



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

We have omitted some results that have been superseded by later experiments.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

### ***n* MASS (atomic mass units *u*)**

The mass is known much more precisely in *u* (atomic mass units) than in MeV. See the next data block.

| <u>VALUE (<i>u</i>)</u>   | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>         |
|---|--------------------|-------------|------------------------|
| <b>1.00866491560 ± 0.00000000055</b>  | MOHR               | 05          | RVUE 2002 CODATA value |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ● |                    |             |                        |
| 1.00866491578 ± 0.00000000055   | MOHR               | 99          | RVUE 1998 CODATA value |
| 1.008665904 ± 0.000000014   | COHEN              | 87          | RVUE 1986 CODATA value |

### ***n* MASS (MeV)**

The mass is known much more precisely in *u* (atomic mass units) than in MeV. The conversion from *u* to MeV,  $1 \text{ u} = 931.494043 \pm 0.000080 \text{ MeV}/c^2$  (MOHR 05, the 2002 CODATA value), involves the relatively poorly known electronic charge.

| <u>VALUE (MeV)</u>  | <u>DOCUMENT ID</u>       | <u>TECN</u> | <u>COMMENT</u>                |
|---|--------------------------|-------------|-------------------------------|
| <b>939.565360 ± 0.000081</b>  | MOHR                     | 05          | RVUE 2002 CODATA value        |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ● |                          |             |                               |
| 939.565331 ± 0.000037   | <sup>1</sup> KESSLER     | 99          | SPEC $np \rightarrow d\gamma$ |
| 939.565330 ± 0.000038   | MOHR                     | 99          | RVUE 1998 CODATA value        |
| 939.56565 ± 0.00028   | <sup>2,3</sup> DIFILIPPO | 94          | TRAP Penning trap             |
| 939.56563 ± 0.00028   | COHEN                    | 87          | RVUE 1986 CODATA value        |
| 939.56564 ± 0.00028   | <sup>3,4</sup> GREENE    | 86          | SPEC $np \rightarrow d\gamma$ |
| 939.5731 ± 0.0027   | <sup>3</sup> COHEN       | 73          | RVUE 1973 CODATA value        |

<sup>1</sup>We use the 1998 CODATA *u*-to-MeV conversion factor (see the heading above) to get this mass in MeV from the much more precisely measured KESSLER 99 value of  $1.00866491637 \pm 0.00000000082 \text{ u}$ .

<sup>2</sup>The mass is known much more precisely in *u*:  $m = 1.0086649235 \pm 0.0000000023 \text{ u}$ . We use the 1986 CODATA conversion factor to get the mass in MeV.

<sup>3</sup>These determinations are not independent of the  $m_n - m_p$  measurements below.

<sup>4</sup>The mass is known much more precisely in *u*:  $m = 1.008664919 \pm 0.000000014 \text{ u}$ .

### **$\bar{n}$ MASS**

| <u>VALUE (MeV)</u>     | <u>EVTS</u> | <u>DOCUMENT ID</u>  | <u>TECN</u> | <u>COMMENT</u>                      |
|------------------------|-------------|---------------------|-------------|-------------------------------------|
| <b>939.485 ± 0.051</b> | 59          | <sup>5</sup> CRESTI | 86          | HBC $\bar{p}p \rightarrow \bar{n}n$ |

<sup>5</sup>This is a corrected result (see the erratum). The error is statistical. The maximum systematic error is 0.029 MeV.

$$(m_n - m_{\bar{n}}) / m_n$$

A test of *CPT* invariance. Calculated from the  $n$  and  $\bar{n}$  masses, above.

VALUE DOCUMENT ID  
 **$(9 \pm 5) \times 10^{-5}$  OUR EVALUATION**

### $m_n - m_p$

| <u>VALUE (MeV)</u>  | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>                |
|---|--------------------|-------------|-------------------------------|
| <b>1.2933317 ± 0.0000005</b>  | <sup>6</sup> MOHR  | 05          | RVUE 2002 CODATA value        |
| • • • We do not use the following data for averages, fits, limits, etc. • • • |                    |             |                               |
| 1.2933318 ± 0.0000005   | <sup>7</sup> MOHR  | 99          | RVUE 1998 CODATA value        |
| 1.2933318 ± 0.0000009   | <sup>8</sup> COHEN | 87          | RVUE 1986 CODATA value        |
| 1.2933328 ± 0.0000072   | GREENE             | 86          | SPEC $np \rightarrow d\gamma$ |
| 1.293429 ± 0.000036   | COHEN              | 73          | RVUE 1973 CODATA value        |

<sup>6</sup> Calculated by us from the MOHR 05 ratio  $m_n/m_p = 1.00137841870 \pm 0.00000000058$ .  
 In u,  $m_n - m_p = (1.3884487 \pm 0.0000006) \times 10^{-3}$  u.

<sup>7</sup> Calculated by us from the MOHR 99 ratio  $m_n/m_p = 1.00137841887 \pm 0.00000000058$ .  
 In u,  $m_n - m_p = (1.3884489 \pm 0.0000006) \times 10^{-3}$  u.

<sup>8</sup> Calculated by us from the COHEN 87 ratio  $m_n/m_p = 1.001378404 \pm 0.000000009$ . In  
 u,  $m_n - m_p = 0.001388434 \pm 0.000000009$  u.

### $n$ MEAN LIFE

We now compile only direct measurements of the lifetime, not those inferred from decay correlation measurements. For the average, we only use measurements with an error less than 10 s.

The most recent result, that of SEREBROV 05, is so far from other results that it makes no sense to include it in the average. It is up to workers in this field to resolve this issue. Until this major disagreement is understood our present average of  $885.7 \pm 0.8$  s must be suspect.

For an early review, see EROZOLIMSKII 89 and papers that follow it in an issue of NIM devoted to the "Proceedings of the International Workshop on Fundamental Physics with Slow Neutrons" (Grenoble 1989). For later reviews and/or commentary, see FREEDMAN 90, SCHRECKENBACH 92, and PENDLEBURY 93.

Limits on lifetimes for *bound* neutrons are given in the section "*p* PARTIAL MEAN LIVES."

| <u>VALUE (s)</u>               | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>              |
|--------------------------------|--------------------|-------------|-----------------------------|
| <b>885.7 ± 0.8 OUR AVERAGE</b> |                    |             |                             |
| 886.8 ± 1.2 ± 3.2              | DEWEY              | 03          | CNTR In-beam $n$ , $p$ trap |
| 885.4 ± 0.9 ± 0.4              | ARZUMANOV          | 00          | CNTR UCN double bottle      |
| 889.2 ± 3.0 ± 3.8              | BYRNE              | 96          | CNTR Penning trap           |
| 882.6 ± 2.7                    | <sup>9</sup> MAMPE | 93          | CNTR Gravitational trap     |
| 888.4 ± 3.1 ± 1.1              | NESVIZHEV...       | 92          | CNTR Gravitational trap     |
| 887.6 ± 3.0                    | MAMPE              | 89          | CNTR Gravitational trap     |
| 891 ± 9                        | SPIVAK             | 88          | CNTR Beam                   |

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

|                   |                        |    |      |                      |
|-------------------|------------------------|----|------|----------------------|
| 878.5 ± 0.7 ± 0.3 | <sup>10</sup> SEREBROV | 05 | CNTR | Gravitational trap   |
| 888.4 ± 2.9       | ALFIMENKOV             | 90 | CNTR | See NESVIZHEVSKII 92 |
| 893.6 ± 3.8 ± 3.7 | BYRNE                  | 90 | CNTR | See BYRNE 96         |
| 878 ± 27 ± 14     | KOSSAKOW...            | 89 | TPC  | Pulsed beam          |
| 877 ± 10          | PAUL                   | 89 | CNTR | Storage ring         |
| 876 ± 10 ± 19     | LAST                   | 88 | SPEC | Pulsed beam          |
| 903 ± 13          | KOSVINTSEV             | 86 | CNTR | Gravitational trap   |
| 937 ± 18          | <sup>11</sup> BYRNE    | 80 | CNTR |                      |
| 875 ± 95          | KOSVINTSEV             | 80 | CNTR |                      |
| 881 ± 8           | BONDAREN...            | 78 | CNTR | See SPIVAK 88        |
| 918 ± 14          | CHRISTENSEN            | 72 | CNTR |                      |

<sup>9</sup>IGNATOVICH 95 calls into question some of the corrections and averaging procedures used by MAMPE 93. The response, BONDARENKO 96, denies the validity of the criticisms.

<sup>10</sup>This SEREBROV 05 result is 6.5 standard deviations from our average of previous results and 5.6 standard deviations from the previous most precise result (that of ARZUMANOV 00).

<sup>11</sup>This measurement has been withdrawn (J. Byrne, private communication, 1990).

## *n* MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the *A* Listings.

| VALUE ( $\mu_N$ )   | DOCUMENT ID          | TECN | COMMENT                |
|---|----------------------|------|------------------------|
| <b>-1.91304273 ± 0.00000045</b>   | MOHR                 | 05   | RVUE 2002 CODATA value |
| • • • We do not use the following data for averages, fits, limits, etc. • • • |                      |      |                        |
| -1.91304272 ± 0.00000045  | MOHR                 | 99   | RVUE 1998 CODATA value |
| -1.91304275 ± 0.00000045  | COHEN                | 87   | RVUE 1986 CODATA value |
| -1.91304277 ± 0.00000048  | <sup>12</sup> GREENE | 82   | MRS                    |

<sup>12</sup>GREENE 82 measures the moment to be  $(1.04187564 \pm 0.00000026) \times 10^{-3}$  Bohr magnetons. The value above is obtained by multiplying this by  $m_p/m_e = 1836.152701 \pm 0.000037$  (the 1986 CODATA value from COHEN 87).

## *n* ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both *T* invariance and *P* invariance. A number of early results have been omitted. See RAMSEY 90 and GOLUB 94 for reviews.

| VALUE ( $10^{-25}$ ecm)   | CL% | DOCUMENT ID          | TECN | COMMENT   |
|---|-----|----------------------|------|---|
| <b>&lt; 0.63</b>  | 90  | <sup>13</sup> HARRIS | 99   | MRS $d = (-0.1 \pm 0.36) \times 10^{-25}$       |
| • • • We do not use the following data for averages, fits, limits, etc. • • • |     |                      |      |   |
| < 0.97  | 90  | ALTAREV              | 96   | MRS $(+0.26 \pm 0.40 \pm 0.16) \times 10^{-25}$ |
| < 1.1   | 95  | ALTAREV              | 92   | MRS See ALTAREV 96                              |
| < 1.2   | 95  | SMITH                | 90   | MRS See HARRIS 99                               |
| < 2.6   | 95  | ALTAREV              | 86   | MRS $d = (-1.4 \pm 0.6) \times 10^{-25}$        |
| 0.3 ± 4.8   |     | PENDLEBURY           | 84   | MRS Ultracold neutrons                          |
| < 6   | 90  | ALTAREV              | 81   | MRS $d = (2.1 \pm 2.4) \times 10^{-25}$         |
| < 16  | 90  | ALTAREV              | 79   | MRS $d = (4.0 \pm 7.5) \times 10^{-25}$         |

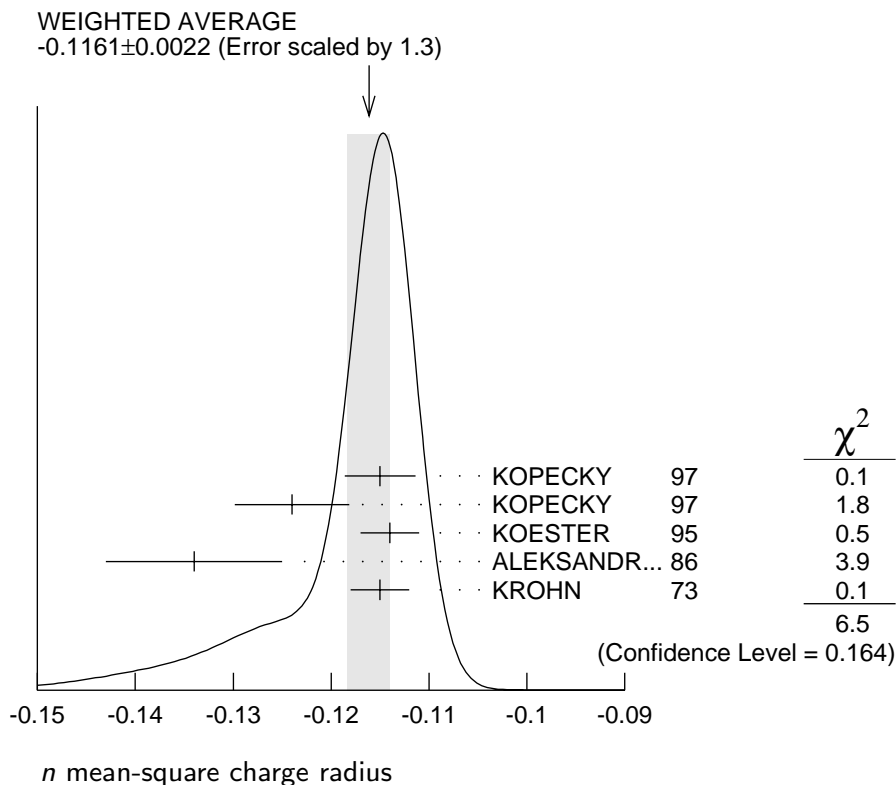
<sup>13</sup> This HARRIS 99 result includes the result of SMITH 90. However, the averaging of the results of these two experiments has been criticized by LAMOREAUX 00.

### ***n* MEAN-SQUARE CHARGE RADIUS**

The mean-square charge radius of the neutron,  $\langle r_n^2 \rangle$ , is related to the neutron-electron scattering length  $b_{ne}$  by  $\langle r_n^2 \rangle = 3(m_e a_0 / m_n) b_{ne}$ , where  $m_e$  and  $m_n$  are the masses of the electron and neutron, and  $a_0$  is the Bohr radius. Numerically,  $\langle r_n^2 \rangle = 86.34 b_{ne}$ , if we use  $a_0$  for a nucleus with infinite mass.

| VALUE (fm <sup>2</sup> )  | DOCUMENT ID            | COMMENT   |
|---|------------------------|---|
| <b>-0.1161 ± 0.0022 OUR AVERAGE</b>   |                        | Error includes scale factor of 1.3. See the ideogram below. |
| -0.115 ± 0.002 ± 0.003  | KOPECKY 97             | <i>ne</i> scattering (Pb)                                   |
| -0.124 ± 0.003 ± 0.005  | KOPECKY 97             | <i>ne</i> scattering (Bi)                                   |
| -0.114 ± 0.003  | KOESTER 95             | <i>ne</i> scattering (Pb, Bi)                               |
| -0.134 ± 0.009  | ALEKSANDR... 86        | <i>ne</i> scattering (Bi)                                   |
| -0.115 ± 0.003  | <sup>14</sup> KROHN 73 | <i>ne</i> scattering (Ne, Ar, Kr, Xe)                       |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ● |                        |   |
| -0.113 ± 0.003 ± 0.004  | KOPECKY 95             | <i>ne</i> scattering (Pb)                                   |
| -0.114 ± 0.003  | KOESTER 86             | <i>ne</i> scattering (Pb, Bi)                               |
| -0.118 ± 0.002  | KOESTER 76             | <i>ne</i> scattering (Pb)                                   |
| -0.120 ± 0.002  | KOESTER 76             | <i>ne</i> scattering (Bi)                                   |
| -0.116 ± 0.003  | KROHN 66               | <i>ne</i> scattering (Ne, Ar, Kr, Xe)                       |

<sup>14</sup> This value is as corrected by KOESTER 76.



## $n$ ELECTRIC POLARIZABILITY $\alpha_n$

Following is the electric polarizability  $\alpha_n$  defined in terms of the induced electric dipole moment by  $\mathbf{D} = 4\pi\epsilon_0\alpha_n\mathbf{E}$ . For a review, see SCHMIED-MAYER 89.

| VALUE ( $10^{-4} \text{ fm}^3$ )   | DOCUMENT ID | TECN     | COMMENT                          |
|--|-------------|----------|----------------------------------|
| <b>11.6<math>\pm</math> 1.5 OUR AVERAGE</b>  |             |          |                                  |
| 12.5 $\pm$ 1.8 $^{+1.6}_{-1.3}$  | 15 KOSSERT  | 03 CNTR  | $\gamma d \rightarrow \gamma pn$ |
| 8.8 $\pm$ 2.4 $\pm$ 3.0  | 16 LUNDIN   | 03 CNTR  | $\gamma d \rightarrow \gamma d$  |
| 12.0 $\pm$ 1.5 $\pm$ 2.0   | SCHMIEDM... | 91 CNTR  | $n$ Pb transmission              |
| 10.7 $^{+3.3}_{-10.7}$   | ROSE        | 90B CNTR | $\gamma d \rightarrow \gamma np$ |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●  |             |          |                                  |
| 13.6   | 17 KOLB     | 00 CNTR  | $\gamma d \rightarrow \gamma np$ |
| 0.0 $\pm$ 5.0  | 18 KOESTER  | 95 CNTR  | $n$ Pb, $n$ Bi transmission      |
| 11.7 $^{+4.3}_{-11.7}$   | ROSE        | 90 CNTR  | See ROSE 90B                     |
| 8 $\pm$ 10   | KOESTER     | 88 CNTR  | $n$ Pb, $n$ Bi transmission      |
| 12 $\pm$ 10  | SCHMIEDM... | 88 CNTR  | $n$ Pb, $n$ C transmission       |
| 15 KOSSERT 03 gets $\alpha_n - \beta_n = (9.8 \pm 3.6^{+2.1}_{-1.1} \pm 2.2) \times 10^{-4} \text{ fm}^3$ , and uses $\alpha_n + \beta_n = (15.2 \pm 0.5) \times 10^{-4} \text{ fm}^3$ from LEVCHUK 00. Thus the errors on $\alpha_n$ and $\beta_n$ are anti-correlated.                                   |             |          |                                  |
| 16 LUNDIN 03 measures $\alpha_N - \beta_N = (6.4 \pm 2.4) \times 10^{-4} \text{ fm}^3$ and uses accurate values for $\alpha_p$ and $\alpha_p$ and a precise sum-rule result for $\alpha_n + \beta_n$ . The second error is a model uncertainty, and errors on $\alpha_n$ and $\beta_n$ are anticorrelated. |             |          |                                  |
| 17 KOLB 00 obtains this value with a lower limit of $7.6 \times 10^{-4} \text{ fm}^3$ but no upper limit from this experiment alone. Combined with results of ROSE 90, the 1- $\sigma$ range is $(7.6\text{--}14.0) \times 10^{-4} \text{ fm}^3$ .   |             |          |                                  |
| 18 KOESTER 95 uses natural Pb and the isotopes 208, 207, and 206. See this paper for a discussion of methods used by various groups to extract $\alpha_n$ from data.   |             |          |                                  |

## $n$ MAGNETIC POLARIZABILITY $\beta_n$

| VALUE ( $10^{-4} \text{ fm}^3$ )   | DOCUMENT ID | TECN    | COMMENT                          |
|--|-------------|---------|----------------------------------|
| <b>3.7<math>\pm</math>2.0 OUR AVERAGE</b>  |             |         |                                  |
| 2.7 $\pm$ 1.8 $^{+1.3}_{-1.6}$   | 19 KOSSERT  | 03 CNTR | $\gamma d \rightarrow \gamma pn$ |
| 6.5 $\pm$ 2.4 $\pm$ 3.0  | 20 LUNDIN   | 03 CNTR | $\gamma d \rightarrow \gamma d$  |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●  |             |         |                                  |
| 1.6  | 21 KOLB     | 00 CNTR | $\gamma d \rightarrow \gamma np$ |
| 19 KOSSERT 03 gets $\alpha_n - \beta_n = (9.8 \pm 3.6^{+2.1}_{-1.1} \pm 2.2) \times 10^{-4} \text{ fm}^3$ , and uses $\alpha_n + \beta_n = (15.2 \pm 0.5) \times 10^{-4} \text{ fm}^3$ from LEVCHUK 00. Thus the errors on $\alpha_n$ and $\beta_n$ are anti-correlated.                                   |             |         |                                  |
| 20 LUNDIN 03 measures $\alpha_N - \beta_N = (6.4 \pm 2.4) \times 10^{-4} \text{ fm}^3$ and uses accurate values for $\alpha_p$ and $\alpha_p$ and a precise sum-rule result for $\alpha_n + \beta_n$ . The second error is a model uncertainty, and errors on $\alpha_n$ and $\beta_n$ are anticorrelated. |             |         |                                  |
| 21 KOLB 00 obtains this value with an upper limit of $7.6 \times 10^{-4} \text{ fm}^3$ but no lower limit from this experiment alone. Combined with results of ROSE 90, the 1- $\sigma$ range is $(1.2\text{--}7.6) \times 10^{-4} \text{ fm}^3$ .   |             |         |                                  |

## ***n* CHARGE**

See also “ $|q_p + q_e|/e$ ” in the proton Listings.

| <u>VALUE (<math>10^{-21} e</math>)</u>  | <u>DOCUMENT ID</u>    | <u>TECN</u> | <u>COMMENT</u>           |
|---|-----------------------|-------------|--------------------------|
| <b><math>-0.4 \pm 1.1</math></b>  | <sup>22</sup> BAUMANN | 88          | Cold <i>n</i> deflection |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●                     |                       |             |                          |
| $-15 \pm 22$  | <sup>23</sup> GAEHLER | 82 CNTR     | Cold <i>n</i> deflection |
| <sup>22</sup> The BAUMANN 88 error $\pm 1.1$ gives the 68% CL limits about the the value $-0.4$ . |                       |             |                          |
| <sup>23</sup> The GAEHLER 82 error $\pm 22$ gives the 90% CL limits about the the value $-15$ .   |                       |             |                          |

## **LIMIT ON *n* $\bar{n}$ OSCILLATIONS**

### **Mean Time for *n* $\bar{n}$ Transition in Vacuum**

A test of  $\Delta B=2$  baryon number nonconservation. MOHAPATRA 80 and MOHAPATRA 89 discuss the theoretical motivations for looking for *n* $\bar{n}$  oscillations. DOVER 83 and DOVER 85 give phenomenological analyses. The best limits come from looking for the decay of neutrons bound in nuclei. However, these analyses require model-dependent corrections for nuclear effects. See KABIR 83, DOVER 89, ALBERICO 91, and GAL 00 for discussions. Direct searches for  $n \rightarrow \bar{n}$  transitions using reactor neutrons are cleaner but give somewhat poorer limits. We include limits for both free and bound neutrons in the Summary Table.

| <u>VALUE (s)</u>  | <u>CL%</u> | <u>DOCUMENT ID</u> | <u>TECN</u> | <u>COMMENT</u>           |
|---|------------|--------------------|-------------|--------------------------|
| <b><math>&gt;1.3 \times 10^8</math></b>                                       | 90         | CHUNG              | 02B SOU2    | <i>n</i> bound in iron   |
| <b><math>&gt;8.6 \times 10^7</math></b>                                       | 90         | BALDO-...          | 94 CNTR     | Reactor (free) neutrons  |
| ● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ● |            |                    |             |                          |
| $>1 \times 10^7$  | 90         | BALDO-...          | 90 CNTR     | See BALDO-CEOLIN 94      |
| $>1.2 \times 10^8$  | 90         | BERGER             | 90 FREJ     | <i>n</i> bound in iron   |
| $>4.9 \times 10^5$  | 90         | BRESSI             | 90 CNTR     | Reactor neutrons         |
| $>4.7 \times 10^5$  | 90         | BRESSI             | 89 CNTR     | See BRESSI 90            |
| $>1.2 \times 10^8$  | 90         | TAKITA             | 86 CNTR     | <i>n</i> bound in oxygen |
| $>1 \times 10^6$  | 90         | FIDECARO           | 85 CNTR     | Reactor neutrons         |
| $>8.8 \times 10^7$  | 90         | PARK               | 85B CNTR    |                          |
| $>3 \times 10^7$  |            | BATTISTONI         | 84 NUSX     |                          |
| $>2.7 \times 10^7 - 1.1 \times 10^8$  |            | JONES              | 84 CNTR     |                          |
| $>2 \times 10^7$  |            | CHERRY             | 83 CNTR     |                          |

## ***n* DECAY MODES**

| Mode  | Fraction ( $\Gamma_i/\Gamma$ ) | Confidence level |
|---|--------------------------------|------------------|
| $\Gamma_1$ $p e^- \bar{\nu}_e$                | 100 %                          |                  |
| $\Gamma_2$ hydrogen-atom $\bar{\nu}_e$        |                                |                  |
| $\Gamma_3$ $p e^- \bar{\nu}_e \gamma$         | [a] $< 6.9 \times 10^{-3}$     | 90%              |
| <b>Charge conservation (Q) violating mode</b> |                                |                  |
| $\Gamma_4$ $p \nu_e \bar{\nu}_e$              | Q $< 8 \times 10^{-27}$        | 68%              |

[a] This limit is for  $\gamma$  energies between 35 and 100 keV.

## $n$ BRANCHING RATIOS

### $\Gamma(\text{hydrogen-atom } \bar{\nu}_e) / \Gamma_{\text{total}}$

$\Gamma_2 / \Gamma$

| VALUE | CL% | DOCUMENT ID | TECN |
|-------|-----|-------------|------|
|-------|-----|-------------|------|

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

|                      |    |                     |         |
|----------------------|----|---------------------|---------|
| $< 3 \times 10^{-2}$ | 95 | <sup>24</sup> GREEN | 90 RVUE |
|----------------------|----|---------------------|---------|

<sup>24</sup> GREEN 90 infers that  $\tau(\text{hydrogen-atom } \bar{\nu}_e) > 3 \times 10^4$  s by comparing neutron lifetime measurements made in storage experiments with those made in  $\beta$ -decay experiments. However, the result depends sensitively on the lifetime measurements, and does not of course take into account more recent measurements of same.

### $\Gamma(p e^- \bar{\nu}_e \gamma) / \Gamma_{\text{total}}$

$\Gamma_3 / \Gamma$

| VALUE | CL% | DOCUMENT ID | TECN | COMMENT |
|-------|-----|-------------|------|---------|
|-------|-----|-------------|------|---------|

|                        |    |                    |         |          |
|------------------------|----|--------------------|---------|----------|
| $< 6.9 \times 10^{-3}$ | 90 | <sup>25</sup> BECK | 02 CNTR | Cold $n$ |
|------------------------|----|--------------------|---------|----------|

<sup>25</sup> This BECK 02 limit is for  $\gamma$  energies between 35 and 100 keV.

### $\Gamma(p \nu_e \bar{\nu}_e) / \Gamma_{\text{total}}$

$\Gamma_4 / \Gamma$

Forbidden by charge conservation.

| VALUE | CL% | DOCUMENT ID | TECN | COMMENT |
|-------|-----|-------------|------|---------|
|-------|-----|-------------|------|---------|

|                       |    |                      |         |  |
|-----------------------|----|----------------------|---------|--|
| $< 8 \times 10^{-27}$ | 68 | <sup>26</sup> NORMAN | 96 RVUE | <sup>71</sup> Ga $\rightarrow$ <sup>71</sup> Ge neutrals |
|-----------------------|----|----------------------|---------|--|

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

|                         |    |           |         |  |
|-------------------------|----|-----------|---------|--|
| $< 9.7 \times 10^{-18}$ | 90 | ROY       | 83 CNTR | <sup>113</sup> Cd $\rightarrow$ <sup>113m</sup> In neut. |
| $< 7.9 \times 10^{-21}$ |    | VAIDYA    | 83 CNTR | <sup>87</sup> Rb $\rightarrow$ <sup>87m</sup> Sr neut.   |
| $< 9 \times 10^{-24}$   | 90 | BARABANOV | 80 CNTR | <sup>71</sup> Ga $\rightarrow$ <sup>71</sup> GeX         |
| $< 3 \times 10^{-19}$   |    | NORMAN    | 79 CNTR | <sup>87</sup> Rb $\rightarrow$ <sup>87m</sup> Sr neut.   |

<sup>26</sup> NORMAN 96 gets this limit by attributing SAGE and GALLEX counting rates to the charge-nonconserving transition <sup>71</sup>Ga  $\rightarrow$  <sup>71</sup>Ge+neutrals rather than to solar-neutrino reactions.

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## $n \rightarrow p e^- \bar{\nu}_e$ DECAY PARAMETERS

See the above “Note on Baryon Decay Parameters.” For discussions of recent results, see the references cited at the beginning of the section on the neutron mean life. For discussions of the values of the weak coupling constants  $g_A$  and  $g_V$  obtained using the neutron lifetime and asymmetry parameter  $A$ , comparisons with other methods of obtaining these constants, and implications for particle physics and for astrophysics, see DUBBERS 91 and WOOLCOCK 91. For tests of the  $V-A$  theory of neutron decay, see EROZOLIMSKII 91B and MOSTOVOI 96.

### $\lambda \equiv g_A / g_V$

| VALUE | DOCUMENT ID | TECN | COMMENT |
|-------|-------------|------|---------|
|-------|-------------|------|---------|

|                                  |   |  |  |
|----------------------------------|---|--|--|
| $-1.2695 \pm 0.0029$ OUR AVERAGE | Error includes scale factor of 2.0. See the ideogram below. |  |  |
|----------------------------------|---|--|--|

|                                |                           |         |                                |
|--------------------------------|---------------------------|---------|--------------------------------|
| $-1.2739 \pm 0.0019$           | <sup>27</sup> ABELE       | 02 SPEC | Cold $n$ , polarized, A        |
| $-1.2686 \pm 0.0046 \pm 0.007$ | <sup>28</sup> MOSTOVOI    | 01 CNTR | A and B $\times$ polarizations |
| $-1.266 \pm 0.004$             | LIAUD                     | 97 TPC  | Cold $n$ , polarized, A        |
| $-1.2594 \pm 0.0038$           | <sup>29</sup> YEROZLIM... | 97 CNTR | Cold $n$ , polarized, A        |
| $-1.262 \pm 0.005$             | BOPP                      | 86 SPEC | Cold $n$ , polarized, A        |

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

|                |                          |          |                                     |
|----------------|--------------------------|----------|-------------------------------------|
| -1.274 ±0.003  | ABELE                    | 97D SPEC | Cold <i>n</i> , polarized, <i>A</i> |
| -1.266 ±0.004  | SCHRECK...               | 95 TPC   | See LIAUD 97                        |
| -1.2544±0.0036 | EROZOLIM...              | 91 CNTR  | See YEROZOLIM-SKY 97                |
| -1.226 ±0.042  | MOSTOVOY                 | 83 RVUE  |                                     |
| -1.261 ±0.012  | EROZOLIM...              | 79 CNTR  | Cold <i>n</i> , polarized, <i>A</i> |
| -1.259 ±0.017  | <sup>30</sup> STRATOWA   | 78 CNTR  | <i>p</i> recoil spectrum, <i>a</i>  |
| -1.263 ±0.015  | EROZOLIM...              | 77 CNTR  | See EROZOLIMSKII 79                 |
| -1.250 ±0.036  | <sup>30</sup> DOBROZE... | 75 CNTR  | See STRATOWA 78                     |
| -1.258 ±0.015  | <sup>31</sup> KROHN      | 75 CNTR  | Cold <i>n</i> , polarized, <i>A</i> |
| -1.263 ±0.016  | <sup>32</sup> KROPF      | 74 RVUE  | <i>n</i> decay alone                |
| -1.250 ±0.009  | <sup>32</sup> KROPF      | 74 RVUE  | <i>n</i> decay + nuclear ft         |

<sup>27</sup> This is the combined result of ABELE 02 and ABELE 97D.

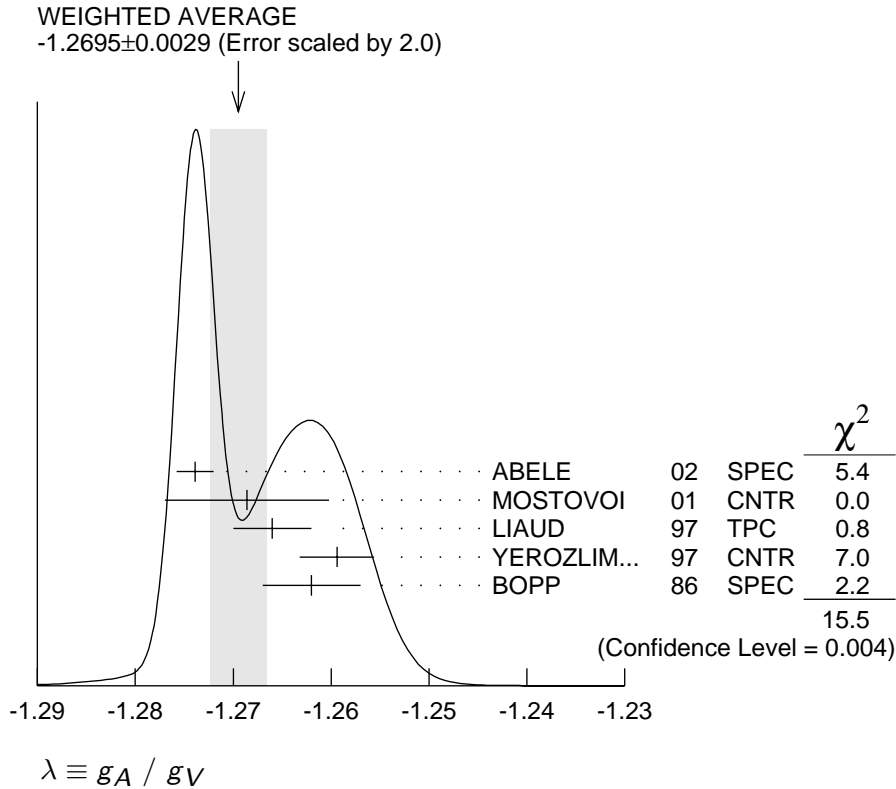
<sup>28</sup> MOSTOVOI 01 measures the two *P*-odd correlations *A* and *B*, or rather *SA* and *SB*, where *S* is the *n* polarization, in free neutron decay.

<sup>29</sup> YEROZOLIMSKY 97 makes a correction to the EROZOLIMSKII 91 value.

<sup>30</sup> These experiments measure the absolute value of  $g_A/g_V$  only.

<sup>31</sup> KROHN 75 includes events of CHRISTENSEN 70.

<sup>32</sup> KROPF 74 reviews all data through 1972.





## $\beta$ ASYMMETRY PARAMETER A

This is the neutron-spin electron-momentum correlation coefficient. Unless otherwise noted, the values are corrected for radiative effects and weak magnetism.

| VALUE | DOCUMENT ID | TECN | COMMENT |
|-------|-------------|------|---------|
|-------|-------------|------|---------|

**-0.1173±0.0013 OUR AVERAGE** Error includes scale factor of 2.3. See the ideogram below.

|                       |                |         |                           |
|-----------------------|----------------|---------|---------------------------|
| -0.1189±0.0007        | 33 ABELE       | 02 SPEC | Cold <i>n</i> , polarized |
| -0.1160±0.0009±0.0012 | LIAUD          | 97 TPC  | Cold <i>n</i> , polarized |
| -0.1135±0.0014        | 34 YEROZLIM... | 97 CNTR | Cold <i>n</i> , polarized |
| -0.1146±0.0019        | BOPP           | 86 SPEC | Cold <i>n</i> , polarized |

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

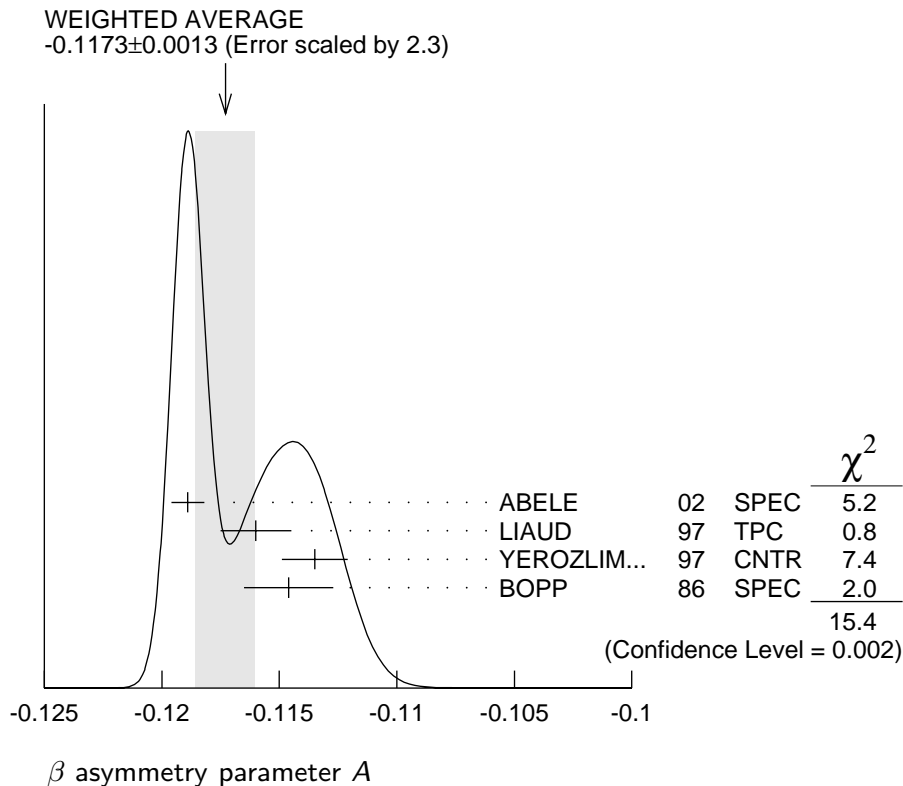
|                       |                |          |                           |
|-----------------------|----------------|----------|---------------------------|
| -0.1168±0.0017        | 35 MOSTOVOI    | 01 CNTR  | Inferred                  |
| -0.1189±0.0012        | ABELE          | 97D SPEC | Cold <i>n</i> , polarized |
| -0.1160±0.0009±0.0011 | SCHRECK...     | 95 TPC   | See LIAUD 97              |
| -0.1116±0.0014        | EROZOLIM...    | 91 CNTR  | See YEROZOLIM-SKY 97      |
| -0.114 ±0.005         | 36 EROZOLIM... | 79 CNTR  | Cold <i>n</i> , polarized |
| -0.113 ±0.006         | 36 KROHN       | 75 CNTR  | Cold <i>n</i> , polarized |

<sup>33</sup> This is the combined result of ABELE 02 and ABELE 97D.

<sup>34</sup> YEROZOLIMSKY 97 makes a correction to the EROZOLIMSKII 91 value.

<sup>35</sup> MOSTOVOI 01 calculates this from its measurement of  $\lambda=g_A/g_V$  above.

<sup>36</sup> These results are not corrected for radiative effects and weak magnetism, but the corrections are small compared to the errors.



## $\bar{\nu}_e$ ASYMMETRY PARAMETER $B$

This is the neutron-spin antineutrino-momentum correlation coefficient.

| <u>VALUE</u>   | <u>DOCUMENT ID</u>        | <u>TECN</u> | <u>COMMENT</u>       |
|--|---------------------------|-------------|----------------------|
| <b>0.983 ± 0.004 OUR AVERAGE</b>   |                           |             |                      |
| 0.9801 ± 0.0046  | SEREBROV 98               | CNTR        | Cold $n$ , polarized |
| 0.9894 ± 0.0083  | KUZNETSOV 95              | CNTR        | Cold $n$ , polarized |
| 0.995 ± 0.034  | CHRISTENSEN70             | CNTR        | Cold $n$ , polarized |
| 1.00 ± 0.05  | EROZOLIM...               | 70C CNTR    | Cold $n$ , polarized |
| • • • We do not use the following data for averages, fits, limits, etc. • • •                |                           |             |                      |
| 0.9876 ± 0.0004  | <sup>37</sup> MOSTOVOI 01 | CNTR        | Inferred             |
| <sup>37</sup> MOSTOVOI 01 calculates this from its measurement of $\lambda = g_A/g_V$ above. |                           |             |                      |

## $e\bar{\nu}_e$ ANGULAR CORRELATION COEFFICIENT $a$

| <u>VALUE</u>   | <u>DOCUMENT ID</u>        | <u>TECN</u> | <u>COMMENT</u>         |
|--|---------------------------|-------------|------------------------|
| <b>-0.103 ± 0.004 OUR AVERAGE</b>  |                           |             |                        |
| -0.1054 ± 0.0055   | BYRNE 02                  | SPEC        | Proton recoil spectrum |
| -0.1017 ± 0.0051   | STRATOWA 78               | CNTR        | Proton recoil spectrum |
| -0.091 ± 0.039   | GRIGOREV 68               | SPEC        | Proton recoil spectrum |
| • • • We do not use the following data for averages, fits, limits, etc. • • •                |                           |             |                        |
| -0.1045 ± 0.0014   | <sup>38</sup> MOSTOVOI 01 | CNTR        | Inferred               |
| <sup>38</sup> MOSTOVOI 01 calculates this from its measurement of $\lambda = g_A/g_V$ above. |                           |             |                        |

## $\phi_{AV}$ , PHASE OF $g_A$ RELATIVE TO $g_V$

Time reversal invariance requires this to be 0 or 180°. This is related to  $D$  given in the next data block and  $\lambda \equiv g_A/g_V$  by  $\sin(\phi_{AV}) = D(1+3\lambda^2)/2\lambda$ .

| <u>VALUE (°)</u>  | <u>DOCUMENT ID</u>     | <u>TECN</u> | <u>COMMENT</u>       |
|---|------------------------|-------------|----------------------|
| <b>180.06 ± 0.07 OUR AVERAGE</b>  |                        |             |                      |
| 180.04 ± 0.09   | SOLDNER 04             | CNTR        | Cold $n$ , polarized |
| 180.08 ± 0.13   | LISING 00              | CNTR        | Polarized >93%       |
| 179.71 ± 0.39   | EROZOLIM...            | 78 CNTR     | Cold $n$ , polarized |
| 180.35 ± 0.43   | EROZOLIM...            | 74 CNTR     | Cold $n$ , polarized |
| 180.14 ± 0.22   | STEINBERG 74           | CNTR        | Cold $n$ , polarized |
| • • • We do not use the following data for averages, fits, limits, etc. • • • |                        |             |                      |
| 181.1 ± 1.3   | <sup>39</sup> KROPF 74 | RVUE        | $n$ decay            |
| <sup>39</sup> KROPF 74 reviews all data through 1972.                         |                        |             |                      |

## TRIPLE CORRELATION COEFFICIENT $D$

These are measurements of the component of  $n$  spin perpendicular to the decay plane in  $\beta$  decay. Should be zero if  $T$  invariance is not violated.

| <u>VALUE (units 10<sup>-4</sup>)</u>  | <u>DOCUMENT ID</u>        | <u>TECN</u> | <u>COMMENT</u>       |
|---|---------------------------|-------------|----------------------|
| <b>- 4 ± 6 OUR AVERAGE</b>  |                           |             |                      |
| - 2.8 ± 6.4 ± 3.0   | SOLDNER 04                | CNTR        | Cold $n$ , polarized |
| - 6 ± 12 ± 5  | LISING 00                 | CNTR        | Polarized >93%       |
| +22 ± 30  | EROZOLIM...               | 78 CNTR     | Cold $n$ , polarized |
| -27 ± 50  | <sup>40</sup> EROZOLIM... | 74 CNTR     | Cold $n$ , polarized |
| -11 ± 17  | STEINBERG 74              | CNTR        | Cold $n$ , polarized |
| <sup>40</sup> EROZOLIMSKII 78 says asymmetric proton losses and nonuniform beam polarization may give a systematic error up to $30 \times 10^{-4}$ , thus increasing the EROZOLIMSKII 74 error to $50 \times 10^{-4}$ . STEINBERG 74 and STEINBERG 76 estimate these systematic errors to be insignificant in their experiment. |                           |             |                      |

## n REFERENCES

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

|              |     |                                |   |                          |
|--------------|-----|--------------------------------|---|--------------------------|
| MOHR         | 05  | RMP 77 1                       | P.J. Mohr, B.N. Taylor                  | (NIST)                   |
| SEREBROV     | 05  | PL B605 72                     | A. Serebrov <i>et al.</i>               | (PNPI, JINR, ILLG)       |
| SOLDNER      | 04  | PL B581 49                     | T. Soldner <i>et al.</i>                | (ILLG, MUNT)             |
| DEWEY        | 03  | PRL 91 152302                  | M.S. Dewey <i>et al.</i>                | (NIST, TULN, IND+)       |
| KOSSERT      | 03  | EPJ A16 259                    | K. Kossert <i>et al.</i>                | (Mainz MAMI Collab.)     |
| Also         | 02  | PRL 88 162301                  | K. Kossert <i>et al.</i>                | (Mainz MAMI Collab.)     |
| LUNDIN       | 03  | PRL 90 192501                  | M. Lundin <i>et al.</i>                 |                          |
| ABELE        | 02  | PRL 88 211801                  | H. Abele <i>et al.</i>                  | (PERKEO-II Collab.)      |
| BECK         | 02  | JETPL 76 332                   | M. Beck <i>et al.</i>                   | (LEUV, SUSS, KIAE, PNPI) |
|              |     | Translated from ZETFP 76 392.  |   |                          |
| BYRNE        | 02  | JPG 28 1325                    | J. Byrne <i>et al.</i>                  |                          |
| CHUNG        | 02B | PR D66 032004                  | J. Chung <i>et al.</i>                  | (SOUDAN-2 Collab.)       |
| MOSTOVOI     | 01  | PAN 64 1955                    | Yu.A. Mostovoi <i>et al.</i>            |                          |
|              |     | Translated from YAF 64 2040.   |   |                          |
| ARZUMANOV    | 00  | PL B483 15                     | S. Arzumanov <i>et al.</i>              |                          |
| GAL          | 00  | PR C61 028201                  | A. Gal                                  |                          |
| KOLB         | 00  | PRL 85 1388                    | N.R. Kolb <i>et al.</i>                 |                          |
| LAMOREAUX    | 00  | PR D61 051301R                 | S.K. Lamoreaux, R. Golub                |                          |
| LEVCHUK      | 00  | NP A674 449                    | M.I. Levchuk, A.I. L'vov                | (BELA, LEBD)             |
| LISING       | 00  | PR C62 055501                  | L.J. Lising <i>et al.</i>               | (NIST emiT Collab.)      |
| HARRIS       | 99  | PRL 82 904                     | P.G. Harris <i>et al.</i>               |                          |
| KESSLER      | 99  | PL A255 221                    | E.G. Kessler Jr <i>et al.</i>           |                          |
| MOHR         | 99  | JPCRD 28 1713                  | P.J. Mohr, B.N. Taylor                  | (NIST)                   |
| Also         | 00  | RMP 72 351                     | P.J. Mohr, B.N. Taylor                  | (NIST)                   |
| SEREBROV     | 98  | JETP 86 1074                   | A.P. Serebrov <i>et al.</i>             |                          |
|              |     | Translated from ZETF 113 1963. |   |                          |
| ABELE        | 97D | PL B407 212                    | H. Abele <i>et al.</i>                  | (HEIDP, ILLG)            |
| KOPECKY      | 97  | PR C56 2229                    | S. Kopecky <i>et al.</i>                |                          |
| LIAUD        | 97  | NP A612 53                     | P. Liaud <i>et al.</i>                  | (ILLG, LAPP)             |
| YEROZLIM...  | 97  | PL B412 240                    | B.G. Erozolimsky <i>et al.</i>          | (HARV, PNPI, KIAE)       |
| ALTAREV      | 96  | PAN 59 1152                    | I.S. Altarev <i>et al.</i>              | (PNPI)                   |
|              |     | Translated from YAF 59 1204.   |   |                          |
| BONDAREN...  | 96  | JETPL 64 416                   | L.N. Bondarenko <i>et al.</i>           | (KIAE)                   |
|              |     | Translated from ZETFP 64 382.  |   |                          |
| BYRNE        | 96  | EPL 33 187                     | J. Byrne <i>et al.</i>                  | (SUSS, ILLG)             |
| MOSTOVOI     | 96  | PAN 59 968                     | Y.A. Mostovoy                           | (KIAE)                   |
|              |     | Translated from YAF 59 1013.   |   |                          |
| NORMAN       | 96  | PR D53 4086                    | E.B. Norman, J.N. Bahcall, M. Goldhaber | (LBL+)                   |
| IGNATOVICH   | 95  | JETPL 62 1                     | V.K. Ignatovich                         | (JINR)                   |
|              |     | Translated from ZETFP 62 3.    |   |                          |
| KOESTER      | 95  | PR C51 3363                    | L. Koester <i>et al.</i>                | (+)                      |
| KOPECKY      | 95  | PRL 74 2427                    | S. Kopecky <i>et al.</i>                |                          |
| KUZNETSOV    | 95  | PRL 75 794                     | I.A. Kuznetsov <i>et al.</i>            | (PNPI, KIAE, HARV+)      |
| SCHRECK...   | 95  | PL B349 427                    | K. Schreckenbach <i>et al.</i>          | (MUNT, ILLG, LAPP)       |
| BALDO-...    | 94  | ZPHY C63 409                   | M. Baldo-Ceolin <i>et al.</i>           | (HEID, ILLG, PADO+)      |
| DIFILIPPO    | 94  | PRL 73 1481                    | F. DiFilippo <i>et al.</i>              | (MIT)                    |
| Also         | 93  | PRL 71 1998                    | V. Natarajan <i>et al.</i>              | (MIT)                    |
| GOLUB        | 94  | PRPL 237C 1                    | R. Golub, K. Lamoreaux                  | (HAHN, WASH)             |
| MAMPE        | 93  | JETPL 57 82                    | B. Mampe <i>et al.</i>                  | (KIAE)                   |
|              |     | Translated from ZETFP 57 77.   |   |                          |
| PENDLEBURY   | 93  | ARNPS 43 687                   | J.M. Pendlebury                         | (ILLG)                   |
| ALTAREV      | 92  | PL B276 242                    | I.S. Altarev <i>et al.</i>              | (PNPI)                   |
| NESVIZHEV... | 92  | JETP 75 405                    | V.V. Nesvizhevsky <i>et al.</i>         | (PNPI, JINR)             |
|              |     | Translated from ZETF 102 740.  |   |                          |
| SCHRECK...   | 92  | JPG 18 1                       | K. Schreckenbach, W. Mampe              | (ILLG)                   |
| ALBERICO     | 91  | NP A523 488                    | W.M. Alberico, A. de Pace, M. Pignone   | (TORI)                   |
| DUBBERS      | 91  | NP A527 239c                   | D. Dubbers                              | (ILLG)                   |
| Also         | 90  | EPL 11 195                     | D. Dubbers, W. Mampe, J. Dohner         | (ILLG, HEID)             |
| EROZOLIM...  | 91  | PL B263 33                     | B.G. Erozolimsky <i>et al.</i>          | (PNPI, KIAE)             |
| Also         | 90  | SJNP 52 999                    | B.G. Erozolimsky <i>et al.</i>          | (PNPI, KIAE)             |
|              |     | Translated from YAF 52 1583.   |   |                          |
| EROZOLIM...  | 91B | SJNP 53 260                    | B.G. Erozolimsky, Y.A. Mostovoy         | (KIAE)                   |
|              |     | Translated from YAF 53 418.    |   |                          |
| SCHMIEDM...  | 91  | PRL 66 1015                    | J. Schmiedmayer <i>et al.</i>           | (TUW, ORNL)              |
| WOOLCOCK     | 91  | MPL A6 2579                    | W.S. Woolcock                           | (CANB)                   |
| ALFIMENKOV   | 90  | JETPL 52 373                   | V.P. Alfimenkov <i>et al.</i>           | (PNPI, JINR)             |
|              |     | Translated from ZETFP 52 984.  |   |                          |

|              |     |                               |  |                          |
|--------------|-----|-------------------------------|--|--------------------------|
| BALDO-...    | 90  | PL B236 95                    | M. Baldo-Ceolin <i>et al.</i>                | (PADO, PAVI, HEIDP+)     |
| BERGER       | 90  | PL B240 237                   | C. Berger <i>et al.</i>                      | (FREJUS Collab.)         |
| BRESSI       | 90  | NC 103A 731                   | G. Bressi <i>et al.</i>                      | (PAVI, ROMA, MILA)       |
| BYRNE        | 90  | PRL 65 289                    | J. Byrne <i>et al.</i>                       | (SUSS, NBS, SCOT, CBNM)  |
| FREEDMAN     | 90  | CNPP A19 209                  | S.J. Freedman                                | (ANL)                    |
| GREEN        | 90  | JPG 16 L75                    | K. Green, D. Thompson                        | (RAL)                    |
| RAMSEY       | 90  | ARNPS 40 1                    | N.F. Ramsey                                  | (HARV)                   |
| ROSE         | 90  | PL B234 460                   | K.W. Rose <i>et al.</i>                      | (GOET, MPCM, MANZ)       |
| ROSE         | 90B | NP A514 621                   | K.W. Rose <i>et al.</i>                      | (GOET, MPCM)             |
| SMITH        | 90  | PL B234 191                   | K.F. Smith <i>et al.</i>                     | (SUSS, RAL, HARV+)       |
| BRESSI       | 89  | ZPHY C43 175                  | G. Bressi <i>et al.</i>                      | (INFN, MILA, PAVI, ROMA) |
| DOVER        | 89  | NIM A284 13                   | C.B. Dover, A. Gal, J.M. Richard             | (BNL, HEBR+)             |
| EROZOLIM...  | 89  | NIM A284 89                   | B.G. Erozolinsky                             | (PNPI)                   |
| KOSSAKOW...  | 89  | NP A503 473                   | R. Kossakowski <i>et al.</i>                 | (LAPP, SAVO, ISNG+)      |
| MAMPE        | 89  | PRL 63 593                    | W. Mampe <i>et al.</i>                       | (ILLG, RISL, SUSS, URI)  |
| MOHAPATRA    | 89  | NIM A284 1                    | R.N. Mohapatra                               | (UMD)                    |
| PAUL         | 89  | ZPHY C45 25                   | W. Paul <i>et al.</i>                        | (BONN, WUPP, MPIH, ILLG) |
| SCHMIEDM...  | 89  | NIM A284 137                  | J. Schmiedmayer, H. Rauch, P. Riehs          | (WIEN)                   |
| BAUMANN      | 88  | PR D37 3107                   | J. Baumann <i>et al.</i>                     | (BAYR, MUNI, ILLG)       |
| KOESTER      | 88  | ZPHY A329 229                 | L. Koester, W. Waschkowski, J. Meier         | (MUNI, MUNT)             |
| LAST         | 88  | PRL 60 995                    | I. Last <i>et al.</i>                        | (HEIDP, ILLG, ANL)       |
| SCHMIEDM...  | 88  | PRL 61 1065                   | J. Schmiedmayer, H. Rauch, P. Riehs          | (TUW)                    |
| Also         | 88B | PRL 61 2509 erratum           | J. Schmiedmayer, H. Rauch, P. Riehs          | (TUW)                    |
| SPIVAK       | 88  | JETP 67 1735                  | P.E. Spivak                                  | (KIAE)                   |
|              |     | Translated from ZETF 94 1.    |  |                          |
| COHEN        | 87  | RMP 59 1121                   | E.R. Cohen, B.N. Taylor                      | (RISC, NBS)              |
| ALEKSANDR... | 86  | SJNP 44 900                   | Yu.A. Aleksandrov <i>et al.</i>              |                          |
|              |     | Translated from YAF 44 1384.  |  |                          |
| ALTAREV      | 86  | JETPL 44 460                  | I.S. Altarev <i>et al.</i>                   | (PNPI)                   |
|              |     | Translated from ZETFP 44 360. |  |                          |
| BOPP         | 86  | PRL 56 919                    | P. Bopp <i>et al.</i>                        | (HEIDP, ANL, ILLG)       |
| Also         | 88  | ZPHY C37 179                  | E. Klempt <i>et al.</i>                      | (HEIDP, ANL, ILLG)       |
| CRESTI       | 86  | PL B177 206                   | M. Cresti <i>et al.</i>                      | (PADO)                   |
| Also         | 88  | PL B200 587 erratum           | M. Cresti <i>et al.</i>                      | (PADO)                   |
| GREENE       | 86  | PRL 56 819                    | G.L. Greene <i>et al.</i>                    | (NBS, ILLG)              |
| KOESTER      | 86  | Physica B137 282              | L. Koester <i>et al.</i>                     |                          |
| KOSVINTSEV   | 86  | JETPL 44 571                  | Y.Y. Kosvintsev, V.I. Morozov, G.I. Terekhov | (KIAE)                   |
|              |     | Translated from ZETFP 44 444. |  |                          |
| TAKITA       | 86  | PR D34 902                    | M. Takita <i>et al.</i>                      | (KEK, TOKY+)             |
| DOVER        | 85  | PR C31 1423                   | C.B. Dover, A. Gal, J.M. Richard             | (BNL)                    |
| FIDECARO     | 85  | PL 156B 122                   | G. Fidecaro <i>et al.</i>                    | (CERN, ILLG, PADO+)      |
| PARK         | 85B | NP B252 261                   | H.S. Park <i>et al.</i>                      | (IMB Collab.)            |
| BATTISTONI   | 84  | PL 133B 454                   | G. Battistoni <i>et al.</i>                  | (NUSEX Collab.)          |
| JONES        | 84  | PRL 52 720                    | T.W. Jones <i>et al.</i>                     | (IMB Collab.)            |
| PENDLEBURY   | 84  | PL 136B 327                   | J.M. Pendlebury <i>et al.</i>                | (SUSS, HARV, RAL+)       |
| CHERRY       | 83  | PRL 50 1354                   | M.L. Cherry <i>et al.</i>                    | (PENN, BNL)              |
| DOVER        | 83  | PR D27 1090                   | C.B. Dover, A. Gal, J.M. Richard             | (BNL)                    |
| KABIR        | 83  | PRL 51 231                    | P.K. Kabir                                   | (HARV)                   |
| MOSTOVOY     | 83  | JETPL 37 196                  | Y.A. Mostovoy                                | (KIAE)                   |
|              |     | Translated from ZETFP 37 162. |  |                          |
| ROY          | 83  | PR D28 1770                   | A. Roy <i>et al.</i>                         | (TATA)                   |
| VAIDYA       | 83  | PR D27 486                    | S.C. Vaidya <i>et al.</i>                    | (TATA)                   |
| GAHLER       | 82  | PR D25 2887                   | R. Gahler, J. Kalus, W. Mampe                | (BAYR, ILLG)             |
| GREENE       | 82  | Metrologia 18 93              | G.L. Greene <i>et al.</i>                    | (YALE, HARV, ILLG+)      |
| ALTAREV      | 81  | PL 102B 13                    | I.S. Altarev <i>et al.</i>                   | (PNPI)                   |
| BARABANOV    | 80  | JETPL 32 359                  | I.R. Barabanov <i>et al.</i>                 | (PNPI)                   |
|              |     | Translated from ZETFP 32 384. |  |                          |
| BYRNE        | 80  | PL 92B 274                    | J. Byrne <i>et al.</i>                       | (SUSS, RL)               |
| KOSVINTSEV   | 80  | JETPL 31 236                  | Y.Y. Kosvintsev <i>et al.</i>                | (JINR)                   |
|              |     | Translated from ZETFP 31 257. |  |                          |
| MOHAPATRA    | 80  | PRL 44 1316                   | R.N. Mohapatra, R.E. Marshak                 | (CUNY, VPI)              |
| ALTAREV      | 79  | JETPL 29 730                  | I.S. Altarev <i>et al.</i>                   | (PNPI)                   |
|              |     | Translated from ZETFP 29 794. |  |                          |
| EROZOLIM...  | 79  | SJNP 30 356                   | B.G. Erozolinsky <i>et al.</i>               | (KIAE)                   |
|              |     | Translated from YAF 30 692.   |  |                          |
| NORMAN       | 79  | PRL 43 1226                   | E.B. Norman, A.G. Seamster                   | (WASH)                   |
| BONDAREN...  | 78  | JETPL 28 303                  | L.N. Bondarenko <i>et al.</i>                | (KIAE)                   |
|              |     | Translated from ZETFP 28 328. |  |                          |
| Also         | 82  | Smolenice Conf.               | P.G. Bondarenko                              | (KIAE)                   |
| EROZOLIM...  | 78  | SJNP 28 48                    | B.G. Erozolinsky <i>et al.</i>               | (KIAE)                   |
|              |     | Translated from YAF 28 98.    |  |                          |
| STRATOWA     | 78  | PR D18 3970                   | C. Stratowa, R. Dobrozemsky, P. Weinzierl    | (SEIB)                   |
| EROZOLIM...  | 77  | JETPL 23 663                  | B.G. Erozolinsky <i>et al.</i>               | (KIAE)                   |
|              |     | Translated from ZETFP 23 720. |  |                          |

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|-------------|-----|-------------------------------|--|--------------|
| KOESTER     | 76  | PRL 36 1021                   | L. Koester <i>et al.</i>                 |              |
| STEINBERG   | 76  | PR D13 2469                   | R.I. Steinberg <i>et al.</i>             | (YALE, ISNG) |
| DOBROZE...  | 75  | PR D11 510                    | R. Dobrozemsky <i>et al.</i>             | (SEIB)       |
| KROHN       | 75  | PL 55B 175                    | V.E. Krohn, G.R. Ringo                   | (ANL)        |
| EROZOLIM... | 74  | JETPL 20 345                  | B.G. Erozolimsky <i>et al.</i>           |              |
|             |     | Translated from ZETFP 20 745. |  |              |
| KROPF       | 74  | ZPHY 267 129                  | H. Kropf, E. Paul                        | (LINZ)       |
| Also        | 70  | NP A154 160                   | H. Paul                                  | (VIEN)       |
| STEINBERG   | 74  | PRL 33 41                     | R.I. Steinberg <i>et al.</i>             | (YALE, ISNG) |
| COHEN       | 73  | JPCRD 2 664                   | E.R. Cohen, B.N. Taylor                  | (RISC, NBS)  |
| KROHN       | 73  | PR D8 1305                    | V.E. Krohn, G.R. Ringo                   |              |
| CHRISTENSEN | 72  | PR D5 1628                    | C.J. Christensen <i>et al.</i>           | (RISO)       |
| CHRISTENSEN | 70  | PR C1 1693                    | C.J. Christensen, V.E. Krohn, G.R. Ringo | (ANL)        |
| EROZOLIM... | 70C | PL 33B 351                    | B.G. Erozolimsky <i>et al.</i>           | (KIAE)       |
| GRIGOREV    | 68  | SJNP 6 239                    | V.K. Grigoriev <i>et al.</i>             | (ITEP)       |
|             |     | Translated from YAF 6 329.    |  |              |
| KROHN       | 66  | PR 148 1303                   | V.E. Krohn, G.R. Ringo                   |              |

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