# $\Sigma^-$

$I(J^P) = 1(\frac{1}{2}^+)$ 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We have omitted some results that have been superseded by later experiments.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 |
|---|---|---|---|---|---|
| **1197.449±0.030 OUR FIT** Error includes scale factor of 1.2. | | | | | |
| **1197.45 ±0.04 OUR AVERAGE** Error includes scale factor of 1.2. | | | | | |
| 1197.417±0.040 | | GUREV | 93 | SPEC | $\Sigma^-$ C atom, crystal diff. |
| 1197.532±0.057 | | GALL | 88 | CNTR | $\Sigma^-$ Pb, $\Sigma^-$ W atoms |
| 1197.43 ±0.08 | 3000 | SCHMIDT | 65 | HBC | See note with $\Lambda$ mass |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 1197.24 ±0.15 | | [1] DUGAN | 75 | CNTR | Exotic atoms |

[1] GALL 88 concludes that the DUGAN 75 mass needs to be reevaluated.

## $m_{\Sigma^-} - m_{\Sigma^+}$

| VALUE (MeV) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **8.08±0.08 OUR FIT** Error includes scale factor of 1.9. | | | | |
| **8.09±0.16 OUR AVERAGE** | | | | |
| 7.91±0.23 | 86 | BOHM | 72 | EMUL |
| 8.25±0.25 | 2500 | DOSCH | 65 | HBC |
| 8.25±0.40 | 87 | BARKAS | 63 | EMUL |

## $m_{\Sigma^-} - m_{\Lambda}$

| VALUE (MeV) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **81.766±0.030 OUR FIT** Error includes scale factor of 1.2. | | | | | |
| **81.69 ±0.07 OUR AVERAGE** | | | | | |
| 81.64 ±0.09 | 2279 | HEPP | 68 | HBC | |
| 81.80 ±0.13 | 85 | SCHMIDT | 65 | HBC | See note with $\Lambda$ mass |
| 81.70 ±0.19 | | BURNSTEIN | 64 | HBC | |

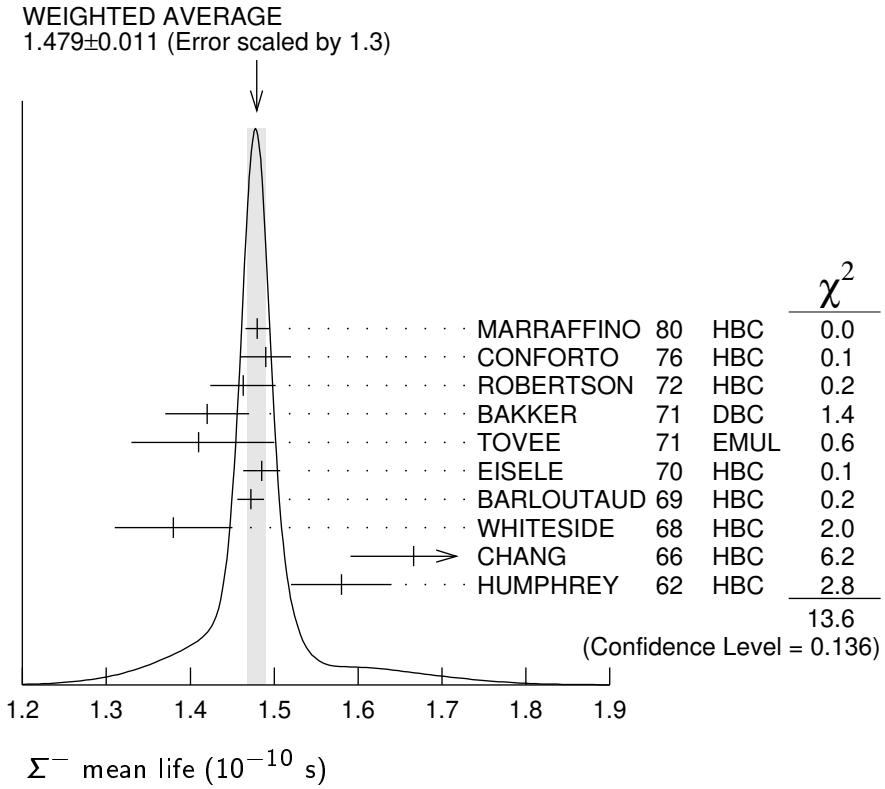
## $\Sigma^-$ MEAN LIFE

Measurements with an error $\geq 0.2 \times 10^{-10}$ s have been omitted.

| VALUE ($10^{-10}$ s) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.479±0.011 OUR AVERAGE** Error includes scale factor of 1.3. See the ideogram below. | | | | | |
| 1.480±0.014 | 16k | MARRAFFINO | 80 | HBC | $K^-$ $p$ 0.42–0.5 GeV/$c$ |
| 1.49 ±0.03 | 8437 | CONFORTO | 76 | HBC | $K^-$ $p$ 1–1.4 GeV/$c$ |
| 1.463±0.039 | 2400 | ROBERTSON | 72 | HBC | $K^-$ $p$ 0.25 GeV/$c$ |
| 1.42 ±0.05 | 1383 | BAKKER | 71 | DBC | $K^- N \rightarrow \Sigma^- \pi\pi$ |
| $1.41\ ^{+0.09}_{-0.08}$ | | TOVEE | 71 | EMUL | |

| | | | | | |
|---|---|---|---|---|---|
| 1.485 ± 0.022 | 100k | EISELE | 70 | HBC | $K^-$ $p$ at rest |
| 1.472 ± 0.016 | 10k | BARLOUTAUD | 69 | HBC | $K^-$ $p$ 0.4–1.2 GeV/$c$ |
| 1.38 ± 0.07 | 506 | WHITESIDE | 68 | HBC | $K^-$ $p$ at rest |
| 1.666 ± 0.075 | 3267 | [2] CHANG | 66 | HBC | $K^-$ $p$ at rest |
| 1.58 ± 0.06 | 1208 | HUMPHREY | 62 | HBC | $K^-$ $p$ at rest |

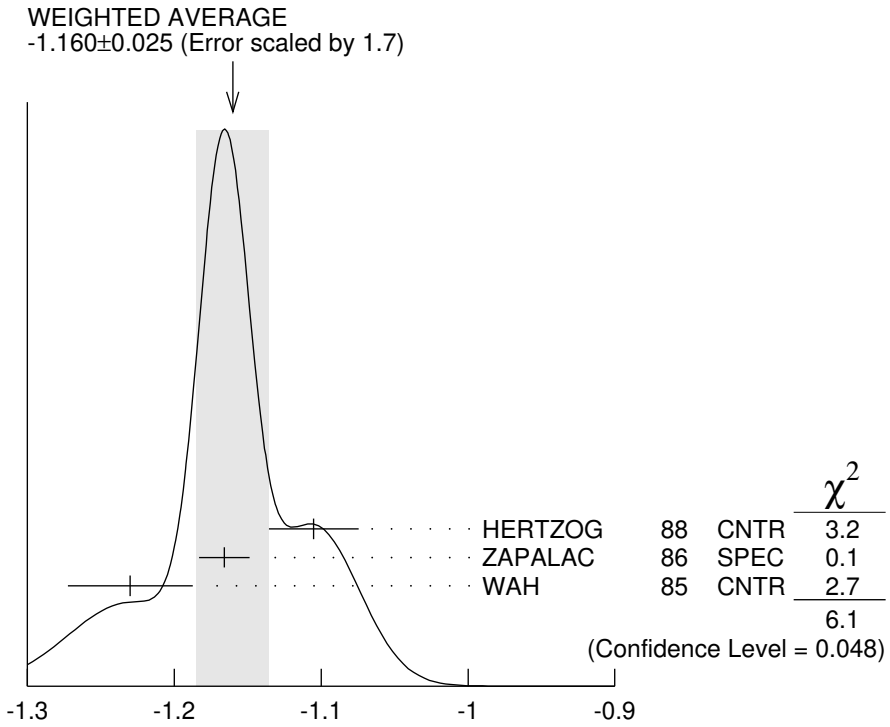
[2] We have increased the CHANG 66 error of 0.018; see our 1970 edition, Reviews of Modern Physics **42** No. 1 (1970).




## $\Sigma^-$ MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the $\Lambda$ Listings. Measurements with an error $\geq 0.3\ \mu_N$ have been omitted.

| *VALUE* ($\mu_N$) | *EVTS* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **−1.160 ± 0.025 OUR AVERAGE** Error includes scale factor of 1.7. See the ideogram below. | | | | |
| −1.105 ± 0.029 ± 0.010 | | HERTZOG 88 | CNTR | $\Sigma^-$ Pb, $\Sigma^-$ W atoms |
| −1.166 ± 0.014 ± 0.010 | 671k | ZAPALAC 86 | SPEC | $ne^-\nu$, $n\pi^-$ decays |
| −1.23 ± 0.03 ± 0.03 | | WAH 85 | CNTR | $p$Cu → $\Sigma^-$ X |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.89 ± 0.14 | 516k | DECK 83 | SPEC | $p$Be → $\Sigma^-$ X |




## $\Sigma^-$ CHARGE RADIUS

| *VALUE* (fm) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **0.780±0.080±0.060** | [3] ESCHRICH | 01 | SELX | $\Sigma^- e \rightarrow \Sigma^- e$ |

[3] ESCHRICH 01 actually gives $\langle r^2 \rangle = (0.61 \pm 0.12 \pm 0.09)$ fm$^2$.

## $\Sigma^-$ DECAY MODES

| | Mode | Fraction ($\Gamma_i/\Gamma$) |
|---|---|---|
| $\Gamma_1$ | $n\pi^-$ | (99.848±0.005) % |
| $\Gamma_2$ | $n\pi^-\gamma$ | [a] ( 4.6 ±0.6 ) × $10^{-4}$ |
| $\Gamma_3$ | $ne^-\overline{\nu}_e$ | ( 1.017±0.034) × $10^{-3}$ |
| $\Gamma_4$ | $n\mu^-\overline{\nu}_\mu$ | ( 4.5 ±0.4 ) × $10^{-4}$ |
| $\Gamma_5$ | $\Lambda e^-\overline{\nu}_e$ | ( 5.73 ±0.27 ) × $10^{-5}$ |

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

## CONSTRAINED FIT INFORMATION

An overall fit to 3 branching ratios uses 16 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2 =$ 8.7 for 13 degrees of freedom.

The following *off-diagonal* array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j)$, 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.

| | | | |
|---|---|---|---|
| $x_3$ | −64 | | |
| $x_4$ | −77 | 0 | |
| $x_5$ | −5 | 0 | 0 |
| | $x_1$ | $x_3$ | $x_4$ |

## $\Sigma^-$ BRANCHING RATIOS

### $\Gamma(n\pi^-\gamma)/\Gamma(n\pi^-)$ $\Gamma_2/\Gamma_1$

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

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.46±0.06** | 292 | EBENHOH | 73 | HBC | $\pi^+ < 150$ MeV/$c$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.10±0.02 | 23 | ANG | 69B | HBC | $\pi^- < 110$ MeV/$c$ |
| ~ 1.1 | | BAZIN | 65B | HBC | $\pi^- < 166$ MeV/$c$ |

### $\Gamma(ne^-\overline{\nu}_e)/\Gamma(n\pi^-)$ $\Gamma_3/\Gamma_1$

Measurements with an error $\geq 0.2 \times 10^{-3}$ have been omitted.

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.019±0.035 OUR FIT** | | | | | |
| **$1.019^{+0.031}_{-0.036}$ OUR AVERAGE** | | | | | |
| 0.96 ±0.05 | 2847 | BOURQUIN | 83C | SPEC | SPS hyperon beam |
| $1.09^{+0.06}_{-0.08}$ | 601 | [4] EBENHOH | 74 | HBC | $K^-p$ at rest |
| $1.05^{+0.07}_{-0.13}$ | 455 | [4] SECHI-ZORN | 73 | HBC | $K^-p$ at rest |
| 0.97 ±0.15 | 57 | COLE | 71 | HBC | $K^-p$ at rest |
| 1.11 ±0.09 | 180 | BIERMAN | 68 | HBC | |

[4] An additional negative systematic error is included for internal radiative corrections and latest form factors; see BOURQUIN 83C.

### $\Gamma(n\mu^-\overline{\nu}_\mu)/\Gamma(n\pi^-)$ $\Gamma_4/\Gamma_1$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.45±0.04 OUR FIT** | | | | | |
| **0.45±0.04 OUR AVERAGE** | | | | | |
| 0.38±0.11 | 13 | COLE | 71 | HBC | $K^-p$ at rest |
| 0.43±0.06 | 72 | ANG | 69 | HBC | $K^-p$ at rest |
| 0.43±0.09 | 56 | BAGGETT | 69 | HBC | $K^-p$ at rest |
| 0.56±0.20 | 11 | BAZIN | 65B | HBC | $K^-p$ at rest |
| 0.66±0.15 | 22 | COURANT | 64 | HBC | |

### $\Gamma(\Lambda e^-\overline{\nu}_e)/\Gamma(n\pi^-)$ $\Gamma_5/\Gamma_1$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.574±0.027 OUR FIT** | | | | | |
| **0.574±0.027 OUR AVERAGE** | | | | | |
| 0.561±0.031 | 1620 | [5] BOURQUIN | 82 | SPEC | SPS hyperon beam |
| 0.63 ±0.11 | 114 | THOMPSON | 80 | ASPK | Hyperon beam |
| 0.52 ±0.09 | 31 | BALTAY | 69 | HBC | $K^-p$ at rest |
| 0.69 ±0.12 | 31 | EISELE | 69 | HBC | $K^-p$ at rest |
| 0.64 ±0.12 | 35 | BARASH | 67 | HBC | $K^-p$ at rest |
| 0.75 ±0.28 | 11 | COURANT | 64 | HBC | $K^-p$ at rest |

[5] The value is from BOURQUIN 83B, and includes radiation corrections and new acceptance.

## $\Sigma^-$ DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings. Older, outdated results have been omitted.

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

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **−0.068±0.008 OUR AVERAGE** | | | | | |
| −0.062±0.024 | 28k | HANSL | 78 | HBC | $K^-p \to \Sigma^-\pi^+$ |
| −0.067±0.011 | 60k | BOGERT | 70 | HBC | $K^-p$ 0.4 GeV/$c$ |
| −0.071±0.012 | 51k | 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 |
|---|---|---|---|---|---|
| **10±15 OUR AVERAGE** | | | | | |
| + 5±23 | 1092 | [6] BERLEY | 70B | HBC | $n$ rescattering |
| 14±19 | 1385 | BANGERTER | 69B | HBC | $K^-p$ 0.4 GeV/$c$ |

[6] BERLEY 70B changed from −5 to +5° to agree with our sign convention.

### $g_A/g_V$ FOR $\Sigma^- \to ne^-\overline{\nu}_e$

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. What is actually listed is $|g_1/f_1 -$

$0.237 g_2/f_1|$. This reduces to $g_A/g_V \equiv g_1(0)/f_1(0)$ on making the usual assumption that $g_2 = 0$. See also the note on HSUEH 88.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.340±0.017 OUR AVERAGE** | | | | | |
| $+0.327 \pm 0.007 \pm 0.019$ | 50k | [7] HSUEH | 88 | SPEC | $\Sigma^-$ 250 GeV |
| $+0.34 \pm 0.05$ | 4456 | [8] BOURQUIN | 83C | SPEC | SPS hyperon beam |
| $0.385 \pm 0.037$ | 3507 | [9] TANENBAUM | 74 | ASPK | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $0.29 \pm 0.07$ | 25k | HSUEH | 85 | SPEC | See HSUEH 88 |
| $0.17 \ {}^{+0.07}_{-0.09}$ | 519 | DECAMP | 77 | ELEC | Hyperon beam |

[7] The sign is, *with our conventions*, unambiguously positive. The value assumes, as usual, that $g_2 = 0$. If $g_2$ is included in the fit, than (with our sign convention) $g_2 = -0.56 \pm 0.37$, with a corresponding reduction of $g_A/g_V$ to $+0.20 \pm 0.08$.

[8] BOURQUIN 83C favors the positive sign by at least 2.6 standard deviations.

[9] TANENBAUM 74 gives $0.435 \pm 0.035$, assuming no $q^2$ dependence in $g_A$ and $g_V$. The listed result allows $q^2$ dependence, and is taken from HSUEH 88.

## $f_2(0)/f_1(0)$ FOR $\Sigma^- \to n e^- \overline{\nu}_e$

The signs have been changed to be in accord with our conventions, given in the "Note on Baryon Decay Parameters" in the neutron Listings.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.97±0.14 OUR AVERAGE** | | | | | |
| $+0.96 \pm 0.07 \pm 0.13$ | 50k | HSUEH | 88 | SPEC | $\Sigma^-$ 250 GeV |
| $+1.02 \pm 0.34$ | 4456 | BOURQUIN | 83C | SPEC | SPS hyperon beam |

## TRIPLE CORRELATION COEFFICIENT $D$ for $\Sigma^- \to n e^- \overline{\nu}_e$

The coefficient $D$ of the term $D\ \mathbf{P}\cdot(\hat{\mathbf{p}}_e \times \hat{\mathbf{p}}_\nu)$ in the $\Sigma^- \to n e^- \overline{\nu}$ decay angular distribution. A nonzero value would indicate a violation of time-reversal invariance.

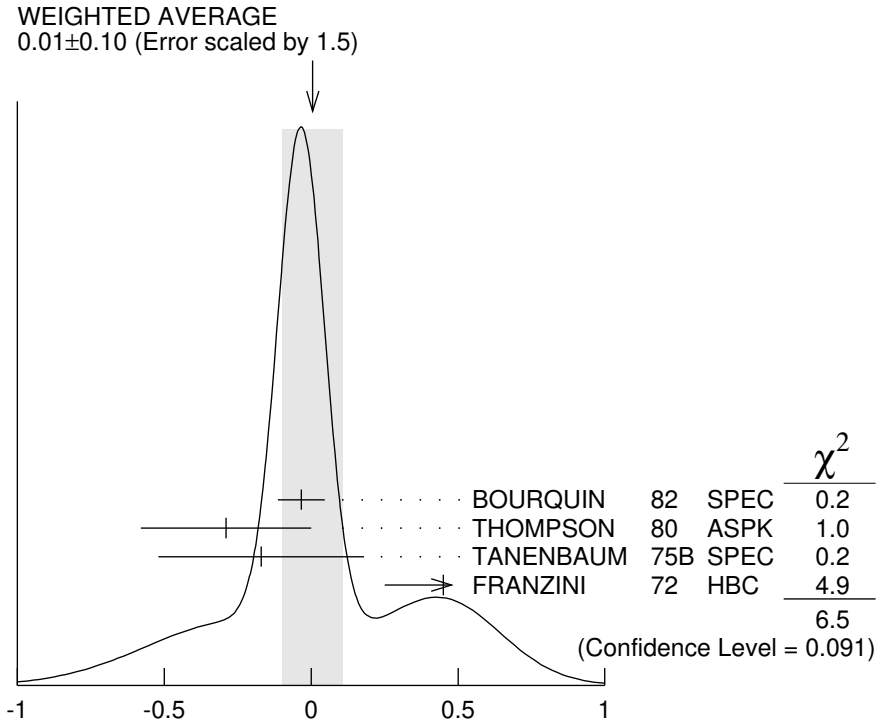
| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.11±0.10** | 50k | HSUEH | 88 | SPEC | $\Sigma^-$ 250 GeV |

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

For the sign convention, see the "Note on Baryon Decay Parameters" in the neutron Listings. The value is predicted to be zero by conserved vector current theory. The values averaged assume CVC-SU(3) weak magnetism term.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.01 ±0.10 OUR AVERAGE** Error includes scale factor of 1.5. See the ideogram below. | | | | | |
| $-0.034 \pm 0.080$ | 1620 | [10] BOURQUIN | 82 | SPEC | SPS hyperon beam |
| $-0.29 \pm 0.29$ | 114 | THOMPSON | 80 | ASPK | BNL hyperon beam |
| $-0.17 \pm 0.35$ | 55 | TANENBAUM | 75B | SPEC | BNL hyperon beam |
| $+0.45 \pm 0.20$ | 186 | [10,11] FRANZINI | 72 | HBC | |

[10] The sign has been changed to agree with our convention.
[11] The FRANZINI 72 value includes the events of earlier papers.




$g_V/g_A$ for $\Sigma^- \rightarrow \Lambda e^- \overline{\nu}_e$

## $g_{WM}/g_A$ FOR $\Sigma^- \rightarrow \Lambda e^- \overline{\nu}_e$

The values quoted assume the CVC prediction $g_V = 0$.

| *VALUE* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **2.4 ±1.7 OUR AVERAGE** | | | | | |
| 1.75±3.5 | 114 | THOMPSON | 80 | ASPK | BNL hyperon beam |
| 3.5 ±4.5 | 55 | TANENBAUM | 75B | SPEC | BNL hyperon beam |
| 2.4 ±2.1 | 186 | FRANZINI | 72 | HBC | |

## $\Sigma^-$ REFERENCES

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


| | | | | |
|---|---|---|---|---|
| ESCHRICH | 01 | PL B522 233 | I. Eschrich *et al.* | (FNAL SELEX Collab.) |
| GUREV | 93 | JETPL 57 400 | M.P. Gurev *et al.* | (PNPI) |
| | | Translated from ZETFP 57 389. | | |
| GALL | 88 | PRL 60 186 | K.P. Gall *et al.* | (BOST, MIT, WILL, CIT+) |
| HERTZOG | 88 | PR D37 1142 | D.W. Hertzog *et al.* | (WILL, BOST, MIT+) |
| HSUEH | 88 | PR D38 2056 | S.Y. Hsueh *et al.* | (CHIC, ELMT, FNAL+) |
| ZAPALAC | 86 | PRL 57 1526 | G. Zapalac *et al.* | (EFI, ELMT, FNAL+) |
| HSUEH | 85 | PRL 54 2399 | S.Y. Hsueh *et al.* | (CHIC, ELMT, FNAL+) |
| WAH | 85 | PRL 55 2551 | Y.W. Wah *et al.* | (FNAL, IOWA, ISU) |
| BOURQUIN | 83B | ZPHY C21 27 | M.H. Bourquin *et al.* | (BRIS, GEVA, HEIDP+) |
| BOURQUIN | 83C | ZPHY C21 17 | M.H. Bourquin *et al.* | (BRIS, GEVA, HEIDP+) |
| DECK | 83 | PR D28 1 | L. Deck *et al.* | (RUTG, WISC, MICH, MINN) |
| BOURQUIN | 82 | ZPHY C12 307 | M.H. Bourquin *et al.* | (BRIS, GEVA, HEIDP+) |
| MARRAFFINO | 80 | PR D21 2501 | J. Marraffino *et al.* | (VAND, MPIM) |
| THOMPSON | 80 | PR D21 25 | J.A. Thompson *et al.* | (PITT, BNL) |

| | | | | |
|---|---|---|---|---|
| HANSL | 78 | NP B132 45 | T. Hansl *et al.* | (MPIM, VAND) |
| DECAMP | 77 | PL 66B 295 | D. Decamp *et al.* | (LALO, EPOL) |
| CONFORTO | 76 | NP B105 189 | B. Conforto *et al.* | (RHEL, LOIC) |
| DUGAN | 75 | NP A254 396 | G. Dugan *et al.* | (COLU, YALE) |
| TANENBAUM | 75B | PR D12 1871 | W. Tanenbaum *et al.* | (YALE, FNAL, BNL) |
| EBENHOH | 74 | ZPHY 266 367 | H. Ebenhoh *et al.* | (HEIDT) |
| TANENBAUM | 74 | PRL 33 175 | W. Tanenbaum *et al.* | (YALE, FNAL, BNL) |
| EBENHOH | 73 | ZPHY 264 413 | W. Ebenhoh *et al.* | (HEIDT) |
| SECHI-ZORN | 73 | PR D8 12 | B. Sechi-Zorn, G.A. Snow | (UMD) |
| BOHM | 72 | NP B48 1 | G. Bohm *et al.* | (BERL, KIDR, BRUX, IASD+) |
| FRANZINI | 72 | PR D6 2417 | P. Franzini *et al.* | (COLU, HEID, UMD+) |
| ROBERTSON | 72 | Thesis UMI 78-00877 | R.M. Robertson | (IIT) |
| BAKKER | 71 | LNC 1 37 | A.M. Bakker *et al.* | (SABRE Collab.) |
| COLE | 71 | PR D4 631 | J. Cole *et al.* | (STON, COLU) |
| Also | 69 | Thesis Nevis 175 | H. Norton | (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) |
| BOGERT | 70 | PR D2 6 | D.V. Bogert *et al.* | (BNL, MASA, YALE) |
| EISELE | 70 | ZPHY 238 372 | F. Eisele *et al.* | (HEID) |
| PDG | 70 | RMP 42 No. 1 | A. Barbaro-Galtieri *et al.* | (LRL, BRAN+) |
| ANG | 69 | ZPHY 223 103 | G. Ang *et al.* | (HEID) |
| ANG | 69B | ZPHY 228 151 | G. Ang *et al.* | (HEID) |
| BAGGETT | 69 | PRL 23 249 | N.V. Baggett, B. Kehoe, G.A. Snow | (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) |
| BIERMAN | 68 | PRL 20 1459 | E. Bierman *et al.* | (PRIN) |
| HEPP | 68 | ZPHY 214 71 | V. Hepp, H. Schleich | (HEID) |
| WHITESIDE | 68 | NC 54A 537 | H. Whiteside, J. Gollub | (OBER) |
| BARASH | 67 | PRL 19 181 | N. Barash *et al.* | (UMD) |
| CHANG | 66 | PR 151 1081 | C.Y. Chang | (COLU) |
| BAZIN | 65B | PR 140B 1358 | M. Bazin *et al.* | (PRIN, RUTG, COLU) |
| DOSCH | 65 | PL 14 239 | H.C. Dosch *et al.* | (HEID) |
| Also | 66 | PR 151 1081 | C.Y. Chang | (COLU) |
| SCHMIDT | 65 | PR 140B 1328 | P. Schmidt | (COLU) |
| BURNSTEIN | 64 | PRL 13 66 | R.A. Burnstein *et al.* | (UMD) |
| COURANT | 64 | PR 136B 1791 | H. Courant *et al.* | (CERN, HEID, UMD+) |
| BARKAS | 63 | PRL 11 26 | W.H. Barkas, J.N. Dyer, H.H. Heckman | (LRL) |
| HUMPHREY | 62 | PR 127 1305 | W.E. Humphrey, R.R. Ross | (LRL) |