# $K^0_L$

$I(J^P) = \frac{1}{2}(0^-)$

## $m_{K^0_L} - m_{K^0_S}$

For earlier measurements, beginning with GOOD 61 and FITCH 61, see our 1986 edition, Physics Letters **170B** 132 (1986).

OUR FIT is described in the note on "Fits for $K^0_L$ *CP*-Violation Parameters" in the $K^0_L$ Particle Listings.

| *VALUE* ($10^{10}$ $\hbar$ s$^{-1}$) | | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **0.5300±0.0012** | **OUR FIT** | | | | |
| **0.5307±0.0015** | **OUR AVERAGE** | Error includes scale factor of 1.1. | | | |
| 0.5240±0.0044 | ±0.0033 | APOSTOLA... | 99C | CPLR | $K^0$-$\overline{K}^0$ to $\pi^+\pi^-$ |
| 0.5295±0.0020 | ±0.0003 | [1] ANGELOPO... | 98D | CPLR | |
| 0.5297±0.0030 | ±0.0022 | [2] SCHWINGEN... | 95 | E773 | 20–160 GeV $K$ beams |
| 0.5257±0.0049 | ±0.0021 | [2] GIBBONS | 93C | E731 | 20–160 GeV $K$ beams |
| 0.5340±0.00255 | ±0.0015 | [3] GEWENIGER | 74C | SPEC | Gap method |
| 0.5334±0.0040 | ±0.0015 | [3] GJESDAL | 74 | SPEC | Charge asymmetry in $K^0_{\ell 3}$ |
| 0.542 ±0.006 | | CULLEN | 70 | CNTR | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.5307±0.0013 | | [4] ADLER | 96C | RVUE | |
| 0.5274±0.0029 | ±0.0005 | [1] ADLER | 95 | CPLR | Sup. by ANGELOPOULOS 98D |
| 0.5286±0.0028 | | [5] GIBBONS | 93 | E731 | 20–160 GeV $K$ beams |
| 0.482 ±0.014 | | [6] ARONSON | 82B | SPEC | $E$=30–110 GeV |
| 0.534 ±0.007 | | [7] CARNEGIE | 71 | ASPK | Gap method |
| 0.542 ±0.006 | | [7] ARONSON | 70 | ASPK | Gap method |

[1] Uses $\overline{K}^0_{e3}$ and $K^0_{e3}$ strangeness tagging at production and decay.

[2] Fits $\Delta m$ and $\phi_{+-}$ simultaneously. GIBBONS 93C systematic error is from B. Winstein via private communtication.

[3] These two experiments have a common systematic error due to the uncertainty in the momentum scale, as pointed out in WAHL 89.

[4] ADLER 96C is the result of a fit which includes nearly the same data as entered into the "OUR FIT" value above.

[5] GIBBONS 93 value assume $\phi_{+-} = \phi_{00} = \phi_{SW} = (43.7 \pm 0.2)^\circ$.

[6] ARONSON 82 find that $\Delta m$ may depend on the kaon energy.

[7] ARONSON 70 and CARNEGIE 71 use $K^0_S$ mean life = $(0.862 \pm 0.006) \times 10^{-10}$ s. We have not attempted to adjust these values for the subsequent change in the $K^0_S$ mean life or in $\eta_{+-}$.

# $K^0_L$ MEAN LIFE

| *VALUE* ($10^{-8}$ s) | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **5.17 ±0.04 OUR FIT** Error includes scale factor of 1.1. | | | | |
| **5.15 ±0.04 OUR AVERAGE** | | | | |
| 5.154±0.044 | 0.4M | VOSBURGH | 72 | CNTR |
| 5.15 ±0.14 | | DEVLIN | 67 | CNTR |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 5.0 ±0.5 | | [8] LOWYS | 67 | HLBC |
| 6.1 $^{+1.5}_{-1.2}$ | 1700 | ASTBURY | 65C | CNTR |
| 5.3 ±0.6 | | FUJII | 64 | OSPK |
| 5.1 $^{+2.4}_{-1.3}$ | 15 | DARMON | 62 | FBC |
| 8.1 $^{+3.2}_{-2.4}$ | 34 | BARDON | 58 | CNTR |

[8] Sum of partial decay rates.

# $K^0_L$ DECAY MODES

| | Mode | | | Fraction ($\Gamma_i/\Gamma$) | Scale factor/ Confidence level |
|---|---|---|---|---|---|
| | **Semileptonic modes** | | | | |
| $\Gamma_1$ | $\pi^\pm e^\mp \nu_e$ | | [a] | ($38.79 \pm 0.28$) % | S=1.1 |
| | Called $K^0_{e3}$. | | | | |
| $\Gamma_2$ | $\pi^- e^+ \nu_e$ | | | | |
| $\Gamma_3$ | $\pi^+ e^- \overline{\nu}_e$ | | | | |
| $\Gamma_4$ | $\pi^\pm \mu^\mp \nu_\mu$ | | [a] | ($27.18 \pm 0.25$) % | S=1.1 |
| | Called $K^0_{\mu 3}$. | | | | |
| $\Gamma_5$ | $\pi^- \mu^+ \nu_\mu$ | | | | |
| $\Gamma_6$ | $\pi^+ \mu^- \overline{\nu}_\mu$ | | | | |
| $\Gamma_7$ | $(\pi \mu \text{atom})\nu$ | | | ($1.06 \pm 0.11$) $\times 10^{-7}$ | |
| $\Gamma_8$ | $\pi^0 \pi^\pm e^\mp \nu$ | | [a] | ($5.18 \pm 0.29$) $\times 10^{-5}$ | |
| | **Hadronic modes, including Charge conjugation×Parity Violating (*CPV*) modes** | | | | |
| $\Gamma_9$ | $3\pi^0$ | | | ($21.11 \pm 0.27$) % | S=1.1 |
| $\Gamma_{10}$ | $\pi^+ \pi^- \pi^0$ | | | ($12.56 \pm 0.20$) % | S=1.7 |
| $\Gamma_{11}$ | $\pi^+ \pi^-$ | *CPV* | | ($2.056 \pm 0.033$) $\times 10^{-3}$ | |
| $\Gamma_{12}$ | $\pi^0 \pi^0$ | *CPV* | | ($9.28 \pm 0.19$) $\times 10^{-4}$ | |
| | **Semileptonic modes with photons** | | | | |
| $\Gamma_{13}$ | $\pi^\pm e^\mp \nu_e \gamma$ | | [a,b,c] | ($3.62 {}^{+0.26}_{-0.21}$) $\times 10^{-3}$ | |
| $\Gamma_{14}$ | $\pi^\pm \mu^\mp \nu_\mu \gamma$ | | | ($5.7 {}^{+0.6}_{-0.7}$) $\times 10^{-4}$ | |

## Hadronic modes with photons or $\ell\overline{\ell}$ pairs

| | | | | | | |
|---|---|---|---|---|---|---|
| $\Gamma_{15}$ | $\pi^0\pi^0\gamma$ | | | $<$ 5.6 | $\times 10^{-6}$ | |
| $\Gamma_{16}$ | $\pi^+\pi^-\gamma$ | | [*b,c*] | ( 4.61 $\pm$0.14 ) | $\times 10^{-5}$ | |
| $\Gamma_{17}$ | $\pi^0 2\gamma$ | | [*c*] | ( 1.68 $\pm$0.10 ) | $\times 10^{-6}$ | |
| $\Gamma_{18}$ | $\pi^0\gamma e^+e^-$ | | | $<$ 7.1 | $\times 10^{-7}$ | CL=90% |

## Other modes with photons or $\ell\overline{\ell}$ pairs

| | | | | | | |
|---|---|---|---|---|---|---|
| $\Gamma_{19}$ | $2\gamma$ | | | ( 5.86 $\pm$0.15 ) | $\times 10^{-4}$ | |
| $\Gamma_{20}$ | $3\gamma$ | | | $<$ 2.4 | $\times 10^{-7}$ | CL=90% |
| $\Gamma_{21}$ | $e^+e^-\gamma$ | | | (10.0 $\pm$0.5 ) | $\times 10^{-6}$ | S=1.5 |
| $\Gamma_{22}$ | $\mu^+\mu^-\gamma$ | | | ( 3.25 $\pm$0.28 ) | $\times 10^{-7}$ | |
| $\Gamma_{23}$ | $e^+e^-\gamma\gamma$ | | [*c*] | ( 6.9 $\pm$1.0 ) | $\times 10^{-7}$ | |
| $\Gamma_{24}$ | $\mu^+\mu^-\gamma\gamma$ | | [*c*] | ( 1.0 $^{+0.8}_{-0.6}$ ) | $\times 10^{-8}$ | |

## Charge conjugation $\times$ Parity (*CP*) or Lepton Family number (*LF*) violating modes, or $\Delta S = 1$ weak neutral current (*S1*) modes

| | | | | | | |
|---|---|---|---|---|---|---|
| $\Gamma_{25}$ | $\mu^+\mu^-$ | *S1* | | ( 7.15 $\pm$0.16 ) | $\times 10^{-9}$ | |
| $\Gamma_{26}$ | $e^+e^-$ | *S1* | | ( 9 $^{+6}_{-4}$ ) | $\times 10^{-12}$ | |
| $\Gamma_{27}$ | $\pi^+\pi^-e^+e^-$ | *S1* | [*c*] | ( 3.5 $\pm$0.6 ) | $\times 10^{-7}$ | |
| $\Gamma_{28}$ | $\mu^+\mu^-e^+e^-$ | *S1* | | ( 2.9 $^{+6.7}_{-2.4}$ ) | $\times 10^{-9}$ | |
| $\Gamma_{29}$ | $e^+e^-e^+e^-$ | *S1* | | ( 4.1 $\pm$0.8 ) | $\times 10^{-8}$ | S=1.2 |
| $\Gamma_{30}$ | $\pi^0\mu^+\mu^-$ | *CP,S1* | [*d*] | $<$ 3.8 | $\times 10^{-10}$ | CL=90% |
| $\Gamma_{31}$ | $\pi^0 e^+e^-$ | *CP,S1* | [*d*] | $<$ 4.3 | $\times 10^{-9}$ | CL=90% |
| $\Gamma_{32}$ | $\pi^0\nu\overline{\nu}$ | *CP,S1* | [*e*] | $<$ 5.9 | $\times 10^{-7}$ | CL=90% |
| $\Gamma_{33}$ | $e^\pm\mu^\mp$ | *LF* | [*a*] | $<$ 4.7 | $\times 10^{-12}$ | CL=90% |
| $\Gamma_{34}$ | $e^\pm e^\pm\mu^\mp\mu^\mp$ | *LF* | [*a*] | $<$ 6.1 | $\times 10^{-9}$ | CL=90% |
| $\Gamma_{35}$ | $\pi^0\mu^\pm e^\mp$ | *LF* | [*a*] | $<$ 6.2 | $\times 10^{-9}$ | CL=90% |

[*a*] The value is for the sum of the charge states or particle/antiparticle states indicated.

[*b*] Most of this radiative mode, the low-momentum $\gamma$ part, is also included in the parent mode listed without $\gamma$'s.

[*c*] See the Particle Listings below for the energy limits used in this measurement.

[*d*] Allowed by higher-order electroweak interactions.

[*e*] Violates *CP* in leading order. Test of direct *CP* violation since the indirect *CP*-violating and *CP*-conserving contributions are expected to be suppressed.

## CONSTRAINED FIT INFORMATION

An overall fit to the mean life, 3 decay rate, and 12 branching ratios uses 45 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2$ = 38.7 for 38 degrees of freedom.

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $x_4$ | −36 | | | | | | |
| $x_9$ | −49 | −37 | | | | | |
| $x_{10}$ | −28 | −28 | −19 | | | | |
| $x_{11}$ | −7 | −8 | −12 | 34 | | | |
| $x_{12}$ | −6 | −6 | −9 | 26 | 77 | | |
| $x_{19}$ | −5 | −5 | −7 | 21 | 63 | 83 | |
| $\Gamma$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | $x_1$ | $x_4$ | $x_9$ | $x_{10}$ | $x_{11}$ | $x_{12}$ | $x_{19}$ |

| | Mode | Rate ($10^8$ s$^{-1}$) | Scale factor |
|---|---|---|---|
| $\Gamma_1$ | $\pi^{\pm} e^{\mp} \nu_e$<br>Called $K^0_{e3}$. | [a] 0.0750±0.0008 | 1.1 |
| $\Gamma_4$ | $\pi^{\pm} \mu^{\mp} \nu_\mu$<br>Called $K^0_{\mu 3}$. | [a] 0.0525±0.0007 | 1.1 |
| $\Gamma_9$ | $3\pi^0$ | 0.0408±0.0006 | |
| $\Gamma_{10}$ | $\pi^+ \pi^- \pi^0$ | 0.0243±0.0004 | 1.5 |
| $\Gamma_{11}$ | $\pi^+ \pi^-$ | $(3.97 \pm 0.07) \times 10^{-4}$ | 1.1 |
| $\Gamma_{12}$ | $\pi^0 \pi^0$ | $(1.79 \pm 0.04) \times 10^{-4}$ | |
| $\Gamma_{19}$ | $2\gamma$ | $(1.133 \pm 0.030) \times 10^{-4}$ | |

## $K^0_L$ DECAY RATES

### $\Gamma(\pi^+ \pi^- \pi^0)$ $\Gamma_{10}$

| VALUE ($10^6$ s$^{-1}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **2.43±0.04 OUR FIT** Error includes scale factor of 1.5. | | | | | |
| **2.38±0.09 OUR AVERAGE** | | | | | |
| $2.32^{+0.13}_{-0.15}$ | 192 | BALDO-... | 75 | HLBC | Assumes *CP* |
| 2.35±0.20 | 180 | [9] JAMES | 72 | HBC | Assumes *CP* |
| 2.71±0.28 | 99 | CHO | 71 | DBC | Assumes *CP* |
| 2.12±0.33 | 50 | MEISNER | 71 | HBC | Assumes *CP* |
| 2.20±0.35 | 53 | WEBBER | 70 | HBC | Assumes *CP* |
| $2.62^{+0.28}_{-0.27}$ | 136 | BEHR | 66 | HLBC | Assumes *CP* |

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

| | | | | | |
|---|---|---|---|---|---|
| 2.5 $\pm$0.3 | 98 | [9] JAMES | 71 | HBC | Assumes *CP* |
| 3.26$\pm$0.77 | 18 | ANDERSON | 65 | HBC | |
| 1.4 $\pm$0.4 | 14 | FRANZINI | 65 | HBC | |

[9] JAMES 72 is a final measurement and includes JAMES 71.

### $\Gamma(\pi^{\pm} e^{\mp} \nu_e)$ — $\Gamma_1$

| *VALUE* ($10^6$ s$^{-1}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **7.50$\pm$0.08 OUR FIT** Error includes scale factor of 1.1. | | | | | |
| **7.7 $\pm$0.5 OUR AVERAGE** | | | | | |
| 7.81$\pm$0.56 | 620 | CHAN | 71 | HBC | |
| $7.52^{+0.85}_{-0.72}$ | | AUBERT | 65 | HLBC | $\Delta S=\Delta Q$, *CP* assumed |

### $\Gamma(\pi^{\pm} e^{\mp} \nu_e) + \Gamma(\pi^{\pm} \mu^{\mp} \nu_\mu)$ — $(\Gamma_1+\Gamma_4)$

| *VALUE* ($10^6$ s$^{-1}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **12.75$\pm$0.12 OUR FIT** Error includes scale factor of 1.1. | | | | | |
| **11.9 $\pm$0.6 OUR AVERAGE** Error includes scale factor of 1.2. | | | | | |
| 12.4 $\pm$0.7 | 410 | [10] BURGUN | 72 | HBC | $K^+ p \rightarrow K^0 p \pi^+$ |
| 13.1 $\pm$1.3 | 252 | [10] WEBBER | 71 | HBC | $K^- p \rightarrow n \overline{K}^0$ |
| 11.6 $\pm$0.9 | 393 | [10,11] CHO | 70 | DBC | $K^+ n \rightarrow K^0 p$ |
| $9.85^{+1.15}_{-1.05}$ | 109 | [10] FRANZINI | 65 | HBC | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 8.47$\pm$1.69 | 126 | [10] MANN | 72 | HBC | $K^- p \rightarrow n \overline{K}^0$ |
| 10.3 $\pm$0.8 | 335 | [11] HILL | 67 | DBC | $K^+ n \rightarrow K^0 p$ |

[10] Assumes $\Delta S = \Delta Q$ rule.
[11] CHO 70 includes events of HILL 67.

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## $K^0_L$ BRANCHING RATIOS

### Semileptonic modes

### $\left[\Gamma(\pi^{\pm} e^{\mp} \nu_e) + \Gamma(\pi^{\pm} \mu^{\mp} \nu_\mu)\right]/\Gamma_{\text{total}}$ — $(\Gamma_1+\Gamma_4)/\Gamma$

| *VALUE* | *DOCUMENT ID* |
|---|---|
| **0.6598$\pm$0.0030 OUR FIT** Error includes scale factor of 1.2. | |

### $\Gamma(\pi^{\pm} \mu^{\mp} \nu_\mu)/\Gamma(\pi^{\pm} e^{\mp} \nu_e)$ — $\Gamma_4/\Gamma_1$

| *VALUE* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **0.701$\pm$0.009 OUR FIT** | | | | |
| **$0.697^{+0.010}_{-0.009}$ OUR AVERAGE** | | | | |
| 0.702$\pm$0.011 | 33k | CHO | 80 | HBC |
| 0.662$\pm$0.037 | 10k | WILLIAMS | 74 | ASPK |
| 0.741$\pm$0.044 | 6700 | BRANDENB... | 73 | HBC |
| 0.662$\pm$0.030 | 1309 | EVANS | 73 | HLBC |
| 0.71 $\pm$0.05 | 770 | BUDAGOV | 68 | HLBC |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.68 $\pm$0.08 | 3548 | BASILE | 70 | OSPK |

### $\Gamma((\pi\mu\text{atom})\nu)/\Gamma(\pi^{\pm}\mu^{\mp}\nu_{\mu})$ $\Gamma_7/\Gamma_4$

| VALUE (units $10^{-7}$) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **3.90±0.39** | 155 | [12] ARONSON | 86 | SPEC |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| seen | 18 | COOMBES | 76 | WIRE |

[12] ARONSON 86 quote theoretical value of $(4.31 \pm 0.08) \times 10^{-7}$.

### $\Gamma(\pi^0\pi^{\pm}e^{\mp}\nu)/\Gamma_{\text{total}}$ $\Gamma_8/\Gamma$

| VALUE (units $10^{-5}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| **5.18±0.29 OUR AVERAGE** | | | | | |
| 5.16±0.20±0.22 | | 729 | MAKOFF | 93 | E731 |
| 6.2 ±2.0 | | 16 | CARROLL | 80C | SPEC |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <220 | 90 | | [13] DONALDSON | 74 | SPEC |

[13] DONALDSON 74 uses $K_L^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all } K_L^0)$ decays = 0.126.

## Hadronic modes, including Charge conjugation×Parity Violating (*CPV*) modes

### $\Gamma(3\pi^0)/\Gamma_{\text{total}}$ $\Gamma_9/\Gamma$

| VALUE | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.2111±0.0027 OUR FIT** Error includes scale factor of 1.1. | | | | |
| **0.2105±0.0028** | 38k | [14] KREUTZ | 95 | NA31 |

[14] KREUTZ 95 measure $3\pi^0$, $\pi^+\pi^-\pi^0$, and $\pi e \nu_e$ modes. They assume PDG 1992 values for $\pi\mu\nu_{\mu}$, $2\pi$, and $2\gamma$ modes.

### $\Gamma(3\pi^0)/\Gamma(\pi^{\pm}e^{\mp}\nu_e)$ $\Gamma_9/\Gamma_1$

| VALUE | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.544±0.009 OUR FIT** Error includes scale factor of 1.1. | | | | |
| **0.545±0.004±0.009** | 38k | [15] KREUTZ | 95 | NA31 |

[15] KREUTZ 95 measurement excluded from fit because it is not independent of their $\Gamma(3\pi^0)/\Gamma_{\text{total}}$ measurement, which is in the fit.

### $\Gamma(3\pi^0)/\left[\Gamma(\pi^{\pm}e^{\mp}\nu_e)+\Gamma(\pi^{\pm}\mu^{\mp}\nu_{\mu})+\Gamma(\pi^+\pi^-\pi^0)\right]$ $\Gamma_9/(\Gamma_1+\Gamma_4+\Gamma_{10})$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.269±0.004 OUR FIT** Error includes scale factor of 1.1. | | | | | |
| **0.260±0.011 OUR AVERAGE** | | | | | |
| 0.251±0.014 | 549 | BUDAGOV | 68 | HLBC | ORSAY measur. |
| 0.277±0.021 | 444 | BUDAGOV | 68 | HLBC | Ecole polytec.meas |
| $0.31\ ^{+0.07}_{-0.06}$ | 29 | KULYUKINA | 68 | CC | |
| 0.24 ±0.08 | 24 | ANIKINA | 64 | CC | |

### $\Gamma(3\pi^0)/\Gamma(\pi^+\pi^-\pi^0)$ — $\Gamma_9/\Gamma_{10}$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **1.68 ±0.04 OUR FIT** Error includes scale factor of 1.3. | | | | | |
| **1.63 ±0.05 OUR AVERAGE** Error includes scale factor of 1.4. | | | | | |
| 1.611±0.014±0.034 | 38k | [16] KREUTZ | 95 | NA31 | |
| 1.80 ±0.13 | 1010 | BUDAGOV | 68 | HLBC | |
| 2.0 ±0.6 | 188 | ALEKSANYAN | 64B | FBC | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 1.65 ±0.07 | 883 | BARMIN | 72B | HLBC | Error statistical only |

[16] KREUTZ 95 excluded from fit because it is not independent of their $\Gamma(3\pi^0)/\Gamma_{total}$ measurement, which is in the fit.

### $\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{total}$ — $\Gamma_{10}/\Gamma$

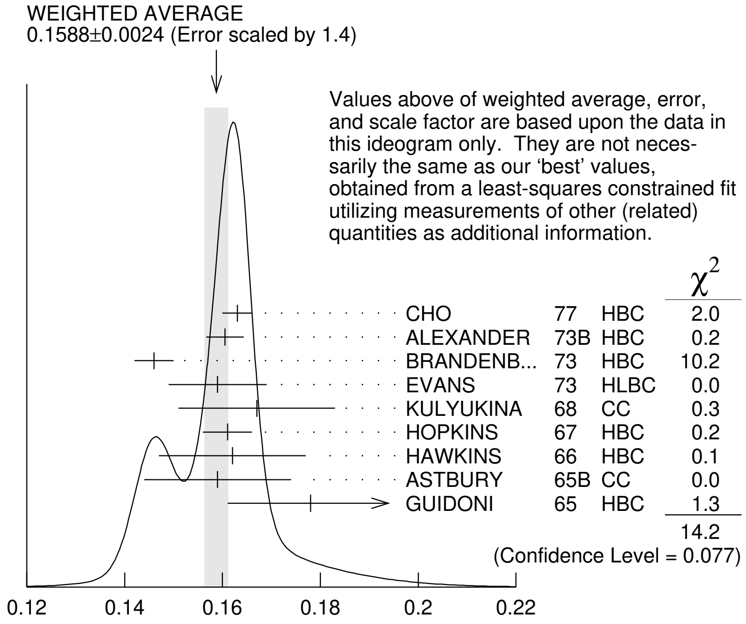
| VALUE | DOCUMENT ID |
|---|---|
| **0.1256±0.0020 OUR FIT** Error includes scale factor of 1.7. | |

### $\Gamma(\pi^+\pi^-\pi^0)/\Gamma(\pi^\pm e^\mp \nu_e)$ — $\Gamma_{10}/\Gamma_1$

| VALUE | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.324±0.006 OUR FIT** Error includes scale factor of 1.6. | | | | |
| **0.336±0.003±0.007** | 28k | KREUTZ | 95 | NA31 |

### $\Gamma(\pi^+\pi^-\pi^0)/[\Gamma(\pi^\pm e^\mp \nu_e)+\Gamma(\pi^\pm \mu^\mp \nu_\mu)+\Gamma(\pi^+\pi^-\pi^0)]$ — $\Gamma_{10}/(\Gamma_1+\Gamma_4+\Gamma_{10})$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.1599±0.0025 OUR FIT** Error includes scale factor of 1.7. | | | | | |
| **0.1588±0.0024 OUR AVERAGE** Error includes scale factor of 1.4. See the ideogram below. | | | | | |
| 0.163 ±0.003 | 6499 | CHO | 77 | HBC | |
| 0.1605±0.0038 | 1590 | ALEXANDER | 73B | HBC | |
| 0.146 ±0.004 | 3200 | BRANDENB... | 73 | HBC | |
| 0.159 ±0.010 | 558 | EVANS | 73 | HLBC | |
| 0.167 ±0.016 | 1402 | KULYUKINA | 68 | CC | |
| 0.161 ±0.005 | | HOPKINS | 67 | HBC | |
| 0.162 ±0.015 | 126 | HAWKINS | 66 | HBC | |
| 0.159 ±0.015 | 326 | ASTBURY | 65B | CC | |
| 0.178 ±0.017 | 566 | GUIDONI | 65 | HBC | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.144 ±0.004 | 1729 | HOPKINS | 65 | HBC | See HOPKINS 67 |




$$\Gamma\left(\pi^+\pi^-\pi^0\right)/\left[\Gamma\left(\pi^\pm e^\mp\nu_e\right)+\Gamma\left(\pi^\pm\mu^\mp\nu_\mu\right)+\Gamma\left(\pi^+\pi^-\pi^0\right)\right]$$

## $\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ $\qquad\qquad$ $\Gamma_{11}/\Gamma$

Violates *CP* conservation.

| *VALUE* (units $10^{-3}$) | *DOCUMENT ID* | |
|---|---|---|
| **2.056±0.033 OUR FIT** | | |
| **2.071±0.049** | [17] ETAFIT | 00 |

[17] This ETAFIT value is computed from fitted values of $|\eta_{+-}|$, the $K^0_L$ and $K^0_S$ lifetimes, and the $K^0_S \rightarrow \pi^+\pi^-$ branching fraction. See the discussion in the note "Fits for $K^0_L$ *CP*-Violation Parameters."

## $\Gamma(\pi^+\pi^-)/\left[\Gamma(\pi^\pm e^\mp\nu_e)+\Gamma(\pi^\pm\mu^\mp\nu_\mu)\right]$ $\qquad\qquad$ $\Gamma_{11}/(\Gamma_1+\Gamma_4)$

Violates *CP* conservation.

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **3.12±0.05 OUR FIT** Error includes scale factor of 1.1. | | | | | |
| **3.08±0.10 OUR AVERAGE** | | | | | |
| 3.13±0.14 | 1687 | COUPAL | 85 | SPEC | $\eta_{+-}$=2.28 ± 0.06 |
| 3.04±0.14 | 2703 | DEVOE | 77 | SPEC | $\eta_{+-}$=2.25 ± 0.05 |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 2.51±0.23 | 309 | [18] DEBOUARD | 67 | OSPK | $\eta_{+-}$=2.00 ± 0.09 |
| 2.35±0.19 | 525 | [18] FITCH | 67 | OSPK | $\eta_{+-}$=1.94 ± 0.08 |

[18] Old experiments excluded from fit. See subsection on $\eta_{+-}$ in section on "PARAMETERS FOR $K^0_L \rightarrow 2\pi$ DECAY" below for average $\eta_{+-}$ of these experiments and for note on discrepancy.

### $\Gamma(\pi^+\pi^-)/[\Gamma(\pi^\pm e^\mp \nu_e)+\Gamma(\pi^\pm \mu^\mp \nu_\mu)+\Gamma(\pi^+\pi^-\pi^0)]$ $\Gamma_{11}/(\Gamma_1+\Gamma_4+\Gamma_{10})$

Violates *CP* conservation.

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **2.62±0.04 OUR FIT** | | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 2.60±0.07 | 4200 | [19] MESSNER | 73 | ASPK | $\eta_{+-}=2.23\pm0.05$ |

[19] From same data as $\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0)$ MESSNER 73, but with different normalization.

### $\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0)$ $\Gamma_{11}/\Gamma_{10}$

Violates *CP* conservation.

| *VALUE* (units $10^{-2}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **1.637±0.030 OUR FIT** | Error includes scale factor of 1.1. | | | | |
| **1.64 ±0.04** | 4200 | MESSNER | 73 | ASPK | $\eta_{+-}=2.23$ |

### $\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$ $\Gamma_{12}/\Gamma$

Violates *CP* conservation.

| *VALUE* (units $10^{-3}$) | *DOCUMENT ID* |
|---|---|
| **0.928±0.019 OUR FIT** | |

### $\Gamma(\pi^0\pi^0)/\Gamma(\pi^+\pi^-)$ $\Gamma_{12}/\Gamma_{11}$

Violates *CP* conservation.

| *VALUE* | *DOCUMENT ID* | |
|---|---|---|
| **0.451 ±0.006 OUR FIT** | | |
| **0.4517±0.0060** | [20] ETAFIT | 00 |

[20] This ETAFIT value is computed from fitted values of $|\eta_{00}\ /\ \eta_{+-}|$ and the $\Gamma(K^0_S \rightarrow \pi^+\pi^-)\ /\ \Gamma(K^0_S \rightarrow \pi^0\pi^0)$ branching fraction. See the discussion in the note "Fits for $K^0_L$ *CP*-Violation Parameters."

### $\Gamma(\pi^0\pi^0)/\Gamma(3\pi^0)$ $\Gamma_{12}/\Gamma_9$

Violates *CP* conservation.

| *VALUE* (units $10^{-2}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **0.439±0.011 OUR FIT** | Error includes scale factor of 1.1. | | | | |
| **0.39 ±0.06 OUR AVERAGE** | | | | | |
| 0.37 ±0.08 | 29 | BARMIN | 70 | HLBC | $\eta_{00}$=2.02 ± 0.23 |
| 0.32 ±0.15 | 30 | BUDAGOV | 70 | HLBC | $\eta_{00}$=1.9 ± 0.5 |
| 0.46 ±0.11 | 57 | BANNER | 69 | OSPK | $\eta_{00}$=2.2 ± 0.3 |

## Semileptonic modes with photons

### $\Gamma(\pi^\pm e^\mp \nu_e \gamma)/\Gamma(\pi^\pm e^\mp \nu_e)$ $\Gamma_{13}/\Gamma_1$

| *VALUE* (units $10^{-2}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| $\mathbf{0.934\pm0.036^{+0.055}_{-0.039}}$ | 1384 | LEBER | 96 | NA31 | $E^*_\gamma \geq 30$ MeV, $\theta^*_{e\gamma} \geq 20°$ |

### $\Gamma(\pi^\pm \mu^\mp \nu_\mu \gamma)/\Gamma(\pi^\pm \mu^\mp \nu_\mu)$ $\Gamma_{14}/\Gamma_4$

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| $\mathbf{2.08\pm0.17^{+0.16}_{-0.21}}$ | 4261 | BENDER | 98 | NA48 | $E^*_\gamma \geq 30$ MeV |

## Hadronic modes with photons or $\ell\overline{\ell}$ pairs

### $\Gamma(\pi^0\pi^0\gamma)/\Gamma_{total}$ — $\Gamma_{15}/\Gamma$

| VALUE (units $10^{-6}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| **< 5.6** | | | BARR | 94 | NA31 |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <230 | 90 | 0 | ROBERTS | 94 | E799 |

### $\Gamma(\pi^+\pi^-\gamma)/\Gamma_{total}$ — $\Gamma_{16}/\Gamma$

For earlier limits see our 1992 edition Physical Review **D45,** 1 June, Part II (1992).

| VALUE (units $10^{-5}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **4.61±0.14 OUR AVERAGE** | | | | | |
| 4.66±0.15 | 3136 | [21] RAMBERG | 93 | E731 | $E_\gamma$ >20 MeV |
| 4.41±0.32 | 1062 | [22] CARROLL | 80B | SPEC | $E_\gamma$ >20 MeV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 1.52±0.16 | 516 | [23] CARROLL | 80B | SPEC | $E_\gamma$ >20 MeV |
| 2.89±0.28 | 546 | [24] CARROLL | 80B | SPEC | |

[21] RAMBERG 93 finds that fraction of Direct Emission (DE) decays with $E_\gamma$ >20 MeV is 0.685 ± 0.041.

[22] Both components. Uses $K^0_L \rightarrow \pi^+\pi^-\pi^0$/(all $K^0_L$) decays = 0.1239.

[23] Internal Bremsstrahlung component only.

[24] Direct $\gamma$ emission component only.

### $\Gamma(\pi^0 2\gamma)/\Gamma_{total}$ — $\Gamma_{17}/\Gamma$

| VALUE (units $10^{-6}$) | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **1.68±0.10 OUR AVERAGE** | | | | | | |
| 1.68±0.07±0.08 | | 884 | ALAVI-HARATI | 99B | KTEV | |
| 1.7 ±0.2 ±0.2 | | 63 | [25] BARR | 92 | SPEC | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| 1.86±0.60±0.60 | | 60 | PAPADIMITR... | 91 | E731 | $m_{\gamma\gamma}$ > 280 MeV |
| <5.1 | 90 | | PAPADIMITR... | 91 | E731 | $m_{\gamma\gamma}$ < 264 MeV |
| 2.1 ±0.6 | | 14 | [26] BARR | 90C | NA31 | $m_{\gamma\gamma}$ > 280 MeV |

[25] BARR 92 find that $\Gamma(\pi^0 2\gamma$, $m_{\gamma\gamma}$ <240 MeV)/$\Gamma(\pi^0 2\gamma)$< 0.09 (90% CL).

[26] BARR 90C superseded by BARR 92.

### $\Gamma(\pi^0\gamma e^+e^-)/\Gamma_{total}$ — $\Gamma_{18}/\Gamma$

| VALUE (units $10^{-7}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| **<7.1** | 90 | 0 | MURAKAMI | 99 | SPEC |

## Other modes with photons or $\ell\overline{\ell}$ pairs

### $\Gamma(2\gamma)/\Gamma_{total}$ — $\Gamma_{19}/\Gamma$

| VALUE (units $10^{-4}$) | EVTS | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|---|
| **5.86±0.15 OUR FIT** | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |

| | | | | | |
|---|---|---|---|---|---|
| $4.54\pm0.84$ | | [27] BANNER | 72B | OSPK | |
| $4.5\ \pm1.0$ | 23 | ENSTROM | 71 | OSPK | $K^0_L$ 1.5–9 GeV/$c$ |
| $5.0\ \pm1.0$ | | [28] REPELLIN | 71 | OSPK | |
| $5.5\ \pm1.1$ | 90 | KUNZ | 68 | OSPK | Norm.to 3 $\pi$(C+N) |

[27] This value uses $(\eta_{00}/\eta_{+-})^2 = 1.05\pm0.14$. In general, $\Gamma(2\gamma)/\Gamma_{\rm total} = [(4.32\pm0.55)\times 10^{-4}][(\eta_{00}/\eta_{+-})^2]$.

[28] Assumes regeneration amplitude in copper at 2 GeV is 22 mb. To evaluate for a given regeneration amplitude and error, multiply by (regeneration amplitude/22mb)$^2$.

## $\Gamma(2\gamma)/\Gamma(3\pi^0)$ — $\Gamma_{19}/\Gamma_9$

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **2.78±0.08 OUR FIT** | | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $2.13\pm0.43$ | 28 | BARMIN | 71 | HLBC | |
| $2.24\pm0.28$ | 115 | BANNER | 69 | OSPK | |
| $2.5\ \pm0.7$ | 16 | ARNOLD | 68B | HLBC | Vacuum decay |

## $\Gamma(2\gamma)/\Gamma(\pi^0\pi^0)$ — $\Gamma_{19}/\Gamma_{12}$

| *VALUE* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **0.632±0.009 OUR FIT** | | | | |
| **0.632±0.004±0.008** | 110k | BURKHARDT | 87 | NA31 |

## $\Gamma(3\gamma)/\Gamma_{\rm total}$ — $\Gamma_{20}/\Gamma$

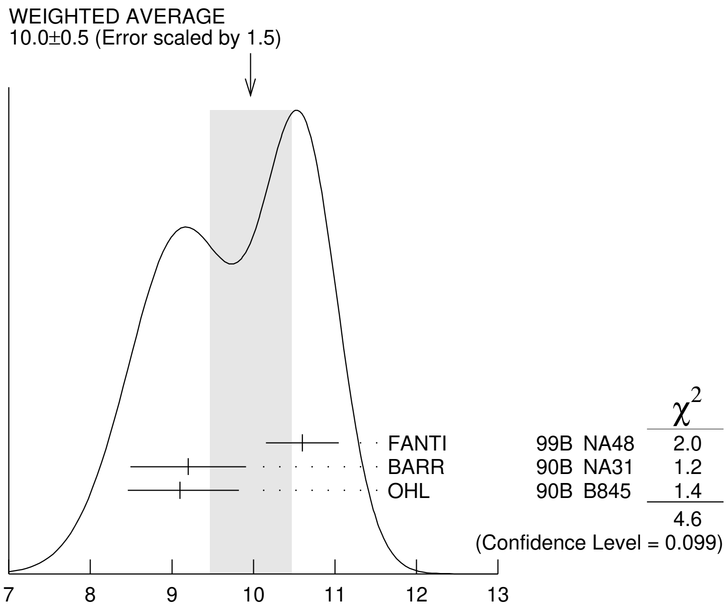
| *VALUE* | *CL%* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| $\mathbf{<2.4\times10^{-7}}$ | 90 | [29] BARR | 95C | NA31 |

[29] Assumes a phase-space decay distribution.

## $\Gamma(e^+e^-\gamma)/\Gamma_{\rm total}$ — $\Gamma_{21}/\Gamma$

| *VALUE* (units $10^{-6}$) | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **10.0±0.5 OUR AVERAGE** Error includes scale factor of 1.5. See the ideogram below. | | | | |
| $10.6\pm0.2\pm0.4$ | 6864 | [30] FANTI | 99B | NA48 |
| $9.2\pm0.5\pm0.5$ | 1053 | BARR | 90B | NA31 |
| $9.1\pm0.4^{+0.6}_{-0.5}$ | 919 | OHL | 90B | B845 |

[30] For FANTI 99B, the $\pm0.4$ systematic error includes for uncertainties in the calculation, primarily uncertainties in the $\pi^0 \rightarrow e^+e^-\gamma$ and $K^0_L \rightarrow \pi^0\pi^0$ branching ratios, evaluated using our 1999 Web edition values.




$\Gamma\left(e^+ e^- \gamma\right)/\Gamma_{\text{total}}$ (units $10^{-6}$)

## $\Gamma(\mu^+\mu^-\gamma)/\Gamma_{\text{total}}$ $\Gamma_{22}/\Gamma$

| *VALUE* (units $10^{-7}$) | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **3.25±0.28 OUR AVERAGE** | | | | |
| 3.4 ±0.6 ±0.4 | 45 | FANTI | 97 | NA48 |
| 3.23±0.23±0.19 | 197 | SPENCER | 95 | E799 |

## $\Gamma(e^+e^-\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_{23}/\Gamma$

| *VALUE* (units $10^{-7}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **6.9±1.0 OUR AVERAGE** | | | | | |
| $8.0\pm1.5^{+1.4}_{-1.2}$ | 40 | SETZU | 98 | NA31 | $E_\gamma > 5$ MeV |
| 6.5±1.2±0.6 | 58 | NAKAYA | 94 | E799 | $E_\gamma > 5$ MeV |
| 6.6±3.2 | | MORSE | 92 | B845 | $E_\gamma > 5$ MeV |

## $\Gamma(\mu^+\mu^-\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_{24}/\Gamma$

| *VALUE* (units $10^{-9}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| $\mathbf{10.4^{+7.5}_{-5.9}\pm0.7}$ | 4 | ALAVI-HARATI | 00E | KTEV | $m_{\gamma\gamma} \geq 1$ MeV/$c^2$ |

## Charge conjugation × Parity ($CP$) or Lepton Family number ($LF$) violating modes, or $\Delta S = 1$ weak neutral current ($S1$) modes

### $\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$ — $\Gamma_{25}/\Gamma_{11}$

Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.

| *VALUE* (units $10^{-6}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **3.48 ±0.05 OUR AVERAGE** | | | | | |
| 3.474±0.057 | 6210 | AMBROSE | 00 | B871 | |
| 3.87 ±0.30 | 179 | [31] AKAGI | 95 | SPEC | |
| 3.38 ±0.17 | 707 | HEINSON | 95 | B791 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 3.9 ±0.3 ±0.1 | 178 | [32] AKAGI | 91B | SPEC | In AKAGI 95 |
| 3.45 ±0.18 ±0.13 | 368 | [33] HEINSON | 91 | SPEC | In HEINSON 95 |
| 4.1 ±0.5 | 54 | INAGAKI | 89 | SPEC | In AKAGI 91B |
| 2.8 ±0.3 ±0.2 | 87 | MATHIAZHA... | 89B | SPEC | In HEINSON 91 |

[31] AKAGI 95 gives this number multiplied by the PDG 1992 average for $\Gamma(K^0_L \to \pi^+\pi^-)/\Gamma(\text{total})$.

[32] AKAGI 91B give this number multiplied by the 1990 PDG average for $\Gamma(K^0_L \to \pi^+\pi^-)/\Gamma(\text{total})$.

[33] HEINSON 91 give $\Gamma(K^0_L \to \mu\mu)/\Gamma_{\text{total}}$. We divide out the $\Gamma(K^0_L \to \pi^+\pi^-)/\Gamma_{\text{total}}$ PDG average which they used.

### $\Gamma(e^+e^-)/\Gamma_{\text{total}}$ — $\Gamma_{26}/\Gamma$

Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.

| *VALUE* (units $10^{-10}$) | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|---|
| $\mathbf{0.087^{+0.057}_{-0.041}}$ | | 4 | AMBROSE | 98 | B871 |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <1.6 | 90 | 1 | AKAGI | 95 | SPEC |
| <0.41 | 90 | 0 | [34] ARISAKA | 93B | B791 |

[34] ARISAKA 93B includes all events with <6 MeV radiated energy.

### $\Gamma(\pi^+\pi^-e^+e^-)/\Gamma_{\text{total}}$ — $\Gamma_{27}/\Gamma$

Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.

| *VALUE* (units $10^{-7}$) | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|---|
| **3.5±0.6 OUR AVERAGE** | | | | | | |
| 3.2±0.6±0.4 | | 37 | ADAMS | 98 | KTEV | |
| 4.4±1.3±0.5 | | 13 | TAKEUCHI | 98 | SPEC | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| <4.6 | 90 | | NOMURA | 97 | SPEC | $m_{ee} > 4$ MeV |

### $\Gamma(\mu^+\mu^-e^+e^-)/\Gamma_{\text{total}}$ — $\Gamma_{28}/\Gamma$

Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.

| *VALUE* (units $10^{-9}$) | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|---|
| $\mathbf{2.9^{+6.7}_{-2.4}}$ | | 1 | GU | 96 | E799 |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <4900 | 90 | | BALATS | 83 | SPEC |

### $\Gamma(e^+e^-e^+e^-)/\Gamma_{\rm total}$ — $\Gamma_{29}/\Gamma$

Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.

| VALUE (units $10^{-8}$) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **4.1 ±0.8 OUR AVERAGE** | | Error includes scale factor of 1.2. | | | |
| 6 ±2 ±1 | 18 | [35] AKAGI | 95 | SPEC | $m_{ee}$ >470 MeV |
| 10.4 ±3.7 ±1.1 | 8 | [36] BARR | 95 | NA31 | |
| 3.96±0.78±0.32 | 27 | GU | 94 | E799 | |
| 3.07±1.25±0.26 | 6 | VAGINS | 93 | B845 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 7 ±3 ±2 | 6 | [35] AKAGI | 95 | SPEC | $m_{ee}$ >470 MeV |
| 6 ±2 ±1 | 18 | AKAGI | 93 | CNTR | Sup. by AKAGI 95 |
| 4 ±3 | 2 | BARR | 91 | NA31 | Sup. by BARR 95 |

[35] Values are for the total branching fraction, acceptance-corrected for the $m_{ee}$ cuts shown.
[36] Distribution of angles between two $e^+e^-$ pair planes favors $CP$=−1 for $K^0_L$.

### $\Gamma(\pi^0\mu^+\mu^-)/\Gamma_{\rm total}$ — $\Gamma_{30}/\Gamma$

Violates $CP$ in leading order. Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.

| VALUE (units $10^{-9}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| **<0.38** | 90 | | ALAVI-HARATI | 00D | KTEV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <5.1 | 90 | 0 | HARRIS | 93 | E799 |

### $\Gamma(\pi^0e^+e^-)/\Gamma_{\rm total}$ — $\Gamma_{31}/\Gamma$

Violates $CP$ in leading order. Direct and indirect $CP$-violating contributions are expected to be comparable and to dominate the $CP$-conserving part. Test for $\Delta S = 1$ weak neutral current. Allowed by higher-order electroweak interaction.

| VALUE (units $10^{-9}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| **< 4.3** | 90 | 0 | HARRIS | 93B | E799 |
| < 7.5 | 90 | 0 | BARKER | 90 | E731 |
| < 5.5 | 90 | 0 | OHL | 90 | B845 |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| < 40 | 90 | | BARR | 88 | NA31 |
| <320 | 90 | | JASTRZEM... | 88 | SPEC |

### $\Gamma(\pi^0\nu\overline{\nu})/\Gamma_{\rm total}$ — $\Gamma_{32}/\Gamma$

Violates $CP$ in leading order. Test of direct $CP$ violation since the indirect $CP$-violating and $CP$-conserving contributions are expected to be suppressed. Test of $\Delta S = 1$ weak neutral current.

| VALUE (units $10^{-5}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| **< 0.059** | 90 | 0 | ALAVI-HARATI | 00 | KTEV |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| < 0.16 | 90 | 0 | ADAMS | 99 | KTEV |
| < 5.8 | 90 | 0 | WEAVER | 94 | E799 |
| <22 | 90 | 0 | GRAHAM | 92 | CNTR |

### $\Gamma(e^{\pm}\mu^{\mp})/\Gamma_{total}$ — $\Gamma_{33}/\Gamma$

Test of lepton family number conservation.

| VALUE (units $10^{-11}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| **<0.47** | 90 | | AMBROSE | 98B | B871 |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <9.4 | 90 | 0 | AKAGI | 95 | SPEC |
| <3.9 | 90 | 0 | ARISAKA | 93 | B791 |
| <3.3 | 90 | 0 | [37] ARISAKA | 93 | B791 |

[37] This is the combined result of ARISAKA 93 and MATHIAZHAGAN 89.

### $\Gamma(e^{\pm}e^{\pm}\mu^{\mp}\mu^{\mp})/\Gamma_{total}$ — $\Gamma_{34}/\Gamma$

Test of lepton family number conservation.

| VALUE (units $10^{-9}$) | CL% | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|---|
| **<6.1** | 90 | 0 | [38] GU | 96 | E799 |

[38] Assuming uniform phase space distribution.

### $\Gamma(\pi^0\mu^{\pm}e^{\mp})/\Gamma_{total}$ — $\Gamma_{35}/\Gamma$

Test of lepton family number conservation.

| VALUE | CL% | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **$<6.2\times10^{-9}$** | 90 | ARISAKA | 98 | E799 |

## ENERGY DEPENDENCE OF $K^0_L$ DALITZ PLOT

For discussion, see note on Dalitz plot parameters in the $K^{\pm}$ section of the Particle Listings above. For definitions of $a_v$, $a_t$, $a_u$, and $a_y$, see the earlier version of the same note in the 1982 edition of this *Review* published in Physics Letters **111B** 70 (1982).

$|\text{matrix element}|^2 = 1 + gu + hu^2 + jv + kv^2 + fuv$
where $u = (s_3 - s_0) / m_\pi^2$ and $v = (s_1 - s_2) / m_\pi^2$

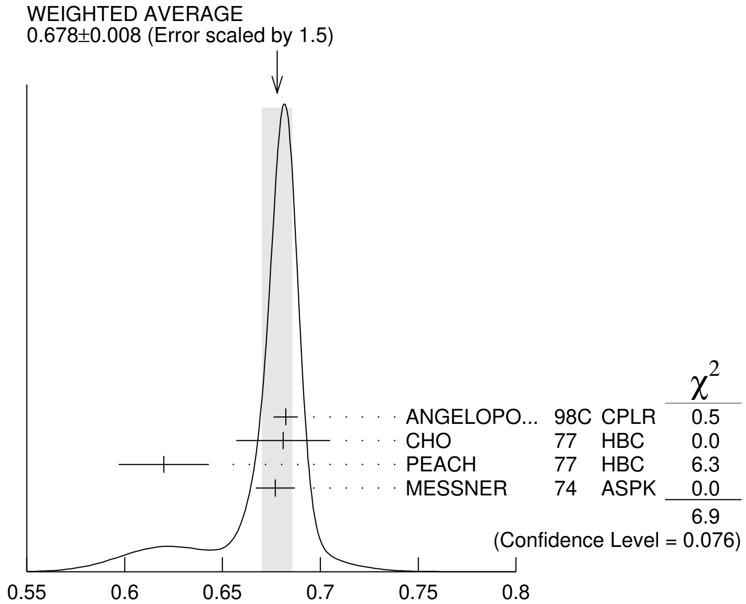
### LINEAR COEFFICIENT $g$ FOR $K^0_L \rightarrow \pi^+\pi^-\pi^0$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.678 ±0.008 OUR AVERAGE** | | Error includes scale factor of 1.5. See the ideogram below. | | | |
| 0.6823±0.0044±0.0044 | 500k | ANGELOPO... | 98C | CPLR | |
| 0.681 ±0.024 | 6499 | CHO | 77 | HBC | |
| 0.620 ±0.023 | 4709 | PEACH | 77 | HBC | |
| 0.677 ±0.010 | 509k | MESSNER | 74 | ASPK | $a_y = -0.917 \pm 0.013$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.69 ±0.07 | 192 | [39] BALDO-... | 75 | HLBC | |
| 0.590 ±0.022 | 56k | [39] BUCHANAN | 75 | SPEC | $a_u = -0.277 \pm 0.010$ |
| 0.619 ±0.027 | 20k | [39,40] BISI | 74 | ASPK | $a_t = -0.282 \pm 0.011$ |
| 0.612 ±0.032 | | [39] ALEXANDER | 73B | HBC | |
| 0.73 ±0.04 | 3200 | [39] BRANDENB... | 73 | HBC | |
| 0.608 ±0.043 | 1486 | [39] KRENZ | 72 | HLBC | $a_t = -0.277 \pm 0.018$ |
| 0.650 ±0.012 | 29k | [39] ALBROW | 70 | ASPK | $a_y = -0.858 \pm 0.015$ |
| 0.593 ±0.022 | 36k | [39,41] BUCHANAN | 70 | SPEC | $a_u = -0.278 \pm 0.010$ |
| 0.664 ±0.056 | 4400 | [39] SMITH | 70 | OSPK | $a_t = -0.306 \pm 0.024$ |
| 0.400 ±0.045 | 2446 | [39] BASILE | 68B | OSPK | $a_t = -0.188 \pm 0.020$ |
| 0.649 ±0.044 | 1350 | [39] HOPKINS | 67 | HBC | $a_t = -0.294 \pm 0.018$ |
| 0.428 ±0.055 | 1198 | [39] NEFKENS | 67 | OSPK | $a_u = -0.204 \pm 0.025$ |

[39] Quadratic dependence required by some experiments. (See sections on "QUADRATIC COEFFICIENT *h*" and "QUADRATIC COEFFICIENT *k*" below.) Correlations prevent us from averaging results of fits not including *g*, *h*, and *k* terms.

[40] BISI 74 value comes from quadratic fit with quad. term consistent with zero. *g* error is thus larger than if linear fit were used.

[41] BUCHANAN 70 result revised by BUCHANAN 75 to include radiative correlations and to use more reliable $K^0_L$ momentum spectrum of second experiment (had same beam).




Linear coeff. *g* for $K^0_L \rightarrow \pi^+\pi^-\pi^0$ matrix element squared

## QUADRATIC COEFFICIENT *h* FOR $K^0_L \rightarrow \pi^+\pi^-\pi^0$

| *VALUE* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **0.076±0.006 OUR AVERAGE** | | | | |
| 0.061±0.004±0.015 | 500k | ANGELOPO... | 98C | CPLR |
| 0.095±0.032 | 6499 | CHO | 77 | HBC |
| 0.048±0.036 | 4709 | PEACH | 77 | HBC |
| 0.079±0.007 | 509k | MESSNER | 74 | ASPK |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| −0.011±0.018 | 29k | [42] ALBROW | 70 | ASPK |
| 0.043±0.052 | 4400 | [42] SMITH | 70 | OSPK |

See notes in section "LINEAR COEFFICIENT *g* FOR $K^0_L \rightarrow \pi^+\pi^-\pi^0$ $|$MATRIX ELEMENT$|^2$" above.

[42] Quadratic coefficients *h* and *k* required by some experiments. (See section on "QUADRATIC COEFFICIENT *k*" below.) Correlations prevent us from averaging results of fits not including *g*, *h*, and *k* terms.

## QUADRATIC COEFFICIENT $k$ FOR $K^0_L \to \pi^+ \pi^- \pi^0$

| VALUE | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **0.0099±0.0015 OUR AVERAGE** | | | | |
| 0.0104±0.0017±0.0024 | 500k | ANGELOPO... | 98C | CPLR |
| 0.024 ±0.010 | 6499 | CHO | 77 | HBC |
| −0.008 ±0.012 | 4709 | PEACH | 77 | HBC |
| 0.0097±0.0018 | 509k | MESSNER | 74 | ASPK |

## LINEAR COEFFICIENT $j$ FOR $K^0_L \to \pi^+ \pi^- \pi^0$ ($CP$-VIOLATING TERM)

Listed in $CP$-violation section below.

## QUADRATIC COEFFICIENT $f$ FOR $K^0_L \to \pi^+ \pi^- \pi^0$ ($CP$-VIOLATING TERM)

Listed in $CP$-violation section below.

## QUADRATIC COEFFICIENT $h$ FOR $K^0_L \to \pi^0 \pi^0 \pi^0$

| VALUE (units $10^{-3}$) | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **−3.3±1.1±0.7** | 5M | [43] SOMALWAR | 92 | E731 |

[43] SOMALWAR 92 chose $m_{\pi^+}$ as normalization to make it compatible with the Particle Data Group $K^0_L \to \pi^+ \pi^- \pi^0$ definitions.

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# $K^0_L$ FORM FACTORS

For discussion, see note on form factors in the $K^\pm$ section of the Particle Listings above.

In the form factor comments, the following symbols are used.

$f_+$ and $f_-$ are form factors for the vector matrix element.

$f_S$ and $f_T$ refer to the scalar and tensor term.

$f_0 = f_+ + f_- t/(m^2_K - m^2_\pi)$.

$\lambda_+$, $\lambda_-$, and $\lambda_0$ are the linear expansion coefficients of $f_+$, $f_-$, and $f_0$.

$\lambda_+$ refers to the $K^0_{\mu3}$ value except in the $K^0_{e3}$ sections.

$d\xi(0)/d\lambda_+$ is the correlation between $\xi(0)$ and $\lambda_+$ in $K^0_{\mu3}$.

$d\lambda_0/d\lambda_+$ is the correlation between $\lambda_0$ and $\lambda_+$ in $K^0_{\mu3}$.

$t$ = momentum transfer to the $\pi$ in units of $m^2_\pi$.

DP = Dalitz plot analysis.

PI = $\pi$ spectrum analysis.

MU = $\mu$ spectrum analysis.

POL= $\mu$ polarization analysis.

BR = $K^0_{\mu3}/K^0_{e3}$ branching ratio analysis.

E = positron or electron spectrum analysis.

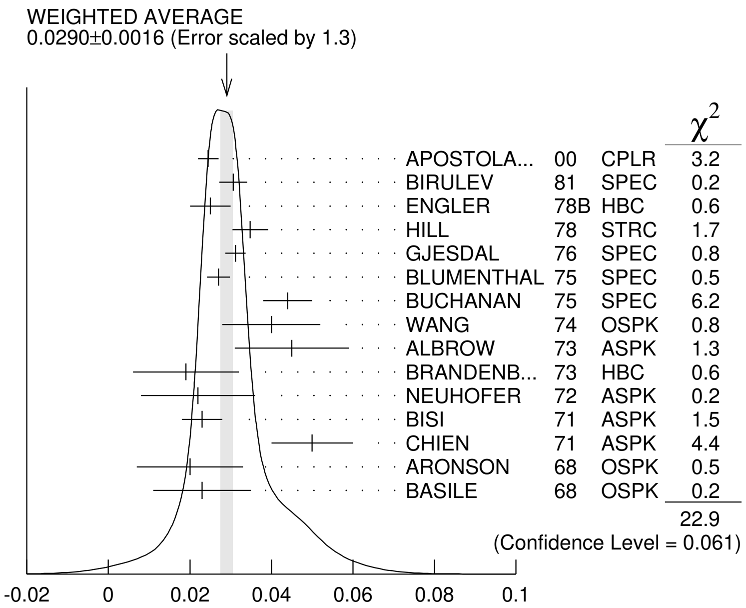
RC = radiative corrections.

## $\lambda_+$ (LINEAR ENERGY DEPENDENCE OF $f_+$ IN $K^0_{e3}$ DECAY)

For radiative correction of $K^0_{e3}$ DP, see GINSBERG 67 and BECHERRAWY 70.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.0290±0.0016 OUR AVERAGE** | | Error includes scale factor of 1.3. See the ideogram below. | | | |
| 0.0245±0.0012±0.0022 | 366k | APOSTOLA... | 00 | CPLR | DP |
| 0.0306±0.0034 | 74k | BIRULEV | 81 | SPEC | DP |
| 0.025 ±0.005 | 12k | [44] ENGLER | 78B | HBC | DP |
| 0.0348±0.0044 | 18k | HILL | 78 | STRC | DP |
| 0.0312±0.0025 | 500k | GJESDAL | 76 | SPEC | DP |
| 0.0270±0.0028 | 25k | BLUMENTHAL | 75 | SPEC | DP |
| 0.044 ±0.006 | 24k | BUCHANAN | 75 | SPEC | DP |
| 0.040 ±0.012 | 2171 | WANG | 74 | OSPK | DP |
| 0.045 ±0.014 | 5600 | ALBROW | 73 | ASPK | DP |
| 0.019 ±0.013 | 1871 | BRANDENB... | 73 | HBC | PI transv. |
| 0.022 ±0.014 | 1910 | NEUHOFER | 72 | ASPK | PI |
| 0.023 ±0.005 | 42k | BISI | 71 | ASPK | DP |
| 0.05 ±0.01 | 16k | CHIEN | 71 | ASPK | DP, no RC |
| 0.02 ±0.013 | 1000 | ARONSON | 68 | OSPK | PI |
| +0.023 ±0.012 | 4800 | BASILE | 68 | OSPK | DP, no RC |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.029 ±0.005 | 19k | [44] CHO | 80 | HBC | DP |

[44] ENGLER 78B uses an unique $K_{e3}$ subset of CHO 80 events and is less subject to systematic effects.




$\lambda_+$ (Linear energy dependence of $f_+$, $K_{e3}$ decay)

### $\xi_a = f_-/f_+$ (determined from $K^0_{\mu 3}$ spectra)

The parameter $\xi$ is redundant with $\lambda_0$ below and is not put into the Meson Summary Table.

| *VALUE* | *$d\xi(0)/d\lambda_+$* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|---|
| **$-0.11\pm0.09$ OUR EVALUATION** | | | | | | Error includes scale factor of 2.3. Correlation is $d\xi(0)/d\lambda_+=-14$. From a fit discussed in note on $K_{\ell 3}$ form factors in 1982 edition, PL **111B** (April 1982). |
| $-0.10\pm0.09$ | $-12$ | 150k | [45] BIRULEV | 81 | SPEC | DP |
| $+0.26\pm0.16$ | $-13$ | 14k | [46] CHO | 80 | HBC | DP |
| $+0.13\pm0.23$ | $-20$ | 16k | [46] HILL | 79 | STRC | DP |
| $-0.25\pm0.22$ | $-5.9$ | 32k | [47] BUCHANAN | 75 | SPEC | DP |
| $-0.11\pm0.07$ | $-17$ | 1.6M | [48] DONALDSON | 74B | SPEC | DP |
| $-1.00\pm0.45$ | $-20$ | 1385 | [49] PEACH | 73 | HLBC | DP |
| $-1.5\ \pm0.7$ | $-28$ | 9086 | [50] ALBROW | 72 | ASPK | DP |
| $+1.2\ \pm0.8$ | $-18$ | 1341 | [51] CARPENTER | 66 | OSPK | DP |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| $+0.50\pm0.61$ | unknown | 16k | [52] DALLY | 72 | ASPK | DP |
| $-3.9\ \pm0.4$ | | 3140 | [53] BASILE | 70 | OSPK | DP, indep of $\lambda_+$ |
| $-0.68^{+0.12}_{-0.20}$ | $-26$ | 16k | [52] CHIEN | 70 | ASPK | DP |

[45] BIRULEV 81 error, $d\xi(0)/d\lambda_+$ calculated by us from $\lambda_0$, $\lambda_+$. $d\lambda_0/d\lambda_+ = 0$ used.

[46] HILL 79 and CHO 80 calculated by us from $\lambda_0$, $\lambda_+$, and $d\lambda_0/d\lambda_+$.

[47] BUCHANAN 75 is calculated by us from $\lambda_0$, $\lambda_+$ and $d\lambda_0/d\lambda_+$ because their appendix A value $-0.20 \pm 22$ assumes $\xi(t)$ constant, i.e. $\lambda_- = \lambda_+$.

[48] DONALDSON 74B gives $\xi = -0.11 \pm 0.02$ not including systematics. Above error and $d\xi(0)/d\lambda_+$ were calculated by us from $\lambda_0$ and $\lambda_+$ errors (which include systematics) and $d\lambda_0/d\lambda_+$.

[49] PEACH 73 gives $\xi(0) = -0.95 \pm 0.45$ for $\lambda_+ = \lambda_- = 0.025$ . The above value is for $\lambda_- = 0$. K.Peach, private communication (1974).

[50] ALBROW 72 fit has $\lambda_-$ free, gets $\lambda_- = -0.030 \pm 0.060$ or $\Lambda = +0.15^{+0.17}_{-0.11}$.

[51] CARPENTER 66 $\xi(0)$ is for $\lambda_+ = 0$. $d\xi(0)/d\lambda_+$ is from figure 9.

[52] CHIEN 70 errors are statistical only. $d\xi(0)/d\lambda_+$ from figure 4. DALLY 72 is a reanalysis of CHIEN 70. The DALLY 72 result is not compatible with assumption $\lambda_- = 0$ so not included in our fit. The nonzero $\lambda_-$ value and the relatively large $\lambda_+$ value found by DALLY 72 come mainly from a single low $t$ bin (figures 1,2). The $(f_+,\xi)$ correlation was ignored. We estimate from figure 2 that fixing $\lambda_- = 0$ would give $\xi(0) = -1.4 \pm 0.3$ and would add 10 to $\chi^2$. $d\xi(0)/d\lambda_+$ is not given.

[53] BASILE 70 is incompatible with all other results. Authors suggest that efficiency estimates might be responsible.

## $\xi_b = f_-/f_+$ (determined from $K^0_{\mu 3}/K^0_{e3}$)

The $K^0_{\mu 3}/K^0_{e3}$ branching ratio fixes a relationship between $\xi(0)$ and $\lambda_+$. We quote the author's $\xi(0)$ and associated $\lambda_+$ but do not average because the $\lambda_+$ values differ. The fit result and scale factor given below are not obtained from these $\xi_b$ values. Instead they are obtained directly from the authors $K^0_{\mu 3}/K^0_{e3}$ branching ratio via the fitted $K^0_{\mu 3}/K^0_{e3}$ ratio $(\Gamma(\pi^{\pm}\mu^{\mp}\nu_{\mu})/\Gamma(\pi^{\pm}e^{\mp}\nu_e))$. The parameter $\xi$ is redundant with $\lambda_0$ below and is not put into the Meson Summary Table.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **−0.11±0.09 OUR EVALUATION** | | | | | Error includes scale factor of 2.3. Correlation is $d\xi(0)/d\lambda_+ = -14$. From a fit discussed in note on $K_{\ell 3}$ form factors in 1982 edition, PL **111B** (April 1982). |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.5 ±0.4 | 6700 | BRANDENB... | 73 | HBC | BR, $\lambda_+$=0.019 ± 0.013 |
| −0.08±0.25 | 1309 | [54] EVANS | 73 | HLBC | BR, $\lambda_+$=0.02 |
| −0.5 ±0.5 | 3548 | BASILE | 70 | OSPK | BR, $\lambda_+$=0.02 |
| +0.45±0.28 | 569 | BEILLIERE | 69 | HLBC | BR, $\lambda_+$=0 |
| −0.22±0.30 | 1309 | [54] EVANS | 69 | HLBC | |
| $+0.2\ ^{+0.8}_{-1.2}$ | | KULYUKINA | 68 | CC | BR, $\lambda_+$=0 |
| +1.1 ±1.1 | 389 | ADAIR | 64 | HBC | BR, $\lambda_+$=0 |
| $+0.66\ ^{+0.9}_{-1.3}$ | | LUERS | 64 | HBC | BR, $\lambda_+$=0 |

[54] EVANS 73 replaces EVANS 69.

## $\xi_c = f_-/f_+$ (determined from $\mu$ polarization in $K^0_{\mu 3}$)

The $\mu$ polarization is a measure of $\xi(t)$. No assumptions on $\lambda_{+-}$ necessary, $t$ (weighted by sensitivity to $\xi(t)$) should be specified. In $\lambda_+$, $\xi(0)$ parametrization this is $\xi(0)$ for $\lambda_+ = 0$. $d\xi/d\lambda = \xi t$. For radiative correction to $\mu$ polarization in $K^0_{\mu 3}$, see GINSBERG 73. The parameter $\xi$ is redundant with $\lambda_0$ below and is not put into the Meson Summary Table.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **−0.11 ±0.09 OUR EVALUATION** | | | | | Error includes scale factor of 2.3. Correlation is $d\xi(0)/d\lambda_+ = -14$. From a fit discussed in note on $K_{\ell 3}$ form factors in 1982 edition, PL **111B** (April 1982). |
| +0.178±0.105 | 207k | [55] CLARK | 77 | SPEC | POL, $d\xi(0)/d\lambda_+ = +0.68$ |
| −0.385±0.105 | 2.2M | [56] SANDWEISS | 73 | CNTR | POL, $d\xi(0)/d\lambda_+ = -6$ |
| $-1.81\ ^{+0.50}_{-0.26}$ | | [57] LONGO | 69 | CNTR | POL, $t$=3.3 |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| −1.6 ±0.5 | 638 | [58] ABRAMS | 68B | OSPK | Polarization |
| −1.2 ±0.5 | 2608 | [58] AUERBACH | 66B | OSPK | Polarization |

[55] CLARK 77 $t = +3.80$, $d\xi(0)/d\lambda_+ = \xi(t)t = 0.178\times3.80 = +0.68$.

[56] SANDWEISS 73 is for $\lambda_+ = 0$ and $t = 0$.

[57] LONGO 69 $t = 3.3$ calculated from $d\xi(0)/d\lambda_+ = -6.0$ (table 1) divided by $\xi = -1.81$.

[58] $t$ value not given.

## Im($\xi$) in $K^0_{\mu 3}$ DECAY (from transverse $\mu$ pol.)

Test of $T$ reversal invariance.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **−0.007±0.026 OUR AVERAGE** | | | | | |
| 0.009±0.030 | 12M | MORSE | 80 | CNTR | Polarization |
| 0.35 ±0.30 | 207k | [59] CLARK | 77 | SPEC | POL, $t$=0 |
| −0.085±0.064 | 2.2M | [60] SANDWEISS | 73 | CNTR | POL, $t$=0 |
| −0.02 ±0.08 | | LONGO | 69 | CNTR | POL, $t$=3.3 |
| −0.2 ±0.6 | | ABRAMS | 68B | OSPK | Polarization |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.012±0.026 | | SCHMIDT | 79 | CNTR | Repl. by MORSE 80 |

[59] CLARK 77 value has additional $\xi(0)$ dependence $+0.21\text{Re}[\xi(0)]$.

[60] SANDWEISS 73 value corrected from value quoted in their paper due to new value of Re($\xi$). See footnote 4 of SCHMIDT 79.

## $\lambda_+$ (LINEAR ENERGY DEPENDENCE OF $f_+$ IN $K^0_{\mu 3}$ DECAY)

See also the corresponding entries and notes in section "$\xi_A = f_-/f_+$" above and section "$\lambda_0$ (LINEAR ENERGY DEPENDENCE OF $f_0$ IN $K^0_{\mu 3}$ DECAY)" below. For radiative correction of $K^0_{\mu 3}$ Dalitz plot see GINSBERG 70 and BECHERRAWY 70.

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.034 ±0.005 OUR EVALUATION** | | From a fit discussed in note on $K_{\ell 3}$ form factors in 1982 edition, PL **111B** (April 1982). | | | |
| 0.0427±0.0044 | 150k | BIRULEV | 81 | SPEC | DP |
| 0.028 ±0.010 | 14k | CHO | 80 | HBC | DP |
| 0.028 ±0.011 | 16k | HILL | 79 | STRC | DP |
| 0.046 ±0.030 | 32k | BUCHANAN | 75 | SPEC | DP |
| 0.030 ±0.003 | 1.6M | DONALDSON | 74B | SPEC | DP |
| 0.085 ±0.015 | 9086 | ALBROW | 72 | ASPK | DP |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 0.0337±0.0033 | 129k | DZHORD... | 77 | SPEC | Repl. by BIRULEV 81 |
| 0.046 ±0.008 | 82k | ALBRECHT | 74 | WIRE | Repl. by BIRULEV 81 |
| 0.11 ±0.04 | 16k | DALLY | 72 | ASPK | DP |
| 0.07 ±0.02 | 16k | CHIEN | 70 | ASPK | Repl. by DALLY 72 |

## $\lambda_0$ (LINEAR ENERGY DEPENDENCE OF $f_0$ IN $K^0_{\mu 3}$ DECAY)

Wherever possible, we have converted the above values of $\xi(0)$ into values of $\lambda_0$ using the associated $\lambda_+^{\mu}$ and $d\xi(0)/d\lambda_+$.

| VALUE | $d\lambda_0/d\lambda_+$ | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **0.025 ±0.006** | **OUR EVALUATION** | | Error includes scale factor of 2.3. Correlation is $d\lambda_0/d\lambda_+ = -0.16$. From a fit discussed in note on $K_{\ell 3}$ form factors in 1982 edition, PL **111B** (April 1982). | | | |
| 0.0341±0.0067 | unknown | 150k | [61] BIRULEV | 81 | SPEC | DP |
| +0.050 ±0.008 | −0.11 | 14k | CHO | 80 | HBC | DP |
| +0.039 ±0.010 | −0.67 | 16k | HILL | 79 | STRC | DP |
| +0.047 ±0.009 | 1.06 | 207k | [62] CLARK | 77 | SPEC | POL |
| +0.025 ±0.019 | +0.5 | 32k | [63] BUCHANAN | 75 | SPEC | DP |
| +0.019 ±0.004 | −0.47 | 1.6M | [64] DONALDSON | 74B | SPEC | DP |
| −0.060 ±0.038 | −0.71 | 1385 | [65] PEACH | 73 | HLBC | DP |
| −0.018 ±0.009 | +0.49 | 2.2M | [62] SANDWEISS | 73 | CNTR | POL |
| −0.043 ±0.052 | −1.39 | 9086 | [66] ALBROW | 72 | ASPK | DP |
| $-0.140\ ^{+0.043}_{-0.022}$ | +0.49 | | [62] LONGO | 69 | CNTR | POL |
| +0.08 ±0.07 | −0.54 | 1371 | [62] CARPENTER | 66 | OSPK | DP |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| 0.041 ±0.008 | | 14k | [67] CHO | 80 | HBC | BR, $\lambda_+$=0.028 |
| +0.0485±0.0076 | | 47k | DZHORD... | 77 | SPEC | In BIRULEV 81 |
| +0.024 ±0.011 | | 82k | ALBRECHT | 74 | WIRE | In BIRULEV 81 |
| +0.06 ±0.03 | | 6700 | [68] BRANDENB... | 73 | HBC | BR, $\lambda_+$=0.019 ± 0.013 |
| −0.067 ±0.227 | unknown | 16k | [69] DALLY | 72 | ASPK | DP |
| −0.333 ±0.034 | +1. | 3140 | [70] BASILE | 70 | OSPK | DP |

[61] BIRULEV 81 gives $d\lambda_0/d\lambda_+ = -1.5$, giving an unreasonably narrow error ellipse which dominates all other results. We use $d\lambda_0/d\lambda_+ = 0$.

[62] $\lambda_0$ value is for $\lambda_+ = 0.03$ calculated by us from $\xi(0)$ and $d\xi(0)/d\lambda_+$.

[63] BUCHANAN 75 value is from their appendix A and uses only $K_{\mu 3}$ data. $d\lambda_0/d\lambda_+$ was obtained by private communication, C.Buchanan, 1976.

[64] DONALDSON 74B $d\lambda_0/d\lambda_+$ obtained from figure 18.

[65] PEACH 73 assumes $\lambda_+ = 0.025$. Calculated by us from $\xi(0)$ and $d\xi(0)/d\lambda_+$.

[66] ALBROW 72 $\lambda_0$ is calculated by us from $\xi_A$, $\lambda_+$ and $d\xi(0)/d\lambda_+$. They give $\lambda_0 = -0.043 \pm 0.039$ for $\lambda_- = 0$. We use our larger calculated error.

[67] CHO 80 BR result not independent of their Dalitz plot result.

[68] Fit for $\lambda_0$ does not include this value but instead includes the $K_{\mu 3}/K_{e3}$ result from this experiment.

[69] DALLY 72 gives $f_0 = 1.20 \pm 0.35$, $\lambda_0 = -0.080 \pm 0.272$, $\lambda_0{}' = -0.006 \pm 0.045$, but with a different definition of $\lambda_0$. Our quoted $\lambda_0$ is his $\lambda_0/f_0$. We cannot calculate true $\lambda_0$ error without his ($\lambda_0$,$f_0$) correlations. See also note on DALLY 72 in section $\xi_A$.

[70] BASILE 70 $\lambda_0$ is for $\lambda_+ = 0$. Calculated by us from $\xi_A$ with $d\xi(0)/d\lambda_+ = 0$. BASILE 70 is incompatible with all other results. Authors suggest that efficiency estimates might be responsible.

### $\left|f_S/f_+\right|$ FOR $K^0_{e3}$ DECAY

Ratio of scalar to $f_+$ couplings.

| VALUE | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **<0.04** | 68 | 25k | BLUMENTHAL | 75 | SPEC | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| <0.095 | 95 | 18k | HILL | 78 | STRC | |
| <0.07 | 68 | 48k | BIRULEV | 76 | SPEC | See also BIRULEV 81 |
| <0.19 | 95 | 5600 | ALBROW | 73 | ASPK | |
| <0.15 | 68 | | KULYUKINA | 67 | CC | |

### $\left|f_T/f_+\right|$ FOR $K^0_{e3}$ DECAY

Ratio of tensor to $f_+$ couplings.

| VALUE | CL% | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **<0.23** | 68 | 25k | BLUMENTHAL | 75 | SPEC | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| <0.40 | 95 | 18k | HILL | 78 | STRC | |
| <0.34 | 68 | 48k | BIRULEV | 76 | SPEC | See also BIRULEV 81 |
| <1.0 | 95 | 5600 | ALBROW | 73 | ASPK | |
| <1.0 | 68 | | KULYUKINA | 67 | CC | |

### $\left|f_T/f_+\right|$ FOR $K^0_{\mu 3}$ DECAY

Ratio of tensor to $f_+$ couplings.

| VALUE | DOCUMENT ID | | TECN |
|---|---|---|---|
| **0.12±0.12** | BIRULEV | 81 | SPEC |

### $\alpha_{K^*}$ DECAY FORM FACTOR FOR $K_L \to e^+ e^- \gamma$

$\alpha_{K^*}$ is the constant in the model of BERGSTROM 83 which measures the relative strength of the vector-vector transition $K_L \to K^* \gamma$ with $K^* \to \rho, \omega, \phi \to \gamma^*$ and the pseudoscalar-pseudoscalar transition $K_L \to \pi, \eta, \eta' \to \gamma\gamma^*$.

| VALUE | EVTS | DOCUMENT ID | | TECN |
|---|---|---|---|---|
| **−0.33 ±0.05 OUR AVERAGE** | | | | |
| −0.36 ±0.06 ±0.02 | 6864 | FANTI | 99B | NA48 |
| −0.28 ±0.13 | | BARR | 90B | NA31 |
| $-0.280^{+0.099}_{-0.090}$ | | OHL | 90B | B845 |

### DECAY FORM FACTORS FOR $K^0_L \to \pi^\pm \pi^0 e^\mp \nu_e$

Given in MAKOFF 93.

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## *CP*-VIOLATION PARAMETERS IN $K^0_L$ DECAYS

### ——— CHARGE ASYMMETRY IN $K^0_{\ell 3}$ DECAYS ———

Such asymmetry violates *CP*. It is related to Re($\epsilon$).

### $\delta$ = weighted average of $\delta(\mu)$ and $\delta(e)$

| VALUE (%) | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **0.327±0.012 OUR AVERAGE** | Includes data from the 2 datablocks that follow this one. | | | | |
| 0.333±0.050 | 33M | WILLIAMS | 73 | ASPK | $K_{\mu 3} + K_{e3}$ |

### $\delta(\mu) = [\Gamma(\pi^- \mu^+ \nu_\mu) - \Gamma(\pi^+ \mu^- \overline{\nu}_\mu)]/\text{SUM}$

Only the combined value below is put into the Meson Summary Table.

| *VALUE* (%) | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| The data in this block is included in the average printed for a previous datablock. | | | | |
| **0.304±0.025 OUR AVERAGE** | | | | |
| 0.313±0.029 | 15M | GEWENIGER | 74 | ASPK |
| 0.278±0.051 | 7.7M | PICCIONI | 72 | ASPK |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.60 ±0.14 | 4.1M | MCCARTHY | 73 | CNTR |
| 0.57 ±0.17 | 1M | [71] PACIOTTI | 69 | OSPK |
| 0.403±0.134 | 1M | [71] DORFAN | 67 | OSPK |

[71] PACIOTTI 69 is a reanalysis of DORFAN 67 and is corrected for $\mu^+ \mu^-$ range difference in MCCARTHY 72.

### $\delta(e) = [\Gamma(\pi^- e^+ \nu_e) - \Gamma(\pi^+ e^- \overline{\nu}_e)]/\text{SUM}$

Only the combined value below is put into the Meson Summary Table.

| *VALUE* (%) | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| The data in this block is included in the average printed for a previous datablock. | | | | |
| **0.333±0.014 OUR AVERAGE** | | | | |
| 0.341±0.018 | 34M | GEWENIGER | 74 | ASPK |
| 0.318±0.038 | 40M | FITCH | 73 | ASPK |
| 0.346±0.033 | 10M | MARX | 70 | CNTR |
| 0.246±0.059 | 10M | [72] SAAL | 69 | CNTR |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.36 ±0.18 | 600k | ASHFORD | 72 | ASPK |
| 0.224±0.036 | 10M | [72] BENNETT | 67 | CNTR |

[72] SAAL 69 is a reanalysis of BENNETT 67.

## PARAMETERS FOR $K^0_L \rightarrow 2\pi$ DECAY

$\eta_{+-} = \mathrm{A}(K^0_L \rightarrow \pi^+\pi^-) \,/\, \mathrm{A}(K^0_S \rightarrow \pi^+\pi^-)$
$\eta_{00} = \mathrm{A}(K^0_L \rightarrow \pi^0\pi^0) \,/\, \mathrm{A}(K^0_S \rightarrow \pi^0\pi^0)$

The fitted values of $|\eta_{+-}|$ and $|\eta_{00}|$ given below are the results of a fit to $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$, and $\mathrm{Re}(\epsilon'/\epsilon)$. Independent information on $|\eta_{+-}|$ and $|\eta_{00}|$ can be obtained from the fitted values of the $K^0_L \rightarrow \pi\pi$ and $K^0_S \rightarrow \pi\pi$ branching ratios and the $K^0_L$ and $K^0_S$ lifetimes. This information is included as data in the $|\eta_{+-}|$ and $|\eta_{00}|$ sections with a Document ID "BRFIT." See the note "Fits for $K^0_L$ *CP*-Violation Parameters" above for details.

### $|\eta_{00}| = |\mathrm{A}(K^0_L \rightarrow 2\pi^0) \,/\, \mathrm{A}(K^0_S \rightarrow 2\pi^0)|$

| *VALUE* (units $10^{-3}$) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **2.262±0.017 OUR FIT** | | | | |
| **2.23 ±0.11 OUR AVERAGE** | | | | |
| 2.12 ±0.16 | [73] BRFIT | 00 | | |
| 2.47 ±0.31 ±0.24 | ANGELOPO... | 98 | CPLR | |
| 2.33 ±0.18 | CHRISTENS... | 79 | ASPK | |

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

| | | | | |
|---|---|---|---|---|
| 2.49 ±0.40 | [74] ADLER | 96B | CPLR | Sup. by ANGELOPOULOS 98 |
| 2.71 ±0.37 | [75] WOLFF | 71 | OSPK | Cu reg., 4$\gamma$'s |
| 2.95 ±0.63 | [75] CHOLLET | 70 | OSPK | Cu reg., 4$\gamma$'s |

[73] This BRFIT value is computed from fitted values of the $K^0_L$ and $K^0_S$ lifetimes and branching fractions to $\pi\pi$. See the discussion in the note "Fits for $K^0_L$ *CP*-Violation Parameters."

[74] Error is statistical only.

[75] CHOLLET 70 gives $|\eta_{00}|$ = (1.23 ± 0.24)×(regeneration amplitude, 2 GeV/$c$ Cu)/10000mb. WOLFF 71 gives $|\eta_{00}|$ = (1.13 ± 0.12)×(regeneration amplitude, 2 GeV/$c$ Cu)/10000mb. We compute both $|\eta_{00}|$ values for (regeneration amplitude, 2 GeV/$c$ Cu) = 24 ± 2mb. This regeneration amplitude results from averaging over FAISSNER 69, extrapolated using optical-model calculations of Bohm et al., Physics Letters **27B** 594 (1968) and the data of BALATS 71. (From H. Faissner, private communication).

## $|\eta_{+-}| = |A(K^0_L \to \pi^+\pi^-) / A(K^0_S \to \pi^+\pi^-)|$

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **2.276±0.017 OUR FIT** | | | | | |
| **2.277±0.017 OUR AVERAGE** | | | | | |
| 2.272±0.024 | | [76] BRFIT | 00 | | |
| 2.264±0.023±0.027 | 70M | [77] APOSTOLA... | 99C | CPLR | $K^0$-$\overline{K}^0$ asymmetry |
| 2.30 ±0.035 | | GEWENIGER | 74B | ASPK | |

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

| | | | | | |
|---|---|---|---|---|---|
| 2.310±0.043±0.031 | | [78] ADLER | 95B | CPLR | $K^0$-$\overline{K}^0$ asymmetry |
| 2.32 ±0.14 ±0.03 | $10^5$ | ADLER | 92B | CPLR | $K^0$-$\overline{K}^0$ asymmetry |

[76] This BRFIT value is computed from fitted values of the $K^0_L$ and $K^0_S$ lifetimes and branching fractions to $\pi\pi$. See the discussion in the note "Fits for $K^0_L$ *CP*-Violation Parameters."

[77] APOSTOLAKIS 99C report (2.264 ± 0.023 ± 0.026 + 9.1[$\tau_S$ − 0.8934]) × $10^{-3}$. We evaluate for our 1998 best value $\tau_S$= (0.8934 ± 0.0008) × $10^{-10}$ s.

[78] ADLER 95B report (2.312 ± 0.043 ± 0.030 − 1[$\Delta m$− 0.5274] + 9.1[$\tau_S$ − 0.8926]) × $10^{-3}$. We evaluate for our 1996 best values $\Delta m$ = (0.5304 ± 0.0014) × $10^{-10}$ $\hbar s^{-1}$ and $\tau_S$ = (0.8927 ± 0.0009) × $10^{-10}$ s. Superseded by APOSTOLAKIS 99C.

## $|\eta_{00}/\eta_{+-}|$

| *VALUE* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **0.9936±0.0014 OUR FIT** Error includes scale factor of 1.6. | | | | |
| **0.9930±0.0020 OUR AVERAGE** | | | | |
| 0.9931±0.0020 | | [79,80] BARR | 93D | NA31 |
| 0.9904±0.0084±0.0036 | | [81] WOODS | 88 | E731 |

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

| | | | | |
|---|---|---|---|---|
| 0.9939±0.0013±0.0015 | 1M | [79] BARR | 93D | NA31 |
| 0.9899±0.0020±0.0025 | | [79] BURKHARDT | 88 | NA31 |

[79] This is the square root of the ratio $R$ given by BURKHARDT 88 and BARR 93D.

[80] This is the combined results from BARR 93D and BURKHARDT 88, taking into account a common systematic uncertainty of 0.0014.

[81] We calculate $|\eta_{00}/\eta_{+-}| = 1-3(\epsilon'/\epsilon)$ from WOODS 88 ($\epsilon'/\epsilon$) value.

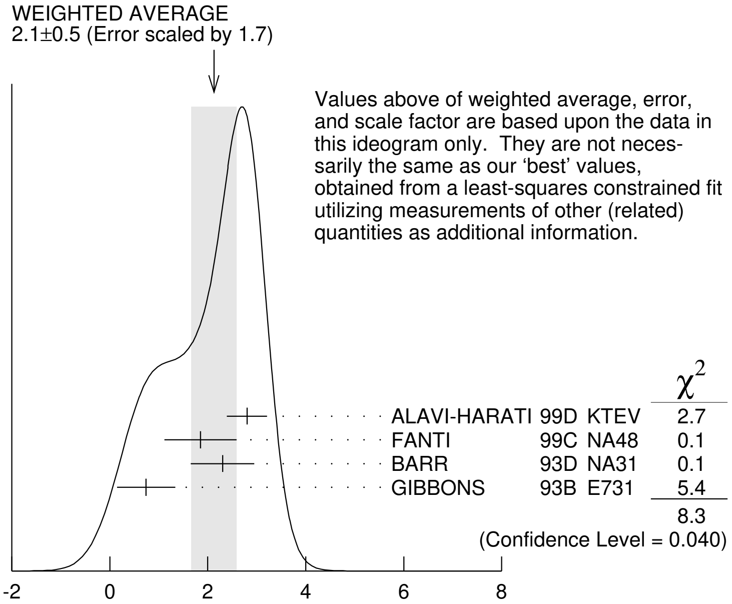
## $\epsilon'/\epsilon \approx \mathrm{Re}(\epsilon'/\epsilon) = (1-|\eta_{00}/\eta_{+-}|)/3$

| VALUE (units $10^{-3}$) | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|
| **2.1 ±0.5 OUR FIT** Error includes scale factor of 1.6. | | | | |
| **2.1 ±0.5 OUR AVERAGE** Error includes scale factor of 1.7. See the ideogram below. | | | | |
| 2.80±0.30±0.28 | ALAVI-HARATI | 99D | KTEV | |
| 1.85±0.45±0.58 | FANTI | 99C | NA48 | |
| 2.3 ±0.65 | [82,83] BARR | 93D | NA31 | |
| 0.74±0.52±0.29 | GIBBONS | 93B | E731 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 2.0 ±0.7 | [84] BARR | 93D | NA31 | |
| −0.4 ±1.4 ±0.6 | PATTERSON | 90 | E731 | in GIBBONS 93B |
| 3.3 ±1.1 | [84] BURKHARDT | 88 | NA31 | |
| 3.2 ±2.8 ±1.2 | [82] WOODS | 88 | E731 | |

[82] These values are derived from $|\eta_{00}/\eta_{+-}|$ measurements. They enter the average in this section but enter the fit via the $|\eta_{00}/\eta_{+-}|$ section only.

[83] This is the combined results from BARR 93D and BURKHARDT 88, taking into account their common systematic uncertainty.

[84] These values are derived from $|\eta_{00}/\eta_{+-}|$ measurements.




$\epsilon'/\epsilon \approx \mathrm{Re}(\epsilon'/\epsilon) = (1-|\eta_{00}/\eta_{+-}|)/3$

## $\phi_{+-}$, PHASE of $\eta_{+-}$

The dependence of the phase on $\Delta m$ and $\tau_S$ is given for each experiment in the comments below, where $\Delta m$ is the $K_L^0 - K_S^0$ mass difference in units $10^{10}$ $\hbar s^{-1}$ and $\tau_s$ is the $K_S$ mean life in units $10^{-10}$ s. For the "used" data, we have evaluated these mass dependences using our 2000 values, $\Delta m = 0.5300 \pm 0.0012$, $\tau_s = 0.8935 \pm 0.0008$ to obtain the values quoted below. We also give the regeneration phase $\phi_f$ in the comments below.

OUR FIT is described in the note on "Fits for $K_L^0$ *CP*-Violation Parameters" in the $K_L^0$ Particle Listings.

| *VALUE* (°) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **43.3 ±0.5 OUR FIT** | | | | | |
| 43.2 ±0.7 | 70M | [85] APOSTOLA... | 99C | CPLR | $K^0$-$\overline{K}^0$ asymmetry |
| 43.6 ±0.8 | | [86,87] SCHWINGEN... | 95 | E773 | $CH_{1.1}$ regenerator |
| 42.4 ±1.0 | | [87,88] GIBBONS | 93 | E731 | $B_4C$ regenerator |
| 44.4 ±1.7 | | [89] CAROSI | 90 | NA31 | Vacuum regen. |
| 44.4 ±2.8 | | [90] CARITHERS | 75 | SPEC | C regenerator |
| 43.8 ±1.2 | | [91] GEWENIGER | 74B | ASPK | Vacuum regen. |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 43.82±0.63 | | [92,93] ADLER | 96C | RVUE | |
| 43.6 ±1.2 | | [94] ADLER | 95B | CPLR | $K^0$-$\overline{K}^0$ asymmetry |
| 42.3 ±4.4 ±1.4 | $10^5$ | [95] ADLER | 92B | CPLR | $K^0$-$\overline{K}^0$ asymmetry |
| 47.7 ±2.0 ±0.9 | | [87,96] KARLSSON | 90 | E731 | |

[85] APOSTOLAKIS 99C report $(43.19 \pm 0.53 \pm 0.28)^\circ + 300\ [\Delta m - 0.5301]^\circ$.

[86] SCHWINGENHEUER 95 reports $\phi_{+-} = 43.53 \pm 0.76 + 173[\Delta m - 0.5282] - 275[\tau_s - 0.8926]$.

[87] These experiments measure $\phi_{+-}-\phi_f$ and calculate the regeneration phase from the power law momentum dependence of the regeneration amplitude using analyticity and dispersion relations. SCHWINGENHEUER 95 [GIBBONS 93] includes a systematic error of 0.35° [0.5°] for uncertainties in their modeling of the regeneration amplitude. See the discussion of these systematic errors, including criticism that they could be underestimated, in the note on "*C* violation in $K_L^0$ decay."

[88] GIBBONS 93 measures $\phi_{+}-\phi_f$ and calculates the regeneration phase $\phi_f$ from the power law momentum dependence of the regeneration amplitude using analyticity. An error of 0.6° is included for possible uncertainties in the regeneration phase. They find $\phi_{+-} = 42.21 \pm 0.9 + 189\ [\Delta m - 0.5257] - 460\ [\tau_s - 0.8922]^\circ$, as given in SCHWINGENHEUER 95, footnote 8. GIBBONS 93 reports $\phi_{+-}$ $(42.2 \pm 1.4)^\circ$

[89] CAROSI 90 $\phi_{+-} = 46.9 \pm 1.4 \pm 0.7 + 579\ [\Delta m - 0.5351] + 303\ [\tau_s - 0.8922]^\circ$.

[90] CARITHERS 75 $\phi_{+-} = (45.5 \pm 2.8) + 224[\Delta m - 0.5348]^\circ$. $\phi_f = -40.9 \pm 2.6^\circ$.

[91] GEWENIGER 74B $\phi_{+-} = (49.4 \pm 1.0) + 565[\Delta m - 0.540]^\circ$.

[92] ADLER 96C fit gives $(43.82 \pm 0.41)^\circ + 339(\Delta m - 0.5307)^\circ - 252(\tau_s - 0.8922)^\circ$.

[93] ADLER 96C is the result of a fit which includes nearly the same data as entered into the "OUR FIT" value in the 1996 edition of this Review (Physical Review **D54** 1 (1996)).

[94] ADLER 95B report $42.7^\circ \pm 0.9^\circ \pm 0.6^\circ + 316[\Delta m - 0.5274]^\circ + 30[\tau_s - 0.8926]^\circ$.

[95] ADLER 92B quote separately two systematic errors: ±0.4 from their experiment and ±1.0 degrees due to the uncertainty in the value of $\Delta m$.

[96] KARLSSON 90 systematic error does not include regeneration phase uncertainty.

## $\phi_{00}$, PHASE OF $\eta_{00}$

See comment in $\phi_{+-}$ header above for treatment of $\Delta m$ and $\tau_S$ dependence.

OUR FIT is described in the note on "Fits for $K_L^0$ *CP*-Violation Parameters" in the $K_L^0$ Particle Listings.

| *VALUE* (°) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **43.2±1.0 OUR FIT** | | | | |
| 41.9±5.6±1.9 | [97] ANGELOPO... | 98 | CPLR | |
| 44.5±2.5 | [98] CAROSI | 90 | NA31 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 50.8±7.1±1.7 | [99] ADLER | 96B | CPLR | Sup. by ANGELOPOULOS 98 |
| 47.4±1.4±0.9 | [100] KARLSSON | 90 | E731 | |

[97] ANGELOPOULOS 98 $\phi_{00} = 42.0 \pm 5.6 \pm 1.9 + 240[\Delta m - 0.5307]$ with negligible $\tau_S$ dependence.
[98] CAROSI 90 $\phi_{00} = 47.1 \pm 2.1 \pm 1.0 + 579\ [\Delta m\ - 0.5351] + 252\ [\tau_S\ - 0.8922]^\circ$.
[99] ADLER 96B identified initial neutral kaon individually as being a $K^0$ or a $\overline{K}^0$. The systematic uncertainty is $\pm 1.5^\circ$ combined in quadrature with $\pm 0.8^\circ$ due to $\Delta m$.
[100] KARLSSON 90 systematic error does not include regeneration phase uncertainty.

## PHASE DIFFERENCE $\phi_{00} - \phi_{+-}$

Test of *CPT*.

OUR FIT is described in the note on "Fits for $K_L^0$ *CP*-Violation Parameters" in the $K_L^0$ Particle Listings.

| *VALUE* (°) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **−0.1 ±0.8 OUR FIT** | | | | |
| **−0.3 ±0.8 OUR AVERAGE** | | | | |
| −0.30±0.88 | [101] SCHWINGEN... | 95 | | Combined E731, E773 |
| 0.2 ±2.6 ±1.2 | [102] CAROSI | 90 | NA31 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.62±0.71±0.75 | SCHWINGEN... | 95 | E773 | |
| −1.6 ±1.2 | [103] GIBBONS | 93 | E731 | |
| −0.3 ±2.4 ±1.2 | KARLSSON | 90 | E731 | |

[101] This SCHWINGENHEUER 95 values is the combined result of SCHWINGENHEUER 95 and GIBBONS 93, accounting for correlated systematic errors.
[102] CAROSI 90 is excluded from the fit because it it is not independent of $\phi_{+-}$ and $\phi_{00}$ values.
[103] GIBBONS 93 give detailed dependence of systematic error on lifetime (see the section on the $K_S^0$ mean life) and mass difference (see the section on $m_{K_L^0} - m_{K_S^0}$).

## DECAY-PLANE ASYMMETRY IN $\pi^+\pi^-e^+e^-$ DECAYS

This is the *CP*-violating asymmetry

$$A = \frac{N_{\sin\phi\cos\phi>0.0} - N_{\sin\phi\cos\phi<0.0}}{N_{\sin\phi\cos\phi>0.0} + N_{\sin\phi\cos\phi<0.0}}$$

where $\phi$ is the angle between the $e^+e^-$ and $\pi^+\pi^-$ planes in the $K_L^0$ rest frame.

## *CP* ASYMMETRY *A* in $K_L^0 \rightarrow \pi^+\pi^-e^+e^-$

| *VALUE* (%) | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|
| **13.6±2.5±1.2** | ALAVI-HARATI | 00B | KTEV |

## CHARGE ASYMMETRY IN $\pi^+\pi^-\pi^0$ DECAYS

These are *CP*-violating charge-asymmetry parameters, defined at beginning of section "LINEAR COEFFICIENT $g$ FOR $K_L^0 \to \pi^+\pi^-\pi^0$ above.

See also note on Dalitz plot parameters in $K^{\pm}$ section and note on *CP* violation in $K_L^0$ decay above.

### LINEAR COEFFICIENT $j$ FOR $K_L^0 \to \pi^+\pi^-\pi^0$

| *VALUE* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **0.0011±0.0008 OUR AVERAGE** | | | | |
| 0.0010±0.0024±0.0030 | 500k | ANGELOPO... | 98C | CPLR |
| 0.001 ±0.011 | 6499 | CHO | 77 | |
| −0.001 ±0.003 | 4709 | PEACH | 77 | |
| 0.0013±0.0009 | 3M | SCRIBANO | 70 | |
| 0.0 ±0.017 | 4400 | SMITH | 70 | OSPK |
| 0.001 ±0.004 | 238k | BLANPIED | 68 | |

### QUADRATIC COEFFICIENT $f$ FOR $K_L^0 \to \pi^+\pi^-\pi^0$

| *VALUE* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **0.0045±0.0024±0.0059** | 500k | ANGELOPO... | 98C | CPLR |

## PARAMETERS for $K_L^0 \to \pi^+\pi^-\gamma$ DECAY

### $|\eta_{+-\gamma}| = |\mathrm{A}(K_L^0 \to \pi^+\pi^-\gamma,\ CP\ \text{violating})/\mathrm{A}(K_S^0 \to \pi^+\pi^-\gamma)|$

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **2.35 ±0.07 OUR AVERAGE** | | | | |
| 2.359±0.062±0.040 | 9045 | MATTHEWS | 95 | E773 |
| 2.15 ±0.26 ±0.20 | 3671 | RAMBERG | 93B | E731 |

### $\phi_{+-\gamma}$ = phase of $\eta_{+-\gamma}$

| *VALUE* (°) | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **44 ± 4 OUR AVERAGE** | | | | |
| 43.8± 3.5± 1.9 | 9045 | MATTHEWS | 95 | E773 |
| 72 ±23 ±17 | 3671 | RAMBERG | 93B | E731 |

### $|\epsilon'_{+-\gamma}|/\epsilon$ for $K_L^0 \to \pi^+\pi^-\gamma$

| *VALUE* | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|---|
| **<0.3** | 90 | 3671 | [104] RAMBERG | 93B | E731 |

[104] RAMBERG 93B limit on $|\epsilon'_{+-\gamma}|/\epsilon$ assumes than any difference between $\eta_{+-}$ and $\eta_{+-\gamma}$ is due to direct *CP* violation.

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## $x = \mathrm{A}(\overline{K}^0 \to \pi^- \ell^+ \nu)/\mathrm{A}(K^0 \to \pi^- \ell^+ \nu) = \mathrm{A}(\Delta S{=}-\Delta Q)/\mathrm{A}(\Delta S{=}\Delta Q)$

### REAL PART OF $x$

| VALUE | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|
| **$-0.0018 \pm 0.0041 \pm 0.0045$** | | ANGELOPO... | 98D | CPLR | $K_{e3}$ from $K^0$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| $0.10\ ^{+0.18}_{-0.19}$ | 79 | SMITH | 75B | WIRE | $\pi^- p \to K^0 \Lambda$ |
| $0.04 \pm 0.03$ | 4724 | NIEBERGALL | 74 | ASPK | $K^+ p \to K^0 p \pi^+$ |
| $-0.008 \pm 0.044$ | 1757 | FACKLER | 73 | OSPK | $K_{e3}$ from $K^0$ |
| $-0.03 \pm 0.07$ | 1367 | HART | 73 | OSPK | $K_{e3}$ from $K^0 \Lambda$ |
| $-0.070 \pm 0.036$ | 1079 | MALLARY | 73 | OSPK | $K_{e3}$ from $K^0 \Lambda X$ |
| $0.03 \pm 0.06$ | 410 | [105] BURGUN | 72 | HBC | $K^+ p \to K^0 p \pi^+$ |
| $0.04\ ^{+0.10}_{-0.13}$ | 100 | [106] GRAHAM | 72 | OSPK | $K_{\mu 3}$ from $K^0 \Lambda$ |
| $-0.05 \pm 0.09$ | 442 | [106] GRAHAM | 72 | OSPK | $\pi^- p \to K^0 \Lambda$ |
| $0.26\ ^{+0.10}_{-0.14}$ | 126 | MANN | 72 | HBC | $K^- p \to n \overline{K}^0$ |
| $-0.13 \pm 0.11$ | 342 | [106] MANTSCH | 72 | OSPK | $K_{e3}$ from $K^0 \Lambda$ |
| $0.04\ ^{+0.07}_{-0.08}$ | 222 | [105] BURGUN | 71 | HBC | $K^+ p \to K^0 p \pi^+$ |
| $0.25\ ^{+0.07}_{-0.09}$ | 252 | WEBBER | 71 | HBC | $K^- p \to n \overline{K}^0$ |
| $0.12 \pm 0.09$ | 215 | [107] CHO | 70 | DBC | $K^+ d \to K^0 p p$ |
| $-0.020 \pm 0.025$ | | [108] BENNETT | 69 | CNTR | Charge asym+ Cu regen. |
| $0.09\ ^{+0.14}_{-0.16}$ | 686 | LITTENBERG | 69 | OSPK | $K^+ n \to K^0 p$ |
| $0.03 \pm 0.03$ | | [108] BENNETT | 68 | CNTR | |
| $0.09\ ^{+0.07}_{-0.09}$ | 121 | JAMES | 68 | HBC | $\overline{p} p$ |
| $0.17\ ^{+0.16}_{-0.35}$ | 116 | FELDMAN | 67B | OSPK | $\pi^- p \to K^0 \Lambda$ |
| $0.17 \pm 0.10$ | 335 | [107] HILL | 67 | DBC | $K^+ d \to K^0 p p$ |
| $0.035\ ^{+0.11}_{-0.13}$ | 196 | AUBERT | 65 | HLBC | $K^+$ charge exchange |
| $0.06\ ^{+0.18}_{-0.44}$ | 152 | [109] BALDO-... | 65 | HLBC | $K^+$ charge exchange |
| $-0.08\ ^{+0.16}_{-0.28}$ | 109 | [110] FRANZINI | 65 | HBC | $\overline{p} p$ |

[105] BURGUN 72 is a final result which includes BURGUN 71.
[106] First GRAHAM 72 value is second GRAHAM 72 value combined with MANTSCH 72.
[107] CHO 70 is analysis of unambiguous events in new data and HILL 67.
[108] BENNETT 69 is a reanalysis of BENNETT 68.
[109] BALDO-CEOLIN 65 gives $x$ and $\theta$ converted by us to Re($x$) and Im($x$).
[110] FRANZINI 65 gives $x$ and $\theta$ for Re($x$) and Im($x$). See SCHMIDT 67.

## IMAGINARY PART OF *x*

Assumes $m_{K^0_L} - m_{K^0_S}$ positive. See Listings above.

| VALUE | | EVTS | DOCUMENT ID | | TECN | COMMENT |
|---|---|---|---|---|---|---|
| **0.0012±0.0019** | | 640k | ANGELOPO... | 98E | CPLR | $K_{e3}$ from $K^0$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | | |
| $-0.10$ | $^{+0.16}_{-0.19}$ | 79 | SMITH | 75B | WIRE | $\pi^- p \rightarrow K^0 \Lambda$ |
| $-0.06$ | $\pm 0.05$ | 4724 | NIEBERGALL | 74 | ASPK | $K^+ p \rightarrow K^0 p \pi^+$ |
| $-0.017$ | $\pm 0.060$ | 1757 | FACKLER | 73 | OSPK | $K_{e3}$ from $K^0$ |
| 0.09 | $\pm 0.07$ | 1367 | HART | 73 | OSPK | $K_{e3}$ from $K^0 \Lambda$ |
| 0.107 | $^{+0.092}_{-0.074}$ | 1079 | MALLARY | 73 | OSPK | $K_{e3}$ from $K^0 \Lambda X$ |
| 0.07 | $^{+0.06}_{-0.07}$ | 410 | [111] BURGUN | 72 | HBC | $K^+ p \rightarrow K^0 p \pi^+$ |
| 0.12 | $^{+0.17}_{-0.16}$ | 100 | [112] GRAHAM | 72 | OSPK | $K_{\mu 3}$ from $K^0 \Lambda$ |
| 0.05 | $\pm 0.13$ | 442 | [112] GRAHAM | 72 | OSPK | $\pi^- p \rightarrow K^0 \Lambda$ |
| 0.21 | $^{+0.15}_{-0.12}$ | 126 | MANN | 72 | HBC | $K^- p \rightarrow n \overline{K}^0$ |
| $-0.04$ | $\pm 0.16$ | 342 | [112] MANTSCH | 72 | OSPK | $K_{e3}$ from $K^0 \Lambda$ |
| 0.12 | $^{+0.08}_{-0.09}$ | 222 | [111] BURGUN | 71 | HBC | $K^+ p \rightarrow K^0 p \pi^+$ |
| 0.0 | $\pm 0.08$ | 252 | WEBBER | 71 | HBC | $K^- p \rightarrow n \overline{K}^0$ |
| $-0.08$ | $\pm 0.07$ | 215 | [113] CHO | 70 | DBC | $K^+ d \rightarrow K^0 p p$ |
| $-0.11$ | $^{+0.10}_{-0.11}$ | 686 | LITTENBERG | 69 | OSPK | $K^+ n \rightarrow K^0 p$ |
| $+0.22$ | $^{+0.37}_{-0.29}$ | 121 | JAMES | 68 | HBC | $\overline{p} p$ |
| 0.0 | $\pm 0.25$ | 116 | FELDMAN | 67B | OSPK | $\pi^- p \rightarrow K^0 \Lambda$ |
| $-0.20$ | $\pm 0.10$ | 335 | [113] HILL | 67 | DBC | $K^+ d \rightarrow K^0 p p$ |
| $-0.21$ | $^{+0.11}_{-0.15}$ | 196 | AUBERT | 65 | HLBC | $K^+$ charge exchange |
| $-0.44$ | $^{+0.32}_{-0.19}$ | 152 | [114] BALDO-... | 65 | HLBC | $K^+$ charge exchange |
| $+0.24$ | $^{+0.40}_{-0.30}$ | 109 | [115] FRANZINI | 65 | HBC | $\overline{p} p$ |

[111] BURGUN 72 is a final result which includes BURGUN 71.

[112] First GRAHAM 72 value is second GRAHAM 72 value combined with MANTSCH 72.

[113] Footnote 10 of HILL 67 should read $+0.58$, not $-0.58$ (private communication) CHO 70 is analysis of unambiguous events in new data and HILL 67.

[114] BALDO-CEOLIN 65 gives $x$ and $\theta$ converted by us to Re($x$) and Im($x$).

[115] FRANZINI 65 gives $x$ and $\theta$ for Re($x$) and Im($x$). See SCHMIDT 67.

# $K^0_L$ REFERENCES


| | | | | |
|---|---|---|---|---|
| ALAVI-HARATI | 00 | PR D61 072006 | A. Alavi-Harati *et al.* | (KTeV Collab.) |
| ALAVI-HARATI | 00B | PRL 84 408 | A. Alavi-Harati *et al.* | (KTeV Collab.) |
| ALAVI-HARATI | 00D | PRL 84 5279 | A. Alavi-Harati *et al.* | (KTeV Collab.) |
| ALAVI-HARATI | 00E | PR D62 112001 | A. Alavi-Harati *et al.* | (KTeV Collab.) |
| AMBROSE | 00 | PRL 84 1389 | D. Ambrose *et al.* | (BNL E871 Collab.) |
| APOSTOLA... | 00 | PL B473 186 | A. Apostolakis *et al.* | (CPLEAR Collab.) |
| BRFIT | 00 | RPP 2000 edition | T.G. Trippe | |
| Fits for $K^0_L$ *CP*-Violation Parameters | | | | |
| ETAFIT | 00 | RPP 2000 edition | T.G. Trippe | |
| Fits for $K^0_L$ *CP*-Violation Parameters | | | | |
| ADAMS | 99 | PL B447 240 | J. Adams *et al.* | (KTeV Collab.) |
| ALAVI-HARATI | 99B | PRL 83 917 | A. Alavi-Harati *et al.* | (KTeV Collab.) |
| ALAVI-HARATI | 99D | PRL 83 22 | A. Alavi-Harati *et al.* | (KTeV Collab.) |
| APOSTOLA... | 99C | PL B458 545 | A. Apostolakis *et al.* | (CPLEAR Collab.) |
| FANTI | 99B | PL B458 553 | V. Fanti *et al.* | (CERN NA48 Collab.) |
| FANTI | 99C | PL B465 335 | V. Fanti *et al.* | (CERN NA48 Collab.) |
| MURAKAMI | 99 | PL B463 333 | K. Murakami *et al.* | (KEK E162 Collab.) |
| ADAMS | 98 | PRL 80 4123 | J. Adams *et al.* | (KTeV Collab.) |
| AMBROSE | 98 | PRL 81 4309 | D. Ambrose *et al.* | (BNL E871 Collab.) |
| AMBROSE | 98B | PRL 81 5734 | D. Ambrose *et al.* | (BNL E871 Collab.) |
| ANGELOPO... | 98 | PL B420 191 | A. Angelopoulos *et al.* | (CPLEAR Collab.) |
| ANGELOPO... | 98C | EPJ C5 389 | A. Angelopoulos *et al.* | (CPLEAR Collab.) |
| ANGELOPO... | 98D | PL B444 38 | A. Angelopoulos *et al.* | (CPLEAR Collab.) |
| ANGELOPO... | 98E | PL B444 43 | A. Angelopoulos *et al.* | (CPLEAR Collab.) |
| ARISAKA | 98 | PL B432 230 | K. Arisaka *et al.* | (FNAL E799 Collab.) |
| BENDER | 98 | PL B418 411 | M. Bender *et al.* | (CERN NA48 Collab.) |
| SETZU | 98 | PL B420 205 | M.G. Setzu *et al.* | |
| TAKEUCHI | 98 | PL B443 409 | Y. Takeuchi *et al.* | (KYOT, KEK, HIRO) |
| FANTI | 97 | ZPHY C76 653 | V. Fanti *et al.* | (CERN NA48 Collab.) |
| NOMURA | 97 | PL B408 445 | T. Nomura *et al.* | (KYOT, KEK, HIRO) |
| ADLER | 96B | ZPHY C70 211 | R. Adler *et al.* | (CPLEAR Collab.) |
| ADLER | 96C | PL B369 367 | R. Adler *et al.* | (CPLEAR Collab.) |
| GU | 96 | PRL 76 4312 | P. Gu *et al.* | (RUTG, UCLA, EFI, COLO+) |
| LEBER | 96 | PL B369 69 | F. Leber *et al.* | (MANZ, CERN, EDIN, ORSAY+) |
| PDG | 96 | PR D54 1 | R. M. Barnett *et al.* | |
| ADLER | 95 | PL B363 237 | R. Adler *et al.* | (CPLEAR Collab.) |
| ADLER | 95B | PL B363 243 | R. Adler *et al.* | (CPLEAR Collab.) |
| AKAGI | 95 | PR D51 2061 | T. Akagi *et al.* | (TOHOK, TOKY, KYOT, KEK) |
| BARR | 95 | ZPHY C65 361 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| BARR | 95C | PL B358 399 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| HEINSON | 95 | PR D51 985 | A.P. Heinson *et al.* | (BNL E791 Collab.) |
| KREUTZ | 95 | ZPHY C65 67 | A. Kreutz *et al.* | (SIEG, EDIN, MANZ, ORSAY+) |
| MATTHEWS | 95 | PRL 75 2803 | J.N. Matthews *et al.* | (RUTG, EFI, ELMT+) |
| SCHWINGEN... | 95 | PRL 74 4376 | B. Schwingenheuer *et al.* | (EFI, CHIC+) |
| SPENCER | 95 | PRL 74 3323 | M.B. Spencer *et al.* | (UCLA, EFI, COLO+) |
| BARR | 94 | PL B328 528 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| GU | 94 | PRL 72 3000 | P. Gu *et al.* | (RUTG, UCLA, EFI, COLO+) |
| NAKAYA | 94 | PRL 73 2169 | T. Nakaya *et al.* | (OSAK, UCLA, EFI, COLU+) |
| ROBERTS | 94 | PR D50 1874 | D. Roberts *et al.* | (UCLA, EFI, COLU+) |
| WEAVER | 94 | PRL 72 3758 | M. Weaver *et al.* | (UCLA, EFI, COLU, ELMT+) |
| AKAGI | 93 | PR D47 R2644 | T. Akagi *et al.* | (TOHOK, TOKY, KYOT, KEK) |
| ARISAKA | 93 | PRL 70 1049 | K. Arisaka *et al.* | (BNL E791 Collab.) |
| ARISAKA | 93B | PRL 71 3910 | K. Arisaka *et al.* | (BNL E791 Collab.) |
| BARR | 93D | PL B317 233 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| GIBBONS | 93 | PRL 70 1199 | L.K. Gibbons *et al.* | (FNAL E731 Collab.) |
| Also | 97 | PR D55 6625 | L.K. Gibbons *et al.* | (FNAL E731 Collab.) |
| GIBBONS | 93B | PRL 70 1203 | L.K. Gibbons *et al.* | (FNAL E731 Collab.) |
| GIBBONS | 93C | Thesis RX-1487 | L.K. Gibbons | (CHIC) |
| Also | 97 | PR D55 6625 | L.K. Gibbons *et al.* | (FNAL E731 Collab.) |
| HARRIS | 93 | PRL 71 3914 | D.A. Harris *et al.* | (EFI, UCLA, COLO+) |
| HARRIS | 93B | PRL 71 3918 | D.A. Harris *et al.* | (EFI, UCLA, COLO+) |
| MAKOFF | 93 | PRL 70 1591 | G. Makoff *et al.* | (FNAL E731 Collab.) |
| Also | 95 | PRL 75 2069 (erratum) | G. Makoff *et al.* | |
| RAMBERG | 93 | PRL 70 2525 | E. Ramberg *et al.* | (FNAL E731 Collab.) |
| RAMBERG | 93B | PRL 70 2529 | E.J. Ramberg *et al.* | (FNAL E731 Collab.) |
| VAGINS | 93 | PRL 71 35 | M.R. Vagins *et al.* | (BNL E845 Collab.) |
| ADLER | 92B | PL B286 180 | R. Adler *et al.* | (CPLEAR Collab.) |
| Also | 92 | SJNP 55 840 | R. Adler *et al.* | (CPLEAR Collab.) |

| | | | | |
|---|---|---|---|---|
| BARR | 92 | PL B284 440 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| GRAHAM | 92 | PL B295 169 | G.E. Graham *et al.* | (FNAL E731 Collab.) |
| MORSE | 92 | PR D45 36 | W.M. Morse *et al.* | (BNL, YALE, VASS) |
| PDG | 92 | PR D45, 1 June, Part II | K. Hikasa *et al.* | (KEK, LBL, BOST+) |
| SOMALWAR | 92 | PRL 68 2580 | S.V. Somalwar *et al.* | (FNAL E731 Collab.) |
| AKAGI | 91B | PRL 67 2618 | T. Akagi *et al.* | (TOHOK, TOKY, KYOT, KEK) |
| BARR | 91 | PL B259 389 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| HEINSON | 91 | PR D44 R1 | A.P. Heinson *et al.* | (UCI, UCLA, LANL+) |
| PAPADIMITR... | 91 | PR D44 R573 | V. Papadimitriou *et al.* | (FNAL E731 Collab.) |
| BARKER | 90 | PR D41 3546 | A.R. Barker *et al.* | (FNAL E731 Collab.) |
| Also | 88 | PRL 61 2661 | L.K. Gibbons *et al.* | (FNAL E731 Collab.) |
| BARR | 90B | PL B240 283 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| BARR | 90C | PL B242 523 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| CAROSI | 90 | PL B237 303 | R. Carosi *et al.* | (CERN, EDIN, MANZ, LALO+) |
| KARLSSON | 90 | PRL 64 2976 | M. Karlsson *et al.* | (FNAL E731 Collab.) |
| OHL | 90 | PRL 64 2755 | K.E. Ohl *et al.* | (BNL E845 Collab.) |
| OHL | 90B | PRL 65 1407 | K.E. Ohl *et al.* | (BNL E845 Collab.) |
| PATTERSON | 90 | PRL 64 1491 | J.R. Patterson *et al.* | (FNAL E731 Collab.) |
| INAGAKI | 89 | PR D40 1712 | T. Inagaki *et al.* | (KEK, TOKY, KYOT) |
| MATHIAZHA... | 89 | PRL 63 2181 | C. Mathiazhagan *et al.* | (UCI, UCLA, LANL+) |
| MATHIAZHA... | 89B | PRL 63 2185 | C. Mathiazhagan *et al.* | (UCI, UCLA, LANL+) |
| WAHL | 89 | CERN-EP/89-86 | H. Wahl | (CERN) |
| BARR | 88 | PL B214 303 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| BURKHARDT | 88 | PL B206 169 | H. Burkhardt *et al.* | (CERN, EDIN, MANZ+) |
| JASTRZEM... | 88 | PRL 61 2300 | E. Jastrzembski *et al.* | (BNL, YALE) |
| WOODS | 88 | PRL 60 1695 | M. Woods *et al.* | (FNAL E731 Collab.) |
| BURKHARDT | 87 | PL B199 139 | H. Burkhardt *et al.* | (CERN, EDIN, MANZ+) |
| ARONSON | 86 | PR D33 3180 | S.H. Aronson *et al.* | (BNL, CHIC, STAN+) |
| Also | 82 | PRL 48 1078 | S.H. Aronson *et al.* | (BNL, CHIC, STAN+) |
| PDG | 86C | PL 170B 132 | M. Aguilar-Benitez *et al.* | (CERN, CIT+) |
| COUPAL | 85 | PRL 55 566 | D.P. Coupal *et al.* | (CHIC, SACL) |
| BALATS | 83 | SJNP 38 556 | M.Y. Balats *et al.* | (ITEP) |
| | | Translated from YAF 38 927. | | |
| BERGSTROM | 83 | PL 131B 229 | L. Bergstrom, E. Masso, P. Singer | (CERN) |
| ARONSON | 82 | PRL 48 1078 | S.H. Aronson *et al.* | (BNL, CHIC, STAN+) |
| ARONSON | 82B | PRL 48 1306 | S.H. Aronson *et al.* | (BNL, CHIC, PURD) |
| Also | 82B | PL 116B 73 | E. Fischbach *et al.* | (PURD, BNL, CHIC) |
| Also | 83 | PR D28 476 | S.H. Aronson *et al.* | (BNL, CHIC, PURD) |
| Also | 83B | PR D28 495 | S.H. Aronson *et al.* | (BNL, CHIC, PURD) |
| PDG | 82B | PL 111B 70 | M. Roos *et al.* | (HELS, CIT, CERN) |
| BIRULEV | 81 | NP B182 1 | V.K. Birulev *et al.* | (JINR) |
| Also | 80 | SJNP 31 622 | V.K. Birulev *et al.* | (JINR) |
| | | Translated from YAF 31 1204. | | |
| CARROLL | 80B | PRL 44 529 | A.S. Carroll *et al.* | (BNL, ROCH) |
| CARROLL | 80C | PL 96B 407 | A.S. Carroll *et al.* | (BNL, ROCH) |
| CHO | 80 | PR D22 2688 | Y. Cho *et al.* | (ANL, CMU) |
| MORSE | 80 | PR D21 1750 | W.M. Morse *et al.* | (BNL, YALE) |
| CHRISTENS... | 79 | PRL 43 1209 | J.H. Christenson *et al.* | (NYU) |
| HILL | 79 | NP B153 39 | D.G. Hill *et al.* | (BNL, SLAC, SBER) |
| SCHMIDT | 79 | PRL 43 556 | M.P. Schmidt *et al.* | (YALE, BNL) |
| ENGLER | 78B | PR D18 623 | A. Engler *et al.* | (CMU, ANL) |
| HILL | 78 | PL 73B 483 | D.G. Hill *et al.* | (BNL, SLAC, SBER) |
| CHO | 77 | PR D15 587 | Y. Cho *et al.* | (ANL, CMU) |
| CLARK | 77 | PR D15 553 | A.R. Clark *et al.* | (LBL) |
| Also | 75 | Thesis LBL-4275 | G. Shen | (LBL) |
| DEVOE | 77 | PR D16 565 | R. Devoe *et al.* | (EFI, ANL) |
| DZHORD... | 77 | SJNP 26 478 | V.P. Dzhordzhadze *et al.* | (JINR) |
| | | Translated from YAF 26 910. | | |
| PEACH | 77 | NP B127 399 | K.J. Peach *et al.* | (BGNA, EDIN, GLAS+) |
| BIRULEV | 76 | SJNP 24 178 | V.K. Birulev *et al.* | (JINR) |
| | | Translated from YAF 24 340. | | |
| COOMBES | 76 | PRL 37 249 | R.W. Coombes *et al.* | (STAN, NYU) |
| GJESDAL | 76 | NP B109 118 | G. Gjesdal *et al.* | (CERN, HEIDH) |
| BALDO-... | 75 | NC 25A 688 | M. Baldo-Ceolin *et al.* | (PADO, WISC) |
| BLUMENTHAL | 75 | PRL 34 164 | R.B. Blumenthal *et al.* | (PENN, CHIC, TEMP) |
| BUCHANAN | 75 | PR D11 457 | C.D. Buchanan *et al.* | (UCLA, SLAC, JHU) |
| CARITHERS | 75 | PRL 34 1244 | W.C.J. Carithers *et al.* | (COLU, NYU) |
| SMITH | 75B | Thesis UCSD unpub. | J.G. Smith | (UCSD) |
| ALBRECHT | 74 | PL 48B 393 | K.F. Albrecht | (JINR, BERL, BUDA, PRAG, SERP+) |
| BISI | 74 | PL 50B 504 | V. Bisi, M.I. Ferrero | (TORI) |
| DONALDSON | 74 | Thesis SLAC-0184 | G. Donaldson | (SLAC) |
| Also | 76 | PR D14 2839 | G. Donaldson *et al.* | (SLAC) |

| | | | | |
|---|---|---|---|---|
| DONALDSON | 74B | PR D9 2960 | G. Donaldson *et al.* | (SLAC, UCSC) |
| Also | 73B | PRL 31 337 | G. Donaldson *et al.* | (SLAC, UCSC) |
| GEWENIGER | 74 | PL 48B 483 | C. Geweniger *et al.* | (CERN, HEIDH) |
| Also | 74 | Thesis CERN Int. 74-4 | V. Luth | (CERN) |
| GEWENIGER | 74B | PL 48B 487 | C. Geweniger *et al.* | (CERN, HEIDH) |
| Also | 74B | PL 52B 119 | S. Gjesdal *et al.* | (CERN, HEIDH) |
| GEWENIGER | 74C | PL 52B 108 | C. Geweniger *et al.* | (CERN, HEIDH) |
| GJESDAL | 74 | PL 52B 113 | S. Gjesdal *et al.* | (CERN, HEIDH) |
| MESSNER | 74 | PRL 33 1458 | R. Messner *et al.* | (COLO, SLAC, UCSC) |
| NIEBERGALL | 74 | PL 49B 103 | F. Niebergall *et al.* | (CERN, ORSAY, VIEN) |
| WANG | 74 | PR D9 540 | L. Wang *et al.* | (UMD, BNL) |
| WILLIAMS | 74 | PRL 33 240 | H.H. Williams *et al.* | (BNL, YALE) |
| ALBROW | 73 | NP B58 22 | M.G. Albrow *et al.* | (MCHS, DARE) |
| ALEXANDER | 73B | NP B65 301 | G. Alexander *et al.* | (TELA, HEID) |
| BRANDENB... | 73 | PR D8 1978 | G.W. Brandenburg *et al.* | (SLAC) |
| EVANS | 73 | PR D7 36 | G.R. Evans *et al.* | (EDIN, CERN) |
| Also | 69 | PRL 23 427 | G.R. Evans *et al.* | (EDIN, CERN) |
| FACKLER | 73 | PRL 31 847 | O. Fackler *et al.* | (MIT) |
| FITCH | 73 | PRL 31 1524 | V.L. Fitch *et al.* | (PRIN) |
| Also | 72 | Thesis COO-3072-13 | R.C. Webb | (PRIN) |
| GINSBERG | 73 | PR D8 3887 | E.S. Ginsberg, J. Smith | (MIT, STON) |
| HART | 73 | NP B66 317 | J.C. Hart *et al.* | (CAVE, RHEL) |
| MALLARY | 73 | PR D7 1953 | M.L. Mallary *et al.* | (CIT) |
| Also | 70 | PRL 25 1214 | F.J. Sciulli *et al.* | (CIT) |
| MCCARTHY | 73 | PR D7 687 | R.L. McCarthy *et al.* | (LBL) |
| Also | 72 | PL 42B 291 | R.L. McCarthy *et al.* | (LBL) |
| Also | 71 | Thesis LBL-550 | R.L. McCarthy | (LBL) |
| MESSNER | 73 | PRL 30 876 | R. Messner *et al.* | (COLO, SLAC, UCSC) |
| PEACH | 73 | PL 43B 441 | K.J. Peach *et al.* | (EDIN, CERN, AACH) |
| SANDWEISS | 73 | PRL 30 1002 | J. Sandweiss *et al.* | (YALE, ANL) |
| WILLIAMS | 73 | PRL 31 1521 | H.H. Williams *et al.* | (BNL, YALE) |
| ALBROW | 72 | NP B44 1 | M.G. Albrow *et al.* | (MCHS, DARE) |
| ASHFORD | 72 | PL 38B 47 | V.A. Ashford *et al.* | (UCSD) |
| BANNER | 72B | PRL 29 237 | M. Banner *et al.* | (PRIN) |
| BARMIN | 72B | SJNP 15 638 | V.V. Barmin *et al.* | (ITEP) |
| | | Translated from YAF 15 1152. | | |
| BURGUN | 72 | NP B50 194 | G. Burgun *et al.* | (SACL, CERN, OSLO) |
| DALLY | 72 | PL 41B 647 | E.B. Dally *et al.* | (SLAC, JHU, UCLA) |
| Also | 70 | PL 33B 627 | C.Y. Chien *et al.* | (JHU, SLAC, UCLA) |
| Also | 71 | PL 35B 261 | C.Y. Chien *et al.* | (JHU, SLAC, UCLA) |
| GRAHAM | 72 | NC 9A 166 | M.F. Graham *et al.* | (ILL, NEAS) |
| JAMES | 72 | NP B49 1 | F. James *et al.* | (CERN, SACL, OSLO) |
| KRENZ | 72 | LNC 4 213 | W. Krenz *et al.* | (AACH, CERN, EDIN) |
| MANN | 72 | PR D6 137 | W.A. Mann *et al.* | (MASA, BNL, YALE) |
| MANTSCH | 72 | NC 9A 160 | P.M. Mantsch *et al.* | (ILL, NEAS) |
| MCCARTHY | 72 | PL 42B 291 | R.L. McCarthy *et al.* | (LBL) |
| NEUHOFER | 72 | PL 41B 642 | G. Neuhofer *et al.* | (CERN, ORSAY, VIEN) |
| PICCIONI | 72 | PRL 29 1412 | R. Piccioni *et al.* | (SLAC) |
| Also | 74 | PR D9 2939 | R. Piccioni *et al.* | (SLAC, UCSC, COLO) |
| VOSBURGH | 72 | PR D6 1834 | K.G. Vosburgh *et al.* | (RUTG, MASA) |
| Also | 71 | PRL 26 866 | K.G. Vosburgh *et al.* | (RUTG, MASA) |
| BALATS | 71 | SJNP 13 53 | M.Y. Balats *et al.* | (ITEP) |
| | | Translated from YAF 13 93. | | |
| BARMIN | 71 | PL 35B 604 | V.V. Barmin *et al.* | (ITEP) |
| BISI | 71 | PL 36B 533 | V. Bisi *et al.* | (AACH, CERN, TORI) |
| BURGUN | 71 | LNC 2 1169 | G. Burgun *et al.* | (SACL, CERN, OSLO) |
| CARNEGIE | 71 | PR D4 1 | R.K. Carnegie *et al.* | (PRIN) |
| CHAN | 71 | Thesis LBL-350 | J.H.S. Chan | (LBL) |
| CHIEN | 71 | PL 35B 261 | C.Y. Chien *et al.* | (JHU, SLAC, UCLA) |
| Also | 72 | PL 41B 647 | E.B. Dally *et al.* | (SLAC, JHU, UCLA) |
| CHO | 71 | PR D3 1557 | Y. Cho *et al.* | (CMU, BNL, CASE) |
| ENSTROM | 71 | PR D4 2629 | J. Enstrom *et al.* | (SLAC, STAN) |
| Also | 70 | Thesis SLAC-0125 | J.E. Enstrom | (STAN) |
| JAMES | 71 | PL 35B 265 | F. James *et al.* | (CERN, SACL, OSLO) |
| MEISNER | 71 | PR D3 59 | G.W. Meisner *et al.* | (MASA, BNL, YALE) |
| REPELLIN | 71 | PL 36B 603 | J.P. Repellin *et al.* | (ORSAY, CERN) |
| WEBBER | 71 | PR D3 64 | B.R. Webber *et al.* | (LRL) |
| Also | 68 | PRL 21 498 | B.R. Webber *et al.* | (LRL) |
| Also | 69 | Thesis UCRL 19226 | B.R. Webber | (LRL) |
| WOLFF | 71 | PL 36B 517 | B. Wolff *et al.* | (ORSAY, CERN) |

| | | | | |
|---|---|---|---|---|
| ALBROW | 70 | PL 33B 516 | M.G. Albrow *et al.* | (MCHS, DARE) |
| ARONSON | 70 | PRL 25 1057 | S.H. Aronson *et al.* | (EFI, ILLC, SLAC) |
| BARMIN | 70 | PL 33B 377 | V.V. Barmin *et al.* | (ITEP, JINR) |
| BASILE | 70 | PR D2 78 | P. Basile *et al.* | (SACL) |
| BECHERRAWY | 70 | PR D1 1452 | T. Becherrawy | (ROCH) |
| BUCHANAN | 70 | PL 33B 623 | C.D. Buchanan *et al.* | (SLAC, JHU, UCLA) |
| Also | 71 | Private Comm. | A.J. Cox | |
| BUDAGOV | 70 | PR D2 815 | I.A. Budagov *et al.* | (CERN, ORSAY, EPOL) |
| Also | 68B | PL 28B 215 | I.A. Budagov *et al.* | (CERN, ORSAY, EPOL) |
| CHIEN | 70 | PL 33B 627 | C.Y. Chien *et al.* | (JHU, SLAC, UCLA) |
| Also | 71 | Private Comm. | A.J. Cox | |
| CHO | 70 | PR D1 3031 | Y. Cho *et al.* | (CMU, BNL, CASE) |
| Also | 67 | PRL 19 668 | D.G. Hill *et al.* | (BNL, CMU) |
| CHOLLET | 70 | PL 31B 658 | J.C. Chollet *et al.* | (CERN) |
| CULLEN | 70 | PL 32B 523 | M. Cullen *et al.* | (AACH, CERN, TORI) |
| GINSBERG | 70 | PR D1 229 | E.S. Ginsberg | (HAIF) |
| MARX | 70 | PL 32B 219 | J. Marx *et al.* | (COLU, HARV, CERN) |
| Also | 70B | Thesis Nevis 179 | J. Marx | (COLU) |
| SCRIBANO | 70 | PL 32B 224 | A. Scribano *et al.* | (PISA, COLU, HARV) |
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| Also | 68 | PRL 21 1107 | J.W. Cronin, J.K. Liu, J.E. Pilcher | (PRIN) |
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| Also | 69 | PR 175 1708 | S.H. Aronson, K.W. Chen | (PRIN) |
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