| 2.11±0.38 | 46 | MANZ | 80 | HBC | $K^-p \rightarrow \Sigma^+\pi^-$ |
| 2.1 ±0.3 | 45 | ANG | 69B | HBC | $K^-p$ at rest |
| 2.76±0.51 | 31 | GERSHWIN | 69B | HBC | $K-p \rightarrow \Sigma^+\pi^-$ |
| 3.7 ±0.8 | 24 | BAZIN | 65 | HBC | $K^-p$ at rest |

[9] KOBAYASHI 87 actually gives $\Gamma(p\gamma)/\Gamma(\text{total}) = (1.30 \pm 0.15) \times 10^{-3}$.

## $\Gamma(n\pi^+\gamma)/\Gamma(n\pi^+)$ $\Gamma_4/\Gamma_2$

The $\pi^+$ momentum cuts differ, so we do not average the results but simply use the latest value in the Summary Table.

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **0.93±0.10** | 180 | EBENHOH | 73 | HBC | $\pi^+$ $< 150$ MeV/$c$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.27±0.05 | 29 | ANG | 69B | HBC | $\pi^+$ $< 110$ MeV/$c$ |
| $\sim 1.8$ | | BAZIN | 65B | HBC | $\pi^+$ $< 116$ MeV/$c$ |

## $\Gamma(\Lambda e^+\nu_e)/\Gamma_{total}$ $\Gamma_5/\Gamma$

| *VALUE* (units $10^{-5}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **2.0±0.5 OUR AVERAGE** | | | | | |
| 1.6±0.7 | 5 | BALTAY | 69 | HBC | $K^-p$ at rest |
| 2.9±1.0 | 10 | EISELE | 69 | HBC | $K^-p$ at rest |
| 2.0±0.8 | 6 | BARASH | 67 | HBC | $K^-p$ at rest |

## $\Gamma(ne^+\nu_e)/\Gamma(n\pi^+)$ $\Gamma_6/\Gamma_2$

Test of $\Delta S = \Delta Q$ rule. Experiments with an effective denominator less than 100,000 have been omitted.

| *EFFECTIVE DENOM.* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **$< 1.1 \times 10^{-5}$ OUR LIMIT** | | Our 90% CL limit = (2.3 events)/(effective denominator sum). [Number of events increased to 2.3 for a 90% confidence level.] | | | |
| 111000 | 0 | [10] EBENHOH | 74 | HBC | $K^-p$ at rest |
| 105000 | 0 | [10] SECHI-ZORN | 73 | HBC | $K^-p$ at rest |

[10] Effective denominator calculated by us.

## $\Gamma(n\mu^+\nu_\mu)/\Gamma(n\pi^+)$ $\Gamma_7/\Gamma_2$

Test of $\Delta S = \Delta Q$ rule.

| *EFFECTIVE DENOM.* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **$< 6.2 \times 10^{-5}$ OUR LIMIT** | | Our 90% CL limit = (6.7 events)/(effective denominator sum). [Number of events increased to 6.7 for a 90% confidence level.] | | |
| 33800 | 0 | BAGGETT | 69B | HBC |
| 62000 | 2 | [11] EISELE | 69B | HBC |
| 10150 | 0 | [12] COURANT | 64 | HBC |
| 1710 | 0 | [12] NAUENBERG | 64 | HBC |
| 120 | 1 | GALTIERI | 62 | EMUL |

[11] Effective denominator calculated by us.
[12] Effective denominator taken from EISELE 67.

## $\Gamma(pe^+e^-)/\Gamma_{total}$ $\Gamma_8/\Gamma$

| *VALUE* (units $10^{-6}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **<7** | [13] ANG | 69B | HBC | $K^-p$ at rest |

[13] ANG 69B found three $pe^+e^-$ events in agreement with $\gamma \to e^+e^-$ conversion from $\Sigma^+ \to p\gamma$. The limit given here is for neutral currents.

### $\Gamma(\Sigma^+ \to n e^+ \nu_e)/\Gamma(\Sigma^- \to n e^- \overline{\nu}_e)$

| VALUE | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **<0.009 OUR LIMIT** | Our 90% CL limit, using $\Gamma(n e^+ \nu_e)/\Gamma(n\pi^+)$ above. | | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| <0.019 | 90 | 0 | EBENHOH | 74 | HBC | $K^- p$ at rest |
| <0.018 | 90 | 0 | SECHI-ZORN | 73 | HBC | $K^- p$ at rest |
| <0.12 | 95 | 0 | COLE | 71 | HBC | $K^- p$ at rest |
| <0.03 | 90 | 0 | EISELE | 69B | HBC | See EBENHOH 74 |

### $\Gamma(\Sigma^+ \to n \mu^+ \nu_\mu)/\Gamma(\Sigma^- \to n \mu^- \overline{\nu}_\mu)$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **<0.12 OUR LIMIT** | Our 90% CL limit, using $\Gamma(n\mu^+ \nu_\mu)/\Gamma(n\pi^+)$ above. | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $0.06^{+0.045}_{-0.03}$ | 2 | EISELE | 69B | HBC | $K^- p$ at rest |

### $\Gamma(\Sigma^+ \to n \ell^+ \nu)/\Gamma(\Sigma^- \to n \ell^- \overline{\nu})$

Test of $\Delta S = \Delta Q$ rule.

| VALUE | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **<0.043 OUR LIMIT** | Our 90% CL limit, using $\left[\Gamma(n e^+ \nu_e) + \Gamma(n\mu^+ \nu_\mu)\right]/\Gamma(n\pi^+)$. | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| <0.08 | 1 | NORTON | 69 | HBC |
| <0.034 | 0 | BAGGETT | 67 | HBC |

## $\Sigma^+$ DECAY PARAMETERS

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

### $\alpha_0$ FOR $\Sigma^+ \to p\pi^0$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$-0.980^{+0.017}_{-0.015}$ OUR FIT** | | | | | |
| **$-0.980^{+0.017}_{-0.013}$ OUR AVERAGE** | | | | | |
| $-0.945^{+0.055}_{-0.042}$ | 1259 | [14] LIPMAN | 73 | OSPK | $\pi^+ p \to \Sigma^+$ |
| $-0.940 \pm 0.045$ | 16k | BELLAMY | 72 | ASPK | $\pi^+ p \to \Sigma^+ K^+$ |
| $-0.98^{+0.05}_{-0.02}$ | 1335 | [15] HARRIS | 70 | OSPK | $\pi^+ p \to \Sigma^+ K^+$ |
| $-0.999 \pm 0.022$ | 32k | BANGERTER | 69 | HBC | $K^- p$ 0.4 GeV/$c$ |

[14] Decay protons scattered off aluminum.
[15] Decay protons scattered off carbon.

### $\phi_0$ ANGLE FOR $\Sigma^+ \to p\pi^0$ $(\tan\phi_0 = \beta/\gamma)$

| VALUE (°) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **36 ±34 OUR AVERAGE** | | | | | |
| $38.1^{+35.7}_{-37.1}$ | 1259 | [16] LIPMAN | 73 | OSPK | $\pi^+ p \to \Sigma^+ K^+$ |
| 22 ±90 | | [17] HARRIS | 70 | OSPK | $\pi^+ p \to \Sigma^+ K^+$ |

[16] Decay proton scattered off aluminum.
[17] Decay protons scattered off carbon.

### $\alpha_+ / \alpha_0$

Older results have been omitted.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **−0.069±0.013 OUR FIT** | | | | | |
| **−0.073±0.021** | 23k | MARRAFFINO | 80 | HBC | $K^- p$ 0.42–0.5 GeV/$c$ |

### $\alpha_+$ FOR $\Sigma^+ \to n\pi^+$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.068±0.013 OUR FIT** | | | | | |
| **0.066±0.016 OUR AVERAGE** | | | | | |
| 0.037±0.049 | 4101 | BERLEY | 70B | HBC | |
| 0.069±0.017 | 35k | BANGERTER | 69 | HBC | $K^- p$ 0.4 GeV/$c$ |

### $\phi_+$ ANGLE FOR $\Sigma^+ \to n\pi^+$ $(\tan\phi_+ = \beta/\gamma)$

| VALUE (°) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **167±20 OUR AVERAGE** Error includes scale factor of 1.1. | | | | | |
| 184±24 | 1054 | [18] BERLEY | 70B | HBC | |
| 143±29 | 560 | BANGERTER | 69B | HBC | $K^- p$ 0.4 GeV/$c$ |

[18] Changed from 176 to 184° to agree with our sign convention.

### $\alpha_\gamma$ FOR $\Sigma^+ \to p\gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **−0.76 ±0.08 OUR AVERAGE** | | | | | |
| −0.720±0.086±0.045 | 35k | [19] FOUCHER | 92 | SPEC | $\Sigma^+$ 375 GeV |
| −0.86 ±0.13 ±0.04 | 190 | KOBAYASHI | 87 | CNTR | $\pi^+ p \to \Sigma^+ K^+$ |
| $-0.53\ ^{+0.38}_{-0.36}$ | 46 | MANZ | 80 | HBC | $K^- p \to \Sigma^+ \pi^-$ |
| $-1.03\ ^{+0.52}_{-0.42}$ | 61 | GERSHWIN | 69B | HBC | $K^- p \to \Sigma^+ \pi^-$ |

[19] See TIMM 95 for a detailed description of the analysis.

# $\Sigma^+$ REFERENCES

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


| | | | | |
|---|---|---|---|---|
| BARBOSA | 00 | PR D61 031101R | R.F. Barbosa *et al.* | (FNAL E761 Collab.) |
| TIMM | 95 | PR D51 4638 | S. Timm *et al.* | (FNAL E761 Collab.) |
| MORELOS | 93 | PRL 71 3417 | A. Morelos *et al.* | (FNAL E761 Collab.) |
| FOUCHER | 92 | PRL 68 3004 | M. Foucher *et al.* | (FNAL E761 Collab.) |
| HESSEY | 89 | ZPHY C42 175 | N.P. Hessey *et al.* | (BNL-811 Collab.) |
| KOBAYASHI | 87 | PRL 59 868 | M. Kobayashi *et al.* | (KYOT) |
| WILKINSON | 87 | PRL 58 855 | C.A. Wilkinson *et al.* | (WISC, MICH, RUTG+) |
| BIAGI | 85 | ZPHY C28 495 | S.F. Biagi *et al.* | (CERN WA62 Collab.) |
| ANKENBRA... | 83 | PRL 51 863 | C.M. Ankenbrandt *et al.* | (FNAL, IOWA, ISU+) |
| MANZ | 80 | PL 96B 217 | A. Manz *et al.* | (MPIM, VAND) |
| MARRAFFINO | 80 | PR D21 2501 | J. Marraffino *et al.* | (VAND, MPIM) |
| NOWAK | 78 | NP B139 61 | R.J. Nowak *et al.* | (LOUC, BELG, DURH+) |
| CONFORTO | 76 | NP B105 189 | B. Conforto *et al.* | (RHEL, LOIC) |
| EBENHOH | 74 | ZPHY 266 367 | H. Ebenhoh *et al.* | (HEIDT) |
| EBENHOH | 73 | ZPHY 264 413 | W. Ebenhoh *et al.* | (HEIDT) |
| LIPMAN | 73 | PL 43B 89 | N.H. Lipman *et al.* | (RHEL, SUSS, LOWC) |
| PDG | 73 | RMP 45 No. 2 Pt. II | T.A. Lasinski *et al.* | (LBL, BRAN, CERN+) |
| SECHI-ZORN | 73 | PR D8 12 | B. Sechi-Zorn, G.A. Snow | (UMD) |
| BELLAMY | 72 | PL 39B 299 | E.H. Bellamy *et al.* | (LOWC, RHEL, SUSS) |
| BOHM | 72 | NP B48 1 | G. Bohm *et al.* | (BERL, KIDR, BRUX, IASD+) |
| Also | 73 | IIHE-73.2 Nov | G. Bohm | (BERL, KIDR, BRUX, IASD, DUUC+) |
| COLE | 71 | PR D4 631 | J. Cole *et al.* | (STON, COLU) |
| TOVEE | 71 | NP B33 493 | D.N. Tovee *et al.* | (LOUC, KIDR, BERL+) |
| BERLEY | 70B | PR D1 2015 | D. Berley *et al.* | (BNL, MASA, YALE) |
| EISELE | 70 | ZPHY 238 372 | F. Eisele *et al.* | (HEID) |
| HARRIS | 70 | PRL 24 165 | F. Harris *et al.* | (MICH, WISC) |
| PDG | 70 | RMP 42 No. 1 | A. Barbaro-Galtieri *et al.* | (LRL, BRAN+) |
| ANG | 69B | ZPHY 228 151 | G. Ang *et al.* | (HEID) |
| BAGGETT | 69B | Thesis MDDP-TR-973 | N.V. Baggett | (UMD) |
| BALTAY | 69 | PRL 22 615 | C. Baltay *et al.* | (COLU, STON) |
| BANGERTER | 69 | Thesis UCRL 19244 | R.O. Bangerter | (LRL) |
| BANGERTER | 69B | PR 187 1821 | R.O. Bangerter *et al.* | (LRL) |
| BARLOUTAUD | 69 | NP B14 153 | R. Barloutaud *et al.* | (SACL, CERN, HEID) |
| EISELE | 69 | ZPHY 221 1 | F. Eisele *et al.* | (HEID) |
| Also | 64 | PRL 13 291 | W. Willis *et al.* | (BNL, CERN, HEID, UMD) |
| EISELE | 69B | ZPHY 221 401 | F. Eisele *et al.* | (HEID) |
| GERSHWIN | 69B | PR 188 2077 | L.K. Gershwin *et al.* | (LRL) |
| Also | 69 | Thesis UCRL 19246 | L.K. Gershwin | (LRL) |
| NORTON | 69 | Thesis Nevis 175 | H. Norton | (COLU) |
| BAGGETT | 67 | PRL 19 1458 | N. Baggett *et al.* | (UMD) |
| Also | 68 | Vienna Abs. 374 | N.V. Baggett, B. Kehoe | (UMD) |
| Also | 68B | Private Comm. | N.V. Baggett | (UMD) |
| BARASH | 67 | PRL 19 181 | N. Barash *et al.* | (UMD) |
| EISELE | 67 | ZPHY 205 409 | F. Eisele *et al.* | (HEID) |
| HYMAN | 67 | PL 25B 376 | L.G. Hyman *et al.* | (ANL, CMU, NWES) |
| PDG | 67 | RMP 39 1 | A.H. Rosenfeld *et al.* | (LRL, CERN, YALE) |
| CHANG | 66 | PR 151 1081 | C.Y. Chang | (COLU) |
| Also | 65 | Thesis Nevis 145 | C.Y. Chang | (COLU) |
| BAZIN | 65 | PRL 14 154 | M. Bazin *et al.* | (PRIN, COLU) |
| BAZIN | 65B | PR 140B 1358 | M. Bazin *et al.* | (PRIN, RUTG, COLU) |
| SCHMIDT | 65 | PR 140B 1328 | P. Schmidt | (COLU) |
| BHOWMIK | 64 | NP 53 22 | B. Bhowmik *et al.* | (DELH) |
| COURANT | 64 | PR 136B 1791 | H. Courant *et al.* | (CERN, HEID, UMD+) |
| NAUENBERG | 64 | PRL 12 679 | U. Nauenberg *et al.* | (COLU, RUTG, PRIN) |
| BARKAS | 63 | PRL 11 26 | W.H. Barkas, J.N. Dyer, H.H. Heckman | (LRL) |
| Also | 61 | Thesis UCRL 9450 | J.N. Dyer | (LRL) |
| GALTIERI | 62 | PRL 9 26 | A. Barbaro-Galtieri *et al.* | (LRL) |
| HUMPHREY | 62 | PR 127 1305 | W.E. Humphrey, R.R. Ross | (LRL) |