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

## $K^0_S$ MEAN LIFE

For earlier measurements, beginning with BOLDT 58B, see our 1986 edition, Physics Letters **170B** 130 (1986).

OUR FIT is described in the note on "*CP* violation in $K_L$ decays" in the $K^0_L$ Particle Listings. The result labeled "OUR FIT Assuming *CPT*" ["OUR FIT Not assuming *CPT*"] includes all measurements except those with the comment "Not assuming *CPT*" ["Assuming *CPT*"]. Measurements with neither comment do not assume *CPT* and enter both fits.

| *VALUE* ($10^{-10}$ s) | *EVTS* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **0.8953 ±0.0005 OUR FIT** | Error includes scale factor of 1.1. Assuming *CPT* | | | |
| **0.8958 ±0.0005 OUR FIT** | Not assuming *CPT* | | | |
| 0.8965 ±0.0007 | | [1,2] ALAVI-HARATI 03 | KTEV | Assuming *CPT* |
| 0.8958 ±0.0013 | | [2,3] ALAVI-HARATI 03 | KTEV | Not assuming *CPT* |
| 0.89598 ±0.00048 ±0.00051 | 16M | LAI 02C | NA48 | |
| 0.8971 ±0.0021 | | BERTANZA 97 | NA31 | |
| 0.8941 ±0.0014 ±0.0009 | | SCHWINGEN... 95 | E773 | Assuming *CPT* |
| 0.8929 ±0.0016 | | GIBBONS 93 | E731 | Assuming *CPT* |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.8920 ±0.0044 | 214k | GROSSMAN 87 | SPEC | |
| 0.905 ±0.007 | | [4] ARONSON 82B | SPEC | |
| 0.881 ±0.009 | 26k | ARONSON 76 | SPEC | |
| 0.8926 ±0.0032 ±0.0002 | | [5] CARITHERS 75 | SPEC | |
| 0.8937 ±0.0048 | 6M | GEWENIGER 74B | ASPK | |
| 0.8958 ±0.0045 | 50k | [6] SKJEGGEST... 72 | HBC | |
| 0.856 ±0.008 | 19994 | [7] DONALD 68B | HBC | |
| 0.872 ±0.009 | 20000 | [6,7] HILL 68 | DBC | |

[1] This ALAVI-HARATI 03 fit has $\Delta m$ and $\tau_S$ free but constrains $\phi_{+-}$ to the Superweak value, i.e. assumes *CPT*. This $\tau_S$ value is correlated with their $\Delta m = m_{K^0_L} - m_{K^0_S}$ measurement in the $K^0_L$ listings. The correlation coefficient $\rho(\tau_S,\Delta m) = -0.396$.

[2] The two ALAVI-HARATI 03 values use the same data. The first enters the "assuming *CPT*" fit and the second enters the "not assuming *CPT*" fit.

[3] This ALAVI-HARATI 03 fit has $\Delta m$, $\phi_{+-}$, and $\tau_{K_S}$ free. See $\phi_{+-}$ in the "$K_L$ *CP* violation" section for correlation information.

[4] ARONSON 82 find that $K^0_S$ mean life may depend on the kaon energy.

[5] CARITHERS 75 measures the $\Delta m$ dependence of the total decay rate (inverse mean life) to be $\Gamma(K^0_S) = \left[(1.122 \pm 0.004) + 0.16(\Delta m - 0.5348)/\Delta m\right] 10^{10}$/s, or, in terms of mean life, CARITHERS 75 measures $\tau_S = (0.8913 \pm 0.0032) - 0.238\,[\Delta m - 0.5348]$ ($10^{-10}$ s). We have adjusted the measurement to use our best values of ($\Delta m = 0.5292 \pm 0.0009$) ($10^{10}\ \hbar\ \text{s}^{-1}$). Our first error is their experiment's error and our second error is the systematic error from using our best values.

[6] HILL 68 has been changed by the authors from the published value ($0.865 \pm 0.009$) because of a correction in the shift due to $\eta_{+-}$. SKJEGGESTAD 72 and HILL 68 give detailed discussions of systematics encountered in this type of experiment.

[7] Pre-1971 experiments are excluded from the average because of disagreement with later more precise experiments.

## $K^0_S$ DECAY MODES

| | Mode | | | Fraction ($\Gamma_i/\Gamma$) | Scale factor/ Confidence level |
|---|---|---|---|---|---|
| | **Hadronic modes** | | | | |
| $\Gamma_1$ | $\pi^0\pi^0$ | | | $(30.69\pm0.05)$ % | |
| $\Gamma_2$ | $\pi^+\pi^-$ | | | $(69.20\pm0.05)$ % | |
| $\Gamma_3$ | $\pi^+\pi^-\pi^0$ | | | $(3.5\ ^{+1.1}_{-0.9}) \times 10^{-7}$ | |
| | **Modes with photons or $\ell\overline{\ell}$ pairs** | | | | |
| $\Gamma_4$ | $\pi^+\pi^-\gamma$ | | [*a*,*b*] | $(1.79\pm0.05) \times 10^{-3}$ | |
| $\Gamma_5$ | $\pi^+\pi^-e^+e^-$ | | | $(4.69\pm0.30) \times 10^{-5}$ | |
| $\Gamma_6$ | $\pi^0\gamma\gamma$ | | [*a*] | $(4.9\ \pm1.8\ ) \times 10^{-8}$ | |
| $\Gamma_7$ | $\gamma\gamma$ | | | $(2.63\pm0.17) \times 10^{-6}$ | S=3.0 |
| | **Semileptonic modes** | | | | |
| $\Gamma_8$ | $\pi^\pm e^\mp \nu_e$ | | [*c*] | $(7.04\pm0.08) \times 10^{-4}$ | |
| $\Gamma_9$ | $\pi^\pm \mu^\mp \nu_\mu$ | | [*c*,*d*] | $(4.69\pm0.05) \times 10^{-4}$ | |
| | ***CP* violating (*CP*) and $\Delta S = 1$ weak neutral current (*S1*) modes** | | | | |
| $\Gamma_{10}$ | $3\pi^0$ | *CP* | | $< 1.2 \times 10^{-7}$ | CL=90% |
| $\Gamma_{11}$ | $\mu^+\mu^-$ | *S1* | | $< 3.2 \times 10^{-7}$ | CL=90% |
| $\Gamma_{12}$ | $e^+e^-$ | *S1* | | $< 9 \times 10^{-9}$ | CL=90% |
| $\Gamma_{13}$ | $\pi^0 e^+e^-$ | *S1* | [*a*] | $(3.0\ ^{+1.5}_{-1.2}) \times 10^{-9}$ | |
| $\Gamma_{14}$ | $\pi^0\mu^+\mu^-$ | *S1* | | $(2.9\ ^{+1.5}_{-1.2}) \times 10^{-9}$ | |

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

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

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

[*d*] Not a measurement. Calculated as $0.666 \cdot \mathrm{B}(\pi^\pm e^\mp \nu_e)$.

## CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 5 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2 =$ 0.1 for 2 degrees of freedom.

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

$$\begin{array}{c|ccc}
x_2 & -100 & & \\
x_8 & -6 & 3 & \\
x_9 & -6 & 3 & 100 \\
\hline
 & x_1 & x_2 & x_8
\end{array}$$

---

## $K^0_S$ DECAY RATES

### $\Gamma(\pi^\pm e^\mp \nu_e)$ $\Gamma_8$

| *VALUE* ($10^6$ s$^{-1}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| 8.1 ±1.6 | 75 | [8] AKHMETSHIN | 99 | CMD2 | Tagged $K^0_S$ using $\phi \to K^0_L K^0_S$ |
| 7.50±0.08 | | [9] PDG | 98 | | |
| seen | | BURGUN | 72 | HBC | $K^+ p \to K^0 p \pi^+$ |
| 9.3 ±2.5 | | AUBERT | 65 | HLBC | ΔS=ΔQ, *CP* cons. not assumed |

[8] AKHMETSHIN 99 is from a measured branching ratio $\mathrm{B}(K^0_S \to \pi e \nu_e) = (7.2 \pm 1.4) \times 10^{-4}$ and $\tau_{K^0_S} = (0.8934 \pm 0.0008) \times 10^{-10}$ s. Not independent of measured branching ratio.

[9] PDG 98 from $K^0_L$ measurements, assuming that $\Delta S = \Delta Q$ in $K^0$ decay so that $\Gamma(K^0_S \to \pi^\pm e^\mp \nu_e) = \Gamma(K^0_L \to \pi^\pm e^\mp \nu_e)$.

### $\Gamma(\pi^\pm \mu^\mp \nu_\mu)$ $\Gamma_9$

| *VALUE* ($10^6$ s$^{-1}$) | *DOCUMENT ID* | |
|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | |
| 5.25±0.07 | [10] PDG | 98 |

[10] PDG 98 from $K^0_L$ measurements, assuming that $\Delta S = \Delta Q$ in $K^0$ decay so that $\Gamma(K^0_S \to \pi^\pm \mu^\mp \nu_\mu) = \Gamma(K^0_L \to \pi^\pm \mu^\mp \nu_\mu)$.

---

# $K_S^0$ BRANCHING RATIOS

## Hadronic modes

### $\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$ $\Gamma_1/\Gamma$

| VALUE | EVTS | DOCUMENT ID | TECN |
|---|---|---|---|
| **0.3069±0.0005 OUR FIT** | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | |
| 0.335 ±0.014 | 1066 | BROWN 63 | HLBC |
| 0.288 ±0.021 | 198 | CHRETIEN 63 | HLBC |
| 0.30 ±0.035 | | BROWN 61 | HLBC |

### $\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ $\Gamma_2/\Gamma$

| VALUE | EVTS | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|---|
| **0.6920±0.0005 OUR FIT** | | | | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.670 ±0.010 | 3447 | DOYLE 69 | HBC | $\pi^- p \to \Lambda K^0$ |

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

| VALUE | EVTS | DOCUMENT ID | TECN | COMMENT |
|---|---|---|---|---|
| **2.255 ±0.005 OUR FIT** | | | | |
| **2.2549±0.0054** | | [11] AMBROSINO 06C | KLOE | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 2.2555±0.0012±0.0054 | | [12] AMBROSINO 06C | KLOE | |
| 2.236 ±0.003 ±0.015 | 766k | [12] ALOISIO 02B | KLOE | |
| 2.11 ±0.09 | 1315 | EVERHART 76 | WIRE | $\pi^- p \to \Lambda K^0$ |
| 2.169 ±0.094 | 16k | COWELL 74 | OSPK | $\pi^- p \to \Lambda K^0$ |
| 2.16 ±0.08 | 4799 | HILL 73 | DBC | $K^+ d \to K^0 p p$ |
| 2.22 ±0.10 | 3068 | [13] ALITTI 72 | HBC | $K^+ p \to \pi^+ p K^0$ |
| 2.22 ±0.08 | 6380 | MORSE 72B | DBC | $K^+ n \to K^0 p$ |
| 2.10 ±0.11 | 701 | [14] NAGY 72 | HLBC | $K^+ n \to K^0 p$ |
| 2.22 ±0.095 | 6150 | [15] BALTAY 71 | HBC | $K p \to K^0$ neutrals |
| 2.282 ±0.043 | 7944 | [16] MOFFETT 70 | OSPK | $K^+ n \to K^0 p$ |
| 2.12 ±0.17 | 267 | [14] BOZOKI 69 | HLBC | |
| 2.285 ±0.055 | 3016 | [16] GOBBI 69 | OSPK | $K^+ n \to K^0 p$ |
| 2.10 ±0.06 | 3700 | MORFIN 69 | HLBC | $K^+ n \to K^0 p$ |

[11] This result combines AMBROSINO 06C KLOE 2001-02 data with ALOISIO 02B KLOE 2000 data. $K_S^0 \to \pi^+\pi^-$ fully inclusive.

[12] Includes radiative decays $\pi^+\pi^-\gamma$.

[13] The directly measured quantity is $K_S^0 \to \pi^+\pi^-/\text{all } K^0 = 0.345 \pm 0.005$.

[14] NAGY 72 is a final result which includes BOZOKI 69.

[15] The directly measured quantity is $K_S^0 \to \pi^+\pi^-/\text{all } \overline{K}^0 = 0.345 \pm 0.005$.

[16] MOFFETT 70 is a final result which includes GOBBI 69.

## $\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ $\Gamma_3/\Gamma$

| *VALUE* (units $10^{-7}$) | *EVTS* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **$3.5^{+1.1}_{-0.9}$ OUR AVERAGE** | | | | |
| $4.7^{+2.2+1.7}_{-1.7-1.5}$ | | [17] BATLEY 05 | NA48 | |
| $2.5^{+1.3+0.5}_{-1.0-0.6}$ | 500k | [18] ADLER 97B | CPLR | |
| $4.8^{+2.2}_{-1.6}\pm1.1$ | | [19] ZOU 96 | E621 | |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| $4.1^{+2.5+0.5}_{-1.9-0.6}$ | | [20] ADLER 96E | CPLR | Sup. by ADLER 97B |
| $3.9^{+5.4+0.9}_{-1.8-0.7}$ | | [21] THOMSON 94 | E621 | Sup. by ZOU 96 |

[17] BATLEY 05 is obtained by measuring the interference parameters in $K_S$, $K_L \to \pi^+\pi^-\pi^0$: Re($\lambda$) = 0.038 ± 0.008 ± 0.006 and Im($\lambda$) = −0.013 ± 0.005 ± 0.004; the correlation coeff. between Re($\lambda$) and Im($\lambda$) is 0.66 (statistical only).

[18] ADLER 97B find the *CP*-conserving parameters Re($\lambda$) = $(28 \pm 7 \pm 3) \times 10^{-3}$, Im($\lambda$) = $(-10 \pm 8 \pm 2) \times 10^{-3}$. They estimate B($K^0_S \to \pi^+\pi^-\pi^0$) from Re($\lambda$) and the $K^0_L$ decay parameters. See also ANGELOPOULOS 98C.

[19] ZOU 96 is from the the measured quantities $|\rho_{+-0}| = 0.039^{+0.009}_{-0.006} \pm 0.005$ and $\phi_\rho = (-9 \pm 18)^\circ$.

[20] ADLER 96E is from the measured quantities Re($\lambda$) = $0.036 \pm 0.010^{+0.002}_{-0.003}$ and Im($\lambda$) consistent with zero. Note that the quantity $\lambda$ is the same as $\rho_{+-0}$ used in other footnotes.

[21] THOMSON 94 calculates this branching ratio from their measurements $|\rho_{+-0}| = 0.035^{+0.019}_{-0.011} \pm 0.004$ and $\phi_\rho = (-59 \pm 48)^\circ$ where $|\rho_{+-0}|e^{i\phi_\rho} = A(K^0_S \to \pi^+\pi^-\pi^0, I = 2)/A(K^0_L \to \pi^+\pi^-\pi^0)$.

## Modes with photons or $\ell\overline{\ell}$ pairs

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

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **2.59±0.08 OUR AVERAGE** | | | | |
| 2.56±0.09 | 1286 | RAMBERG 93 | E731 | $p_\gamma$ >50 MeV/$c$ |
| 2.68±0.15 | | [22] TAUREG 76 | SPEC | $p_\gamma$ >50 MeV/$c$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 7.10±0.22 | 3723 | RAMBERG 93 | E731 | $p_\gamma$ >20 MeV/$c$ |
| 3.0 ±0.6 | 29 | [23] BOBISUT 74 | HLBC | $p_\gamma$ >40 MeV/$c$ |
| 2.8 ±0.6 | | [24] BURGUN 73 | HBC | $p_\gamma$ >50 MeV/$c$ |

[22] TAUREG 76 find direct emission contribution <0.06, CL = 90%.

[23] BOBISUT 74 not included in average because $p_\gamma$ cut differs. Estimates direct emission contribution to be 0.5 or less, CL = 95%.

[24] BURGUN 73 estimates that direct emission contribution is 0.3 ± 0.6.

## $\Gamma(\pi^+\pi^-e^+e^-)/\Gamma_{\text{total}}$ $\Gamma_5/\Gamma$

| *VALUE* (units $10^{-5}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **4.69±0.30** | 676 | [25] LAI | 03C | NA48 | 1998+1999 data |

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

| *VALUE* (units $10^{-5}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| 4.71±0.23±0.22 | 620 | [25,26] LAI | 03C | NA48 | 1999 data |
| 4.5 ±0.7 ±0.4 | 56 | LAI | 00B | NA48 | 1998 data |

[25] Uses normalization BR($K_L \to \pi^+\pi^-\pi^0$)*BR($\pi^0 \to e^+e^-$) = $(1.505 \pm 0.047) \times 10^{-3}$ from our 2000 Edition.

[26] Second error is 0.16(syst)±0.15(norm) combined in quadrature.

## $\Gamma(\pi^0\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_6/\Gamma$

| *VALUE* (units $10^{-8}$) | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|---|
| **4.9±1.6±0.9** | | 17 | [27] LAI | 04 | NA48 | $m^2_{\gamma\gamma}/m^2_K > 0.2$ |

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

| *VALUE* (units $10^{-8}$) | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|---|
| <33 | 90 | | LAI | 03B | NA48 | $m^2_{\gamma\gamma}/m^2_K > 0.2$ |

[27] Spectrum also measured and found consistent with the one generated by a constant matrix element.

## $\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_7/\Gamma$

| *VALUE* (units $10^{-6}$) | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|---|
| **2.63 ±0.17 OUR AVERAGE** | | | Error includes scale factor of 3.0. | | | |
| 2.26 ±0.12 ±0.06 | | 711 | [28] AMBROSINO | 08C | KLOE | $\phi \to K^0_S K^0_L$ |
| 2.713±0.063±0.005 | | 7.5k | [29] LAI | 03 | NA48 | |

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

| *VALUE* (units $10^{-6}$) | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|---|
| 2.58 ±0.36 ±0.22 | | 149 | LAI | 00 | NA48 | |
| 2.2 ±1.1 | | 16 | [30] BARR | 95B | NA31 | |
| 2.4 ±0.9 | | 35 | [31] BARR | 95B | NA31 | |
| < 13 | 90 | | BALATS | 89 | SPEC | |
| 2.4 ±1.2 | | 19 | BURKHARDT | 87 | NA31 | |
| <133 | 90 | | BARMIN | 86B | XEBC | |

[28] AMBROSINO 08C reports $(2.26 \pm 0.12 \pm 0.06) \times 10^{-6}$ from a measurement of [$\Gamma(K^0_S \to \gamma\gamma)/\Gamma_{\text{total}}$] × [B($K^0_S \to \pi^0\pi^0$)] assuming B($K^0_S \to \pi^0\pi^0$) = $(30.69 \pm 0.05) \times 10^{-2}$.

[29] LAI 03 reports [$\Gamma(K^0_S \to \gamma\gamma)/\Gamma_{\text{total}}$] / [B($K^0_S \to \pi^0\pi^0$)] = $(8.84 \pm 0.18 \pm 0.10) \times 10^{-6}$ which we multiply by our best value B($K^0_S \to \pi^0\pi^0$) = $(30.69 \pm 0.05) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

[30] BARR 95B result is calculated using B($K_L \to \gamma\gamma$) = $(5.86 \pm 0.17) \times 10^{-4}$.

[31] BARR 95B quotes this as the combined BARR 95B + BURKHARDT 87 result after rescaling BURKHARDT 87 to use same branching ratios and lifetimes as BARR 95B.

## Semileptonic modes

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

| *VALUE* (units $10^{-4}$) | *EVTS* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **7.04 ±0.08 OUR FIT** | | | | |
| **7.04 ±0.08 OUR AVERAGE** | | | | |
| 7.046±0.18±0.16 | | [32] BATLEY 07D | NA48 | $K^0(\overline{K}^0)(t) \to \pi e \nu$ |
| 7.05 ±0.09 | 13k | [33] AMBROSINO 06E | KLOE | Not fitted |
| 6.91 ±0.34±0.15 | 624 | [34] ALOISIO 02 | KLOE | Tagged $K^0_S$ using $\phi \to K^0_L K^0_S$ |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 7.2 ±1.4 | 75 | AKHMETSHIN 99 | CMD2 | Tagged $K^0_S$ using $\phi \to K^0_L K^0_S$ |

[32] Reconstructed from $K^0(\overline{K}^0)(t) \to \pi e \nu$ distributions using PDG values of $B(K^0_L \to \pi e \nu) = 0.4053 \pm 0.0015$, $\tau_L = (5.114 \pm 0.021) \times 10^{-8}$ s and $\tau_S = (0.8958 \pm 0.0005) \times 10^{-10}$ s.

[33] Obtained by imposing $\Sigma_i$ $B(K^0_S \to i) = 1$, where $i$ runs over all the four branching ratios $\pi^+\pi^-$, $\pi^0\pi^0$, $\pi e \nu$, and $\pi \mu \nu$. Input value of $B(K^0_S \to \pi^+\pi^-)$ / $B(K^0_S \to \pi^0\pi^0)$ from AMBROSINO 06C is used. To derive $\Gamma(K^0_S \to \pi^+ \mu \nu)$ / $\Gamma(K^0_S \to \pi^+ e \nu)$, lepton universality is assumed, radiative corrections from ANDRE 07 are used, and phase space integrals are taken from KTeV, ALEXOPOULOS 04A. This branching fraction enters our fit via their $\Gamma(\pi^{\pm} e^{\mp} \nu_e)$ / $\Gamma(\pi^+\pi^-)$ branching ratio measurement.

[34] Uses the PDG 00 value for $B(K^0_S \to \pi^+\pi^-)$.

### $\Gamma(\pi^{\pm} \mu^{\mp} \nu_\mu)/\Gamma_{\text{total}}$ $\Gamma_9/\Gamma$

The PDG 06 value below has not been measured but is computed to be 0.666 times the $K_S \to \pi^{\pm} e^{\mp} \nu_e$ branching fraction. It is included in the fit that constrains the four branching ratios $\pi^+\pi^-$, $\pi^0\pi^0$, $\pi e \nu$, and $\pi \mu \nu$ to sum to 1. This treatment, used by AMBROSINO 06E, is preferable to our previous practice of constraining the $\pi^+\pi^-$ and $\pi^0\pi^0$ modes to sum to 1. The 0.666 factor is obtained from AMBROSINO 06E and assumes lepton universality, radiative corrections from ANDRE 07, and phase space integrals from KTeV, ALEXOPOULOS 04A.

| *VALUE* (units $10^{-4}$) | *DOCUMENT ID* | *COMMENT* |
|---|---|---|
| **4.69 ±0.06 OUR FIT** | | |
| **4.691±0.001±0.056** | [35] PDG 06 | calculated from $\pi^{\pm} e^{\mp} \nu_e$ |

[35] The PDG 06 value is computed to be $B_{PDG06}(\pi \mu \nu) = 0.666\ B_{FIT}(\pi e \nu)$. The first error specifies the arbitrarily small error, $0.001 \times 10^{-4}$, on $B_{PDG06}(\pi \mu \nu)$ for fixed $B_{FIT}(\pi e \nu)$. The second error is that due to the uncertainty in $B_{FIT}(\pi e \nu)$.

### $\Gamma(\pi^{\pm} e^{\mp} \nu_e)/\Gamma(\pi^+\pi^-)$ $\Gamma_8/\Gamma_2$

| *VALUE* (units $10^{-4}$) | *EVTS* | *DOCUMENT ID* | *TECN* |
|---|---|---|---|
| **10.18±0.12 OUR FIT** | | | |
| **10.19±0.11±0.07** | 13k | AMBROSINO 06E | KLOE |

## *CP* violating (*CP*) and $\Delta S = 1$ weak neutral current (*S1*) modes

### $\Gamma(3\pi^0)/\Gamma_{\text{total}}$ $\Gamma_{10}/\Gamma$

Violates *CP* conservation.

| *VALUE* (units $10^{-7}$) | *CL%* | *EVTS* | *DOCUMENT ID* | *TECN* |
|---|---|---|---|---|
| **< 1.2** | 90 | 37.8M | AMBROSINO 05B | KLOE |

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

| | | | | | |
|---|---|---|---|---|---|
| $<\ 7.4$ | 90 | 4.9M | [36] LAI | 05A | NA48 |
| $<140$ | 90 | 7M | ACHASOV | 99D | SND |
| $<190$ | 90 | 17300 | [37] ANGELOPO... | 98B | CPLR |
| $<370$ | 90 | | BARMIN | 83 | HLBC |

[36] LAI 05A value is obtained from their bound on $|\eta_{000}|$ (not assuming *CPT*) and B($K^0_L \rightarrow 3\pi^0$) = 0.211 ± 0.003, and PDG 04 values for $K^0_L$ and $K^0_S$ lifetimes. If *CPT* is assumed then B($K^0_S \rightarrow 3\pi^0)_{CPT} < 2.3 \times 10^{-7}$ at 90% CL

[37] ANGELOPOULOS 98B is from Im($\eta_{000}$) = $-0.05 \pm 0.12 \pm 0.05$, assuming Re($\eta_{000}$) = Re($\epsilon$) = $1.635 \times 10^{-3}$ and using the value B($K^0_L \rightarrow \pi^0\pi^0\pi^0$) = $0.2112 \pm 0.0027$.

## $\Gamma(\mu^+\mu^-)/\Gamma_{\rm total}$ $\Gamma_{11}/\Gamma$

Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined with electromagnetic interaction.

| *VALUE* (units $10^{-5}$) | *CL%* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **<0.032** | 90 | GJESDAL | 73 | ASPK |

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

| | | | | |
|---|---|---|---|---|
| $<0.7$ | 90 | HYAMS | 69B | OSPK |

## $\Gamma(e^+e^-)/\Gamma_{\rm total}$ $\Gamma_{12}/\Gamma$

Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined with electromagnetic interaction.

| *VALUE* (units $10^{-7}$) | *CL%* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| **< 0.09** | 90 | [38] AMBROSINO | 09A | KLOE | $e^+e^- \rightarrow \phi \rightarrow K^0_S K^0_L$ |

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

| | | | | | |
|---|---|---|---|---|---|
| $<\ 1.4$ | 90 | ANGELOPO... | 97 | CPLR | |
| $<\ 28$ | 90 | BLICK | 94 | CNTR | Hyperon facility |
| $<100$ | 90 | BARMIN | 86 | XEBC | |

[38] AMBROSINO 09A reports $< 0.09 \times 10^{-7}$ from a measurement of [$\Gamma(K^0_S \rightarrow e^+e^-)/\Gamma_{\rm total}$] / [B($K^0_S \rightarrow \pi^+\pi^-$)] assuming B($K^0_S \rightarrow \pi^+\pi^-$) = $(69.20 \pm 0.05) \times 10^{-2}$.

## $\Gamma(\pi^0 e^+e^-)/\Gamma_{\rm total}$ $\Gamma_{13}/\Gamma$

Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined with electromagnetic interaction.

| *VALUE* (units $10^{-9}$) | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|---|
| $\mathbf{3.0^{+1.5}_{-1.2} \pm 0.2}$ | | 7 | [39] BATLEY | 03 | NA48 | $m_{ee} > 0.165$ GeV |

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

| | | | | | |
|---|---|---|---|---|---|
| $<\ 140$ | 90 | | LAI | 01 | NA48 |
| $<\ 1100$ | 90 | 0 | BARR | 93B | NA31 |
| $<45000$ | 90 | | GIBBONS | 88 | E731 |

[39] BATLEY 03 extrapolate also to the full kinematical region using a constant form factor and a vector matrix element. The resulting branching ratio is $(5.8^{+2.9}_{-2.4}) \times 10^{-9}$.

### $\Gamma(\pi^0\mu^+\mu^-)/\Gamma_{\rm total}$ $\Gamma_{14}/\Gamma$

Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined with electromagnetic interaction.

| *VALUE* (units $10^{-9}$) | *EVTS* | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| $\mathbf{2.9^{+1.5}_{-1.2}\pm0.2}$ | 6 | [40] BATLEY | 04A | NA48 | NA48/1 $K^0_S$ beam |

[40] Background estimate is $0.22^{+0.18}_{-0.11}$ events. Branching ratio assumes a vector matrix element and unit form factor.

## $K^0_S$ FORM FACTORS

For discussion, see note on $K_{\ell3}$ form factors in the $K^\pm$ section of the Particle Listings above. Because the semileptonic branching fraction is smaller in $K^0_S$ than $K^0_L$ by the ratio of the mean lives, the $K^0_S$ semileptonic form factor has so far been measured only in the $K_{e3}$ mode using the linear expansion $f_+(t) = f_+(0)\ (1 + \lambda_+ t\ /m^2_{\pi^+})$, which gives the vector form factor $f_+(t)$ relative to its value at $t = 0$.

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

| *VALUE* (units $10^{-2}$) | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **3.39±0.41** | 15k | AMBROSINO | 06E | KLOE |

A REVIEW GOES HERE – Check our WWW List of Reviews

## *CP*-VIOLATION PARAMETERS IN $K^0_S$ DECAY

### $A_S = [\ \Gamma(K^0_S \to \pi^- e^+ \nu_e)\ \text{-}\ \Gamma(K^0_S \to \pi^+ e^- \overline{\nu}_e)\ ]\ /\ \text{SUM}$

Such asymmetry violates *CP*. If *CPT* is assumed then $A_S = 2\ \text{Re}(\epsilon)$.

| *VALUE* (units $10^{-3}$) | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|
| **1.5± 9.6±2.9** | 13k | AMBROSINO | 06E | KLOE |

## PARAMETERS FOR $K^0_S \to 3\pi$ DECAY

### $\text{Im}(\eta_{+-0})^2 = \Gamma(K^0_S \to \pi^+\pi^-\pi^0,\ CP\text{-violating})\ /\ \Gamma(K^0_L \to \pi^+\pi^-\pi^0)$

*CPT* assumed valid (i.e. $\text{Re}(\eta_{+-0}) \simeq 0$).

| *VALUE* | *CL%* | *EVTS* | *DOCUMENT ID* | | *TECN* |
|---|---|---|---|---|---|
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | | |
| <0.23 | 90 | 601 | [41] BARMIN | 85 | HLBC |
| <0.12 | 90 | 384 | METCALF | 72 | ASPK |

[41] BARMIN 85 find $\text{Re}(\eta_{+-0}) = (0.05 \pm 0.17)$ and $\text{Im}(\eta_{+-0}) = (0.15 \pm 0.33)$. Includes events of BALDO-CEOLIN 75.

## $\mathrm{Im}(\eta_{+-0}) = \mathrm{Im}(\mathrm{A}(K^0_S \to \pi^+\pi^-\pi^0, CP\text{-violating}) \;/\; \mathrm{A}(K^0_L \to \pi^+\pi^-\pi^0))$

| *VALUE* | *EVTS* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| $\mathbf{-0.002 \pm 0.009 ^{+0.002}_{-0.001}}$ | 500k | [42] ADLER 97B | CPLR | |

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

| *VALUE* | *EVTS* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| $-0.002 \pm 0.018 \pm 0.003$ | 137k | [43] ADLER 96D | CPLR | Sup. by ADLER 97B |
| $-0.015 \pm 0.017 \pm 0.025$ | 272k | [44] ZOU 94 | SPEC | |

[42] ADLER 97B also find $\mathrm{Re}(\eta_{+-0}) = -0.002 \pm 0.007^{+0.004}_{-0.001}$. See also ANGELOPOULOS 98C.

[43] The ADLER 96D fit also yields $\mathrm{Re}(\eta_{+-0}) = 0.006 \pm 0.013 \pm 0.001$ with a correlation $+0.66$ between real and imaginary parts. Their results correspond to $|\eta_{+-0}| < 0.037$ with 90% CL.

[44] ZOU 94 use theoretical constraint $\mathrm{Re}(\eta_{+-0}) = \mathrm{Re}(\epsilon) = 0.0016$. Without this constraint they find $\mathrm{Im}(\eta_{+-0}) = 0.019 \pm 0.061$ and $\mathrm{Re}(\eta_{+-0}) = 0.019 \pm 0.027$.

## $\mathrm{Im}(\eta_{000})^2 = \Gamma(K^0_S \to 3\pi^0) \;/\; \Gamma(K^0_L \to 3\pi^0)$

*CPT* assumed valid (i.e. $\mathrm{Re}(\eta_{000}) \simeq 0$). This limit determines branching ratio $\Gamma(3\pi^0)/\Gamma_{\mathrm{total}}$ above.

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

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

| *VALUE* | *CL%* | *EVTS* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|---|
| $<0.1$ | 90 | 632 | [45] BARMIN 83 | HLBC | |
| $<0.28$ | 90 | | [46] GJESDAL 74B | SPEC | Indirect meas. |

[45] BARMIN 83 find $\mathrm{Re}(\eta_{000}) = (-0.08 \pm 0.18)$ and $\mathrm{Im}(\eta_{000}) = (-0.05 \pm 0.27)$. Assuming *CPT* invariance they obtain the limit quoted above.

[46] GJESDAL 74B uses $K2\pi$, $K_{\mu3}$, and $K_{e3}$ decay results, unitarity, and *CPT*. Calculates $|(\eta_{000})| = 0.26 \pm 0.20$. We convert to upper limit.

## $\mathrm{Im}(\eta_{000}) = \mathrm{Im}(A(K^0_S \to \pi^0\pi^0\pi^0)/A(K^0_L \to \pi^0\pi^0\pi^0))$

$K^0_S \to \pi^0\pi^0\pi^0$ violates *CP* conservation, in contrast to $K^0_S \to \pi^+\pi^-\pi^0$ which has a *CP*-conserving part.

| *VALUE* | *EVTS* | *DOCUMENT ID* | *TECN* | *COMMENT* |
|---|---|---|---|---|
| $\mathbf{(-0.1 \pm 1.6) \times 10^{-2}}$ **OUR AVERAGE** | | | | |
| $0.000 \pm 0.009 \pm 0.013$ | 4.9M | [47] LAI 05A | NA48 | Assumes *CPT* |
| $-0.05 \pm 0.12 \pm 0.05$ | 17300 | [48] ANGELOPO... 98B | CPLR | Assumes *CPT* |

[47] LAI 05A assumes $\mathrm{Re}(\eta_{000}) = \mathrm{Re}(\epsilon) = 1.66 \times 10^{-3}$. The equivalent limit is $|\eta_{000}|_{CPT} < 0.025$ at 90% CL Without assuming *CPT* invariance, they obtain $\mathrm{Re}(\eta_{000}) = -0.002 \pm 0.011 \pm 0.015$ and $\mathrm{Im}(\eta_{000}) = -0.003 \pm 0.013 \pm 0.017$ with a statistical correlation coefficient of 0.77 and an overall correlation coefficient of 0.57 between imaginary and real part. The equivalent limit is $|\eta_{000}| < 0.045$ at 90% CL

[48] ANGELOPOULOS 98B assumes $\mathrm{Re}(\eta_{000}) = \mathrm{Re}(\epsilon) = 1.635 \times 10^{-3}$. Without assuming *CPT* invariance, they obtain $\mathrm{Re}(\eta_{000}) = 0.18 \pm 0.14 \pm 0.06$ and $\mathrm{Im}(\eta_{000}) = 0.15 \pm 0.20 \pm 0.03$.

## $|\eta_{000}| = |A(K^0_S \to 3\pi^0)/A(K^0_L \to 3\pi^0)|$

A non-zero value violates CP invariance.

| *VALUE* | *CL%* | *EVTS* | *DOCUMENT ID* | *TECN* |
|---|---|---|---|---|
| $\mathbf{<0.018}$ | 90 | 37.8M | AMBROSINO 05B | KLOE |

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

| *VALUE* | *CL%* | *EVTS* | *DOCUMENT ID* | *TECN* |
|---|---|---|---|---|
| $<0.045$ | 90 | 4.9M | LAI 05A | NA48 |

## 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 $K^0_S$ rest frame.

### *CP* asymmetry *A* in $K^0_S \rightarrow \pi^+\pi^- e^+ e^-$

| *VALUE* (%) | *DOCUMENT ID* | | *TECN* | *COMMENT* |
|---|---|---|---|---|
| **−1.1±4.1** | LAI | 03C | NA48 | 1998+1999 data |
| • • • We do not use the following data for averages, fits, limits, etc. • • • | | | | |
| 0.5±4.0±1.6 | LAI | 03C | NA48 | 1999 data |

## $K^0_S$ REFERENCES

| | | | | |
|---|---|---|---|---|
| AMBROSINO | 09A | PL B672 203 | F. Ambrosino *et al.* | (KLOE Collab.) |
| AMBROSINO | 08C | JHEP 0805 051 | F. Ambrosino *et al.* | (KLOE Collab.) |
| ANDRE | 07 | ANP 322 2518 | T. Andre | (EFI) |
| BATLEY | 07D | PL B653 145 | J.R. Batley *et al.* | (CERN NA48 Collab.) |
| AMBROSINO | 06C | EPJ C48 767 | F. Ambrosino *et al.* | (KLOE Collab.) |
| AMBROSINO | 06E | PL B636 173 | F. Ambrosino *et al.* | (KLOE Collab.) |
| PDG | 06 | JPG 33 1 | W.-M. Yao *et al.* | (PDG Collab.) |
| AMBROSINO | 05B | PL B619 61 | F. Ambrosino *et al.* | (KLOE Collab.) |
| BATLEY | 05 | PL B630 31 | J.R. Batley *et al.* | (NA48 Collab.) |
| LAI | 05A | PL B610 165 | A. Lai *et al.* | (CERN NA48 Collab.) |
| ALEXOPOU... | 04A | PR D70 092007 | T. Alexopoulos *et al.* | (FNAL KTeV Collab.) |
| BATLEY | 04A | PL B599 197 | J.R. Batley *et al.* | (NA48 Collab.) |
| LAI | 04 | PL B578 276 | A. Lai *et al.* | (CERN NA48 Collab.) |
| PDG | 04 | PL B592 1 | S. Eidelman *et al.* | (PDG Collab.) |
| ALAVI-HARATI | 03 | PR D67 012005 | A. Alavi-Harati *et al.* | (FNAL KTeV Collab.) |
| Also | | PR D70 079904 (errat.) | A. Alavi-Harati *et al.* | (FNAL KTeV Collab.) |
| BATLEY | 03 | PL B576 43 | J.R. Batley *et al.* | (CERN NA48 Collab.) |
| LAI | 03 | PL B551 7 | A. Lai *et al.* | (CERN NA48 Collab.) |
| LAI | 03B | PL B556 105 | A. Lai *et al.* | (CERN NA48 Collab.) |
| LAI | 03C | EPJ C30 33 | A. Lai *et al.* | (CERN NA48 Collab.) |
| ALOISIO | 02 | PL B535 37 | A. Aloisio *et al.* | (KLOE Collab.) |
| ALOISIO | 02B | PL B538 21 | A. Aloisio *et al.* | (KLOE Collab.) |
| LAI | 02C | PL B537 28 | A. Lai *et al.* | (CERN NA48 Collab.) |
| LAI | 01 | PL B514 253 | A. Lai *et al.* | (CERN NA48 Collab.) |
| LAI | 00 | PL B493 29 | A. Lai *et al.* | (CERN NA48 Collab.) |
| LAI | 00B | PL B496 137 | A. Lai *et al.* | (CERN NA48 Collab.) |
| PDG | 00 | EPJ C15 1 | D.E. Groom *et al.* | |
| ACHASOV | 99D | PL B459 674 | M.N. Achasov *et al.* | |
| AKHMETSHIN | 99 | PL B456 90 | R.R. Akhmetshin *et al.* | (Novosibirsk CMD-2 Collab.) |
| ANGELOPO... | 98B | PL B425 391 | A. Angelopoulos *et al.* | (CPLEAR Collab.) |
| ANGELOPO... | 98C | EPJ C5 389 | A. Angelopoulos *et al.* | (CPLEAR Collab.) |
| PDG | 98 | EPJ C3 1 | C. Caso *et al.* | |
| ADLER | 97B | PL B407 193 | R. Adler *et al.* | (CPLEAR Collab.) |
| ANGELOPO... | 97 | PL B413 232 | A. Angelopoulos *et al.* | (CPLEAR Collab.) |
| BERTANZA | 97 | ZPHY C73 629 | L. Bertanza | (PISA, CERN, EDIN, MANZ, ORSAY+) |
| ADLER | 96D | PL B370 167 | R. Adler *et al.* | (CPLEAR Collab.) |
| ADLER | 96E | PL B374 313 | R. Adler *et al.* | (CPLEAR Collab.) |
| ZOU | 96 | PL B369 362 | Y. Zou *et al.* | (RUTG, MINN, MICH) |
| BARR | 95B | PL B351 579 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| SCHWINGEN... | 95 | PRL 74 4376 | B. Schwingenheuer *et al.* | (EFI, CHIC+) |
| BLICK | 94 | PL B334 234 | A.M. Blick *et al.* | (SERP, JINR) |
| THOMSON | 94 | PL B337 411 | G.B. Thomson *et al.* | (RUTG, MINN, MICH) |
| ZOU | 94 | PL B329 519 | Y. Zou *et al.* | (RUTG, MINN, MICH) |
| BARR | 93B | PL B304 381 | G.D. Barr *et al.* | (CERN, EDIN, MANZ, LALO+) |
| GIBBONS | 93 | PRL 70 1199 | L.K. Gibbons *et al.* | (FNAL E731 Collab.) |
| Also | | PR D55 6625 | L.K. Gibbons *et al.* | (FNAL E731 Collab.) |

RAMBERG 93 PRL 70 2525 E. Ramberg *et al.* (FNAL E731 Collab.)
BALATS 89 SJNP 49 828 M.Y. Balats *et al.* (ITEP)
Translated from YAF 49 1332.
GIBBONS 88 PRL 61 2661 L.K. Gibbons *et al.* (FNAL E731 Collab.)
BURKHARDT 87 PL B199 139 H. Burkhardt *et al.* (CERN, EDIN, MANZ+)
GROSSMAN 87 PRL 59 18 N. Grossman *et al.* (MINN, MICH, RUTG)
BARMIN 86 SJNP 44 622 V.V. Barmin *et al.* (ITEP)
Translated from YAF 44 965.
BARMIN 86B NC 96A 159 V.V. Barmin *et al.* (ITEP, PADO)
PDG 86B PL 170B 130 M. Aguilar-Benitez *et al.* (CERN, CIT+)
BARMIN 85 NC 85A 67 V.V. Barmin *et al.* (ITEP, PADO)
Also SJNP 41 759 V.V. Barmin *et al.* (ITEP)
Translated from YAF 41 1187.
BARMIN 83 PL 128B 129 V.V. Barmin *et al.* (ITEP, PADO)
Also SJNP 39 269 V.V. Barmin *et al.* (ITEP, PADO)
Translated from YAF 39 428.
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 PL 116B 73 E. Fischbach *et al.* (PURD, BNL, CHIC)
Also PR D28 476 S.H. Aronson *et al.* (BNL, CHIC, PURD)
Also PR D28 495 S.H. Aronson *et al.* (BNL, CHIC, PURD)
ARONSON 76 NC 32A 236 S.H. Aronson *et al.* (WISC, EFI, UCSD+)
EVERHART 76 PR D14 661 G.C. Everhart *et al.* (PENN)
TAUREG 76 PL 65B 92 H. Taureg *et al.* (HEIDH, CERN, DORT)
BALDO-... 75 NC 25A 688 M. Baldo-Ceolin *et al.* (PADO, WISC)
CARITHERS 75 PRL 34 1244 W.C.J. Carithers *et al.* (COLU, NYU)
BOBISUT 74 LNC 11 646 F. Bobisut *et al.* (PADO)
COWELL 74 PR D10 2083 P.L. Cowell *et al.* (STON, COLU)
GEWENIGER 74B PL 48B 487 C. Geweniger *et al.* (CERN, HEIDH)
GJESDAL 74B PL 52B 119 S. Gjesdal *et al.* (CERN, HEIDH)
BURGUN 73 PL 46B 481 G. Burgun *et al.* (SACL, CERN)
GJESDAL 73 PL 44B 217 S. Gjesdal *et al.* (CERN, HEIDH)
HILL 73 PR D8 1290 D.G. Hill *et al.* (BNL, CMU)
ALITTI 72 PL 39B 568 J. Alitti, E. Lesquoy, A. Muller (SACL)
BURGUN 72 NP B50 194 G. Burgun *et al.* (SACL, CERN, OSLO)
METCALF 72 PL 40B 703 M. Metcalf *et al.* (CERN, IPN, WIEN)
MORSE 72B PRL 28 388 R. Morse *et al.* (COLO, PRIN, UMD)
NAGY 72 NP B47 94 E. Nagy, F. Telbisz, G. Vesztergombi (BUDA)
Also PL 30B 498 G. Bozoki *et al.* (BUDA)
SKJEGGEST... 72 NP B48 343 O. Skjeggestad *et al.* (OSLO, CERN, SACL)
BALTAY 71 PRL 27 1678 C. Baltay *et al.* (COLU)
Also Thesis Nevis 187 W.A. Cooper (COLU)
MOFFETT 70 BAPS 15 512 R. Moffett *et al.* (ROCH)
BOZOKI 69 PL 30B 498 G. Bozoki *et al.* (BUDA)
DOYLE 69 Thesis UCRL 18139 J.C. Doyle (LRL)
GOBBI 69 PRL 22 682 B. Gobbi *et al.* (ROCH)
HYAMS 69B PL 29B 521 B.D. Hyams *et al.* (CERN, MPIM)
MORFIN 69 PRL 23 660 J.G. Morfin, D. Sinclair (MICH)
DONALD 68B PL 27B 58 R.A. Donald *et al.* (LIVP, CERN, IPNP+)
HILL 68 PR 171 1418 D.G. Hill *et al.* (BNL, CMU)
AUBERT 65 PL 17 59 B. Aubert *et al.* (EPOL, ORSAY)
BROWN 63 PR 130 769 J.L. Brown *et al.* (LRL, MICH)
CHRETIEN 63 PR 131 2208 M. Chretien *et al.* (BRAN, BROW, HARV+)
BROWN 61 NC 19 1155 J.L. Brown *et al.* (MICH)
BOLDT 58B PRL 1 150 E. Boldt, D.O. Caldwell, Y. Pal (MIT)

## OTHER RELATED PAPERS

LITTENBERG 93 ARNPS 43 729 L.S. Littenberg, G. Valencia (BNL, FNAL)
Rare and Radiative Kaon Decays
BATTISTON 92 PRPL 214 293 R. Battiston *et al.* (PGIA, CERN, TRSTT)
Status and Perspectives of $K$ Decay Physics
TRILLING 65B UCRL 16473 G.N. Trilling (LRL)
Updated from 1965 Argonne Conference, page 115.
CRAWFORD 62 CERN Conf. 827 F.S. Crawford (LRL)
FITCH 61 NC 22 1160 V.L. Fitch, P.A. Piroue, R.B. Perkins (PRIN+)
GOOD 61 PR 124 1223 R.H. Good *et al.* (LRL)
BIRGE 60 Rochester Conf. 601 R.W. Birge *et al.* (LRL, WISC)
MULLER 60 PRL 4 418 F. Muller *et al.* (LRL, BNL)