\( K^0_L \)

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

\[
m_K^0 - m_K^0
\]


OUR FIT is described in the note on “CP violation in \( K_L \) decays” in the \( K_L^0 \) 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.

<table>
<thead>
<tr>
<th>VALUE ((10^{10} , \text{h}^{-1}))</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5293 ± 0.0009</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.3. Assuming CPT</td>
<td></td>
</tr>
<tr>
<td>0.5289 ± 0.0010</td>
<td>OUR FIT</td>
<td>Not assuming CPT</td>
<td></td>
</tr>
<tr>
<td>0.52797 ± 0.00195</td>
<td>1, 2 ABOUZAID 11</td>
<td>KTEV Not assuming CPT</td>
<td></td>
</tr>
<tr>
<td>0.52699 ± 0.00123</td>
<td>1, 3 ABOUZAID 11</td>
<td>KTEV Assuming CPT</td>
<td></td>
</tr>
<tr>
<td>0.5240 ± 0.0044 ± 0.0033</td>
<td>APOSTOLA... 99c</td>
<td>CPLR ( K^0 \bar{K}^0 ) to ( \pi^+ \pi^- )</td>
<td></td>
</tr>
<tr>
<td>0.5297 ± 0.0030 ± 0.0022</td>
<td>4 SCHWINGEN...95</td>
<td>E773 20–160 GeV K beams</td>
<td></td>
</tr>
<tr>
<td>0.5286 ± 0.0028</td>
<td>5 GIBBONS 93</td>
<td>E731 Assuming CPT</td>
<td></td>
</tr>
<tr>
<td>0.5257 ± 0.0049 ± 0.0021</td>
<td>4 GIBBONS 93c</td>
<td>E731 Not assuming CPT</td>
<td></td>
</tr>
<tr>
<td>0.5340 ± 0.00255 ± 0.0015</td>
<td>6 GEWENIGER 74c</td>
<td>SPEC Gap method</td>
<td></td>
</tr>
<tr>
<td>0.5334 ± 0.0040 ± 0.0015</td>
<td>6, 7 GJESDAL 74</td>
<td>SPEC Assuming CPT</td>
<td></td>
</tr>
</tbody>
</table>

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

- 0.5261 ± 0.0015 8 ALAVI-HARATI03 KTEV Assuming CPT
- 0.5288 ± 0.0043 9 ALAVI-HARATI03 KTEV Not assuming CPT
- 0.5343 ± 0.0063 ± 0.0025 10 ANGELOPO... 01 CPLR
- 0.5295 ± 0.0020 ± 0.0003 11 ANGELOPO... 98d CPLR Assuming CPT
- 0.5307 ± 0.0013 12 ADLER 96c RVUE
- 0.5274 ± 0.0029 ± 0.0005 11 ADLER 95 CPLR Sup. by ANGELOPOU-LOS 98d
- 0.482 ± 0.014 13 ARONSON 82b SPEC \( E=30–110 \) GeV
- 0.534 ± 0.007 14 CARNEGIE 71 ASPK Gap method
- 0.542 ± 0.006 14 ARONSON 70 ASPK Gap method
- 0.542 ± 0.006 CULLEN 70 CNTR

1 The two ABOUZAID 11 values use the same data. The first enters the “assuming CPT” fit and the second enters the “not assuming CPT” fit.

2 ABOUZAID 11 fit has \( \Delta m, \tau_S, \phi_\epsilon, \Re(\epsilon'/\epsilon), \) and \( \Im(\epsilon'/\epsilon) \) as free parameters. See \( \Im(\epsilon'/\epsilon) \) in the “\( K^0_L \) CP violation” section for correlation information.

3 ABOUZAID 11 fit has \( \Delta m \) and \( \tau_S \) free but constrains \( \phi_\epsilon \) to the Superweak value, i.e. assumes CPT. See “\( K^0_S \) Mean Life” section for correlation information.

4 Fits \( \Delta m \) and \( \phi_{+-} \) simultaneously. GIBBONS 93c systematic error is from B. Winstein via private communication. 20–160 GeV K beams.

5 GIBBONS 93 value assume \( \phi_{+-} = \phi_{00} = \phi_{SW} = (43.7 \pm 0.2)^\circ \), i.e. assumes CPT. 20–160 GeV K beams.

6 These two experiments have a common systematic error due to the uncertainty in the momentum scale, as pointed out in WAHL 89.
GJESDAL 74 uses charge asymmetry in \( K^0_{L2} \) decays.

ALAVI-HARATI 03 fit \( \Delta m \) and \( \tau_{K^0_S} \) simultaneously. \( \phi_{+-} \) is constrained to the Superweak value, i.e. CPT is assumed. See “\( K^0_S \) Mean Life” section for correlation information. Superseded by ABOUZAID 11.

ALAVI-HARATI 03 fit \( \Delta m \), \( \phi_{+-} \), and \( \tau_{K^0_S} \) simultaneously. See \( \phi_{+-} \) in the “\( K_L \) CP violation” section for correlation information. Superseded by ABOUZAID 11.

ANGELOPOULOS 01 uses strong interactions strangeness tagging at two different times.

Uses \( K^0_{e3} \) and \( K^0_{e3} \) strangeness tagging at production and decay. Assumes CPT conservation on \( \Delta S=\Delta Q \) transitions.

ADLER 96c is the result of a fit which includes nearly the same data as entered into the “OUR FIT” value above.

ARONSON 82 find that \( \Delta m \phi \) may depend on the kaon energy.

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\(^0\) MEAN LIFE**

<table>
<thead>
<tr>
<th>( \text{VALUE} ) ( (10^{-8} ) s)</th>
<th>( \text{EVTS} )</th>
<th>( \text{DOCUMENT ID} )</th>
<th>( \text{TECN} )</th>
<th>( \text{COMMENT} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.116( \pm )0.021 OUR FIT</td>
<td>Error includes scale factor of 1.1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.099( \pm )0.021 OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*5.072\( \pm \)0.011\( \pm \)0.035* 13M AMBROSINO 06 KLOE \( \sum_i B_i = 1 \)

*5.092\( \pm \)0.017\( \pm \)0.025* 15M AMBROSINO 05c KLOE

*5.154\( \pm \)0.044* 0.4M VOSBURGH 72 CNTR

\( \bullet \) \( \bullet \) \( \bullet \) We do not use the following data for averages, fits, limits, etc. \( \bullet \) \( \bullet \) \( \bullet \)

5.15 \( \pm \)0.14 DEVLIN 67 CNTR

1 AMBROSINO 06 uses \( \phi \rightarrow K_L K_S \) with \( K_L \) tagged by \( K_S \rightarrow \pi^+\pi^- \). The four major \( K_L \) BR’s are measured, the small remainder \( (\pi^+\pi^-) \) is taken from PDG 04. This KLOE \( K_L \) lifetime is obtained by imposing \( \sum_i B_i = 1 \). The correlation matrix among the four measured \( K_L \) BR’s and this \( K_L \) lifetime is

\[
\begin{array}{cccc}
K_{e3} & K_{\mu3} & 3\pi^0 & \pi^+\pi^-\pi^0 & \tau_{K_L} \\
K_{e3} & 1 & -0.25 & -0.56 & -0.07 & 0.25 \\
K_{\mu3} & 1 & -0.43 & -0.20 & 0.33 \\
3\pi^0 & 1 & -0.39 & -0.21 \\
\pi^+\pi^-\pi^0 & 1 & -0.39 \\
\tau_{K_L} & 1 & & & \\
\end{array}
\]

These correlations are taken into account in our fit. The average of this KLOE mean life measurement and the independent KLOE measurement in AMBROSINO 05c is \((5.084 \pm 0.023) \times 10^{-8}\) s.

**K\(^L\) DECAY MODES**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Scale factor/Confidence level</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Gamma_1 ) ( \pi^\pm e^\mp \nu_\nu )</td>
<td>[a] ((40.55 \pm 0.11))% S=1.7</td>
</tr>
</tbody>
</table>

Called \( K^0_e \).

---

[a] This value is taken from the Particle Data Group compilation.

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\[ \Gamma_2 \pi^\pm \mu^\mp \nu_\mu \quad [a] \quad (27.04 \pm 0.07) \% \quad S = 1.1 \]

Called \( K^0_{\mu 3} \).

\[ \Gamma_3 (\pi \mu \text{ atom}) \nu \quad \quad (1.05 \pm 0.11) \times 10^{-7} \]

\[ \Gamma_4 \pi^0 \pi^\pm e^\mp \nu \quad [a] \quad (5.20 \pm 0.11) \times 10^{-5} \]

\[ \Gamma_5 \pi^\pm e^\mp \nu e^+ e^- \quad [a] \quad (1.26 \pm 0.04) \times 10^{-5} \]

### Hadronic modes, including Charge conjugation \times Parity Violating (CPV) modes

\[ \Gamma_6 3\pi^0 \quad (19.52 \pm 0.12) \% \quad S = 1.6 \]

\[ \Gamma_7 \pi^+ \pi^- \pi^0 \quad (12.54 \pm 0.05) \% \]

\[ \Gamma_8 \pi^+ \pi^- \quad CPV \quad [b] \quad (1.967 \pm 0.010) \times 10^{-3} \quad S = 1.5 \]

\[ \Gamma_9 \pi^0 \pi^0 \quad CPV \quad (8.64 \pm 0.06) \times 10^{-4} \quad S = 1.8 \]

### Semileptonic modes with photons

\[ \Gamma_{10} \pi^\pm e^\mp \nu e \gamma \quad [a,c,d] \quad (3.79 \pm 0.06) \times 10^{-3} \]

\[ \Gamma_{11} \pi^\pm \mu^\mp \nu_\mu \gamma \quad (5.65 \pm 0.23) \times 10^{-4} \]

### Hadronic modes with photons or \( \ell \ell \) pairs

\[ \Gamma_{12} \pi^0 \pi^0 \gamma \quad < \quad 2.43 \times 10^{-7} \quad CL = 90\% \]

\[ \Gamma_{13} \pi^+ \pi^- \gamma \quad [c,d] \quad (4.15 \pm 0.15) \times 10^{-5} \quad S = 2.8 \]

\[ \Gamma_{14} \pi^+ \pi^- \gamma \quad [DE] \quad (2.84 \pm 0.11) \times 10^{-5} \quad S = 2.0 \]

\[ \Gamma_{15} \pi^0 \gamma \quad [c] \quad (1.273 \pm 0.033) \times 10^{-6} \]

\[ \Gamma_{16} \pi^0 e^+ e^- \quad (1.62 \pm 0.17) \times 10^{-8} \]

### Other modes with photons or \( \ell \ell \) pairs

\[ \Gamma_{17} 2\gamma \quad (5.47 \pm 0.04) \times 10^{-4} \quad S = 1.1 \]

\[ \Gamma_{18} 3\gamma \quad < \quad 7.4 \times 10^{-8} \quad CL = 90\% \]

\[ \Gamma_{19} e^+ e^- \gamma \quad (9.4 \pm 0.4) \times 10^{-6} \quad S = 2.0 \]

\[ \Gamma_{20} \mu^+ \mu^- \gamma \quad (3.59 \pm 0.11) \times 10^{-7} \quad S = 1.3 \]

\[ \Gamma_{21} e^+ e^- \gamma \quad [c] \quad (5.95 \pm 0.33) \times 10^{-7} \]

\[ \Gamma_{22} \mu^+ \mu^- \gamma \quad [c] \quad (1.0 \pm 0.8) \times 10^{-6} \]

### Charge conjugation \times Parity (CP) or Lepton Family number (LF)

\[ \text{violating modes, or } \Delta S = 1 \text{ weak neutral current (SI) modes} \]

\[ \Gamma_{23} \mu^+ \mu^- \quad S1 \quad (6.84 \pm 0.11) \times 10^{-9} \]

\[ \Gamma_{24} e^+ e^- \quad S1 \quad (9 \pm 6^{-4}) \times 10^{-12} \]

\[ \Gamma_{25} \pi^+ \pi^- e^+ e^- \quad S1 \quad [c] \quad (3.11 \pm 0.19) \times 10^{-7} \]

\[ \Gamma_{26} \pi^0 \pi^0 e^+ e^- \quad S1 \quad < \quad 6.6 \times 10^{-9} \quad CL = 90\% \]

\[ \Gamma_{27} \pi^0 \pi^0 \mu^+ \mu^- \quad S1 \quad < \quad 9.2 \times 10^{-11} \quad CL = 90\% \]

\[ \Gamma_{28} \mu^+ \mu^- e^+ e^- \quad S1 \quad (2.69 \pm 0.27) \times 10^{-9} \]

\[ \Gamma_{29} e^+ e^- e^+ e^- \quad S1 \quad (3.56 \pm 0.21) \times 10^{-8} \]

\[ \Gamma_{30} \pi^0 \mu^+ \mu^- \quad CP, S1 \quad [e] \quad < \quad 3.8 \times 10^{-10} \quad CL = 90\% \]

\[ \Gamma_{31} \pi^0 e^+ e^- \quad CP, S1 \quad [e] \quad < \quad 2.8 \times 10^{-10} \quad CL = 90\% \]

\[ \Gamma_{32} \pi^0 \nu \bar{\nu} \quad CP, S1 \quad [f] \quad < \quad 2.6 \times 10^{-8} \quad CL = 90\% \]

\[ \Gamma_{33} \pi^0 \pi^0 \nu \bar{\nu} \quad S1 \quad < \quad 8.1 \times 10^{-7} \quad CL = 90\% \]

\[ \Gamma_{34} e^\pm \mu^\mp \quad LF \quad [a] \quad < \quad 4.7 \times 10^{-12} \quad CL = 90\% \]

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CONSTRANDED FIT INFORMATION

An overall fit to the mean life and 15 branching ratios uses 27 measurements and one constraint to determine 11 parameters. The overall fit has a $\chi^2 = 37.4$ for 17 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta p_i \delta p_j \rangle/(\delta p_i \delta p_j)$, in percent, from the fit to parameters $p_i$, including 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.

| x2 | -21 |
| x6 | -77 -29 |
| x7 | -15 -20 -18 |
| x8 | 53 -11 -47  4 |
| x9 | 30 -23 -11 -12 64 |
| x13|  6 -1  -6  0  12  8 |
| x14|  6 -1  -6  0  11  7  93 |
| x17| -46 -22  64 -14 -21  8 -3 -3 |
| x19|  -5  -2  7  -1 -3 -1  0  0  4 |
| $\Gamma$| -27 -9 24 15 -13 -6 -2 -2 15  2 |

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<table>
<thead>
<tr>
<th>Mode</th>
<th>Rate ($10^8$ s$^{-1}$)</th>
<th>Scale factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Gamma_1$ $\pi^\pm e^\mp \nu_\mu$</td>
<td>$[a]$ $0.07927\pm0.00034$</td>
<td>1.1</td>
</tr>
<tr>
<td>Called $K_{e3}^0$.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Gamma_2$ $\pi^\pm \mu^\mp \nu_\mu$</td>
<td>$[a]$ $0.05286\pm0.00025$</td>
<td>1.1</td>
</tr>
<tr>
<td>Called $K_{\mu3}^0$.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Gamma_6$ $3\pi^0$</td>
<td>$0.03815\pm0.00030$</td>
<td>1.5</td>
</tr>
<tr>
<td>$\Gamma_7$ $\pi^+ \pi^- \pi^0$</td>
<td>$0.02451\pm0.00015$</td>
<td></td>
</tr>
<tr>
<td>$\Gamma_8$ $\pi^+ \pi^-$</td>
<td>$[b]$ $(3.844\pm0.023) \times 10^{-4}$</td>
<td>1.2</td>
</tr>
<tr>
<td>$\Gamma_9$ $\pi^0 \pi^0$</td>
<td>$(1.690\pm0.013) \times 10^{-4}$</td>
<td>1.4</td>
</tr>
<tr>
<td>$\Gamma_{13}$ $\pi^+ \pi^- \gamma$</td>
<td>$[c,d]$ $(8.11\pm0.29) \times 10^{-6}$</td>
<td>2.7</td>
</tr>
<tr>
<td>$\Gamma_{14}$ $\pi^+ \pi^- \gamma$(DE)</td>
<td>$(5.55\pm0.21) \times 10^{-6}$</td>
<td>2.0</td>
</tr>
<tr>
<td>$\Gamma_{17}$ $2\gamma$</td>
<td>$(1.069\pm0.010) \times 10^{-4}$</td>
<td>1.2</td>
</tr>
<tr>
<td>$\Gamma_{19}$ $e^+ e^- \gamma$</td>
<td>$(1.84\pm0.08) \times 10^{-6}$</td>
<td>1.9</td>
</tr>
</tbody>
</table>

### $K_L^0$ Decay Rates

<table>
<thead>
<tr>
<th>$\Gamma(\pi^+ \pi^- \pi^0)$</th>
<th>$\Gamma_7$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VALUE ($10^6$ s$^{-1}$)</strong></td>
<td><strong>EVTS</strong></td>
</tr>
<tr>
<td><strong>2.451±0.015 OUR FIT</strong></td>
<td></td>
</tr>
<tr>
<td>●●● We do not use the following data for averages, fits, limits, etc. ●●●</td>
<td></td>
</tr>
<tr>
<td>2.32 $±0.13$</td>
<td>192</td>
</tr>
<tr>
<td>2.35 $±0.20$</td>
<td>180</td>
</tr>
<tr>
<td>2.71 $±0.28$</td>
<td>99</td>
</tr>
<tr>
<td>2.5 $±0.3$</td>
<td>98</td>
</tr>
<tr>
<td>2.12 $±0.33$</td>
<td>50</td>
</tr>
<tr>
<td>2.20 $±0.35$</td>
<td>53</td>
</tr>
<tr>
<td>2.62 $±0.28$</td>
<td>136</td>
</tr>
<tr>
<td>3.26 $±0.77$</td>
<td>18</td>
</tr>
<tr>
<td>1.4 $±0.4$</td>
<td>14</td>
</tr>
</tbody>
</table>

1 JAMES 72 is a final measurement and includes JAMES 71.

<table>
<thead>
<tr>
<th>$\Gamma(\pi^\pm e^\mp \nu_\mu)$</th>
<th>$\Gamma_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VALUE ($10^6$ s$^{-1}$)</strong></td>
<td><strong>EVTS</strong></td>
</tr>
<tr>
<td><strong>7.927±0.034 OUR FIT</strong></td>
<td></td>
</tr>
<tr>
<td>●●● We do not use the following data for averages, fits, limits, etc. ●●●</td>
<td></td>
</tr>
<tr>
<td>7.81 $±0.56$</td>
<td>620</td>
</tr>
<tr>
<td>7.52 $±0.85$</td>
<td>620</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\Gamma(\pi^\pm e^\mp \nu_\mu) + \Gamma(\pi^\pm \mu^\mp \nu_\mu)$</th>
<th>($\Gamma_1+\Gamma_2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VALUE ($10^6$ s$^{-1}$)</strong></td>
<td><strong>EVTS</strong></td>
</tr>
<tr>
<td><strong>13.21±0.05 OUR FIT</strong></td>
<td></td>
</tr>
<tr>
<td>12.4 $±0.7$</td>
<td>410</td>
</tr>
<tr>
<td>8.47 $±1.69$</td>
<td>126</td>
</tr>
</tbody>
</table>

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\[ K_L^0 \text{ BRANCHING RATIOS} \]

--- Semileptonic modes ---

\[ \frac{\Gamma(\pi^\pm e^\mp \nu_e)}{\Gamma_{\text{total}}} \]

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4055 \pm 0.0011 OUR FIT</td>
<td>Error includes scale factor of 1.7.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4047 \pm 0.0028 OUR AVERAGE</td>
<td>Error includes scale factor of 3.1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4007 \pm 0.0005 \pm 0.0015</td>
<td>13M</td>
<td>1</td>
<td>AMBROSINO 06 KLOE</td>
</tr>
<tr>
<td>0.4067 \pm 0.0011</td>
<td></td>
<td>2</td>
<td>ALEXOPOULOS 04 KTEV</td>
</tr>
</tbody>
</table>

1 There are correlations between these five KLOE measurements: \(B(K_L \rightarrow \pi e\nu), B(K_L \rightarrow \pi \mu\nu), B(K_L \rightarrow 3\pi^0), B(K_L \rightarrow \pi^+\pi^-\pi^0)\), and \(\tau_{K_L}\) measured in AMBROSINO 06. See the footnote for the \(\tau_{K_L}\) measurement for the correlation matrix.

2 ALEXOPOULOS 04 constrains \(\sum_i B_i = 0.9993\) for the six major \(K_L\) branching fractions. The correlations among these branching fractions are taken into account in our fit. The correlation matrix is

\[
\begin{pmatrix}
K_{e3} & K_{\mu3} & 3\pi^0 & \pi^+\pi^-\pi^0 & \pi^+\pi^- & \pi^0\pi^0 \\
K_{e3} & 1 & -0.77 & -0.62 & 1 \\
K_{\mu3} & 1 & 0.15 & 3\pi^0 & -0.28 & 0.22 & 0.18 & 0.08 & -0.54 & 1 \\
3\pi^0 & -0.77 & -0.62 & 1 & -0.72 & -0.54 & 0.89 & -0.46 & -0.39 & 1 \\
\pi^+\pi^-\pi^0 & 0.15 & 3\pi^0 & -0.28 & 0.22 & -0.48 & 0.49 & 1 \\
\pi^+\pi^- & -0.77 & -0.62 & 1 & -0.72 & -0.54 & 0.89 & -0.46 & -0.39 & 1 \\
\pi^0\pi^0 & 0.15 & 3\pi^0 & 0.18 & 0.08 & -0.54 & 1 & -0.72 & -0.54 & 0.89 & -0.46 & -0.39 & 1 \\
\end{pmatrix}
\]

\[ \frac{\Gamma(\pi^\pm \mu^\mp \nu_\mu)}{\Gamma_{\text{total}}} \]

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2704 \pm 0.0007 OUR FIT</td>
<td>Error includes scale factor of 1.1.</td>
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<td></td>
</tr>
<tr>
<td>0.2700 \pm 0.0008 OUR AVERAGE</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>0.2698 \pm 0.0005 \pm 0.0015</td>
<td>13M</td>
<td>1</td>
<td>AMBROSINO 06 KLOE</td>
</tr>
<tr>
<td>0.2701 \pm 0.0009</td>
<td></td>
<td>2</td>
<td>ALEXOPOULOS 04 KTEV</td>
</tr>
</tbody>
</table>

1 There are correlations between these five KLOE measurements: \(B(K_L \rightarrow \pi e\nu), B(K_L \rightarrow \pi \mu\nu), B(K_L \rightarrow 3\pi^0), B(K_L \rightarrow \pi^+\pi^-\pi^0)\), and \(\tau_{K_L}\) measured in AMBROSINO 06. See the footnote for the \(\tau_{K_L}\) measurement for the correlation matrix.

2 For correlations with other ALEXOPOULOS 04 measurements, see the footnote with their \(B(K_L \rightarrow \pi e\nu)\) measurement.

\[ \frac{\Gamma(\pi^\pm e^\mp \nu_e) + \Gamma(\pi^\pm \mu^\mp \nu_\mu)}{\Gamma_{\text{total}}} \]

<table>
<thead>
<tr>
<th>VALUE</th>
<th>DOCUMENT ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6760 \pm 0.0012 OUR FIT</td>
<td>Error includes scale factor of 1.6.</td>
</tr>
</tbody>
</table>

---

Citation: C. Patrignani et al. (Particle Data Group), Chin. Phys. C, 40, 100001 (2016) and 2017 update
\[ \Gamma(\pi^\pm \mu^\mp \nu_\mu) / \Gamma(\pi^\pm e^\mp \nu_e) \quad \Gamma_2/\Gamma_1 \]

\begin{tabular}{llll}
\hline
\textbf{Value} & \textbf{EVTS} & \textbf{Document ID} & \textbf{TECN} & \textbf{Comment} \\
\hline
0.6669 \pm 0.0027 & OUR FIT & & & Error includes scale factor of 1.2. \\
0.666 \pm 0.004 & OUR AVERAGE & & & Error includes scale factor of 1.6. \\
\hline
\end{tabular}

• • • We use the following data for averages but not for fits. • • •

- 0.6740 \pm 0.0059 AMBROSINO 06 KLOE Not in fit
- 0.6640 \pm 0.0014 \pm 0.0022 ALEXOPOULOS 04 KTEV Not in fit

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

- 0.702 \pm 0.011 33k CHO 80 HBC
- 0.662 \pm 0.037 10k WILLIAMS 74 ASPK
- 0.741 \pm 0.044 6700 BRANDENBURG 73 HBC
- 0.662 \pm 0.030 1309 EVANS 73 HLBC
- 0.68 \pm 0.08 3548 BASILE 70 OSPK
- 0.71 \pm 0.05 770 BUDAGOV 68 HLBC

1 AMBROSINO 06 enters the fit via their separate measurements of these two modes.
2 ALEXOPOULOS 04 enters the fit via their separate measurements of these two modes.

\[ \Gamma((\pi \mu \text{atom}) \nu) / \Gamma(\pi^\pm e^\mp \nu) \quad \Gamma_3/\Gamma_2 \]

\begin{tabular}{llll}
\hline
\textbf{Value} (units \(10^{-7}\)) & \textbf{EVTS} & \textbf{Document ID} & \textbf{TECN} \\
\hline
3.90 \pm 0.39 & 155 & 1 ARONSON 86 SPEC & \\
\hline
\end{tabular}

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

- seen 18 COOMBES 76 WIRE

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

\[ \Gamma(\pi^0 \pi^\pm e^\mp \nu) / \Gamma_{\text{total}} \quad \Gamma_4/\Gamma \]

\begin{tabular}{llll}
\hline
\textbf{Value} (units \(10^{-5}\)) & \textbf{CL\%} & \textbf{EVTS} & \textbf{Document ID} & \textbf{TECN} \\
\hline
5.21 \pm 0.07 \pm 0.09 & & 5402 & BATLEY 04 NA48 & \\
5.16 \pm 0.20 & & 729 & MAKOFF 93 E731 & \\
\hline
\end{tabular}

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

- 6.2 \pm 2.0 & 16 CARROLL 80c SPEC
- < 220 & 90 DONALDSON 74 SPEC

1 DONALDSON 74 uses \(K_L^0 \rightarrow \pi^+ \pi^- \pi^0\) (all \(K_L^0\) decays) = 0.126.

\[ \Gamma(\pi^\pm e^\mp \nu e^+ e^-) / \Gamma(\pi^+ \pi^- \pi^0) \quad \Gamma_5/\Gamma_7 \]

\begin{tabular}{llll}
\hline
\textbf{Value} (units \(10^{-5}\)) & \textbf{EVTS} & \textbf{Document ID} & \textbf{TECN} & \textbf{Comment} \\
\hline
10.02 \pm 0.17 \pm 0.29 & 19k & 1 ABOUZAID 07c KTEV & \\
\hline
\end{tabular}

1 \(E_{ee}^*\) is the energy of the \(e^+ e^-\) pair in the kaon rest frame. ABOUZAID 07c reports \(\left[ \Gamma(\pi_L^0 \rightarrow \pi^\pm e^\mp \nu e^+ e^-) / \Gamma(\pi_L^0 \rightarrow \pi^+ \pi^- \pi^0) \right] / [B(\pi^0 \rightarrow e^+ e^-)] = (8.54 \pm 0.07 \pm 0.13) \times 10^{-3}\) which we multiply by our best value \(B(\pi^0 \rightarrow e^+ e^-) = (1.174 \pm 0.035) \times 10^{-2}\). Our first error is their experiment’s error and our second error is the systematic error from using our best value.
**Hadronic modes, including Charge conjugation×Parity Violating (CPV) modes**

\[
\frac{\Gamma(3\pi^0)}{\Gamma_{\text{total}}} \quad \frac{\Gamma_6}{\Gamma} \\
\textbf{VALUE} \quad \textbf{EVTS} \quad \textbf{DOCUMENT ID} \quad \textbf{TECN} \quad \textbf{COMMENT}
\]

\[
0.1952 \pm 0.0012 \quad \text{OUR FIT} \quad \text{Error includes scale factor of 1.6.} \\
0.1969 \pm 0.0026 \quad \text{OUR AVERAGE} \quad \text{Error includes scale factor of 2.0.}
\]

\[
0.1997 \pm 0.0003 \pm 0.0019 \quad 13M \quad 1 \quad \text{AMBROSINO 06 KLOE Not fitted} \\
0.1945 \pm 0.0018 \quad 1 \quad \text{ALEXOPOU... 04 KTEV Not fitted}
\]

We exclude these \(B(K_L \to 3\pi^0)\) measurements from our fit because the authors have constrained \(K_L\) branching fractions to sum to one. It enters our fit via the other measurements from the experiment and their correlations, along with our constraint that the fitted branching fractions sum to one.

\[
\frac{\Gamma(3\pi^0)/\Gamma(\pi^\pm e^\mp \nu_e)}{\Gamma_6/\Gamma_1} \\
\textbf{VALUE} \quad \textbf{EVTS} \quad \textbf{DOCUMENT ID} \quad \textbf{TECN} \quad \textbf{COMMENT}
\]

\[
0.481 \pm 0.004 \quad \text{OUR FIT} \quad \text{Error includes scale factor of 1.8.} \\
\]

\[
0.4782 \pm 0.0014 \pm 0.0053 \quad 209K \quad 1 \quad \text{ALEXOPOU... 04 KTEV Not in fit} \\
\]

\[
0.545 \pm 0.004 \pm 0.009 \quad 38k \quad \text{KREUTZ 95 NA31}
\]

This measurement enters the fit via their separate measurements of these two modes.

\[
\frac{\Gamma(3\pi^0)/[\Gamma(\pi^\pm e^\mp \nu_e) + \Gamma(\pi^\pm \mu^\mp \nu_\mu) + \Gamma(\pi^+ \pi^- \pi^0)]}{\Gamma_6/(\Gamma_1+\Gamma_2+\Gamma_7)} \\
\textbf{VALUE} \quad \textbf{EVTS} \quad \textbf{DOCUMENT ID} \quad \textbf{TECN} \quad \textbf{COMMENT}
\]

\[
0.2436 \pm 0.0018 \quad \text{OUR FIT} \quad \text{Error includes scale factor of 1.6.} \\
\]

\[
0.251 \pm 0.014 \quad 549 \quad \text{BUDAGOV 68 HLBC ORSAY measur.} \\
0.277 \pm 0.021 \quad 444 \quad \text{BUDAGOV 68 HLBC Ecole polytech.meas} \\
0.31 \pm 0.07 \quad 29 \quad \text{KULYUKINA 68 CC} \\
0.24 \pm 0.08 \quad 24 \quad \text{ANIKINA 64 CC}
\]

\[
\frac{\Gamma(3\pi^0)/\Gamma(\pi^+ \pi^- \pi^0)}{\Gamma_6/\Gamma_7} \\
\textbf{VALUE} \quad \textbf{EVTS} \quad \textbf{DOCUMENT ID} \quad \textbf{TECN} \quad \textbf{COMMENT}
\]

\[
1.557 \pm 0.012 \quad \text{OUR FIT} \quad \text{Error includes scale factor of 1.3.} \\
\]

\[
1.582 \pm 0.027 \quad 13M \quad 1 \quad \text{AMBROSINO 06 KLOE Not in fit} \\
\]

\[
1.611 \pm 0.014 \pm 0.034 \quad 28k \quad \text{KREUTZ 95 NA31} \\
1.65 \pm 0.07 \quad 883 \quad \text{BARMIN 72b HLBC Error statistical only} \\
1.80 \pm 0.13 \quad 1010 \quad \text{BUDAGOV 68 HLBC} \\
2.0 \pm 0.6 \quad 188 \quad \text{ALEKSANYAN 64b FBC}
\]

\[1^\text{AMBR0SINO 06 enters the fit via their separate measurements of these two modes.}\]
\( \Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}} \) / \( \Gamma_{7}/\Gamma \)

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1254 ± 0.0005 OUR FIT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1255 ± 0.0006 OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 There are correlations between these five KLOE measurements: \( B(K_L \rightarrow \pi e\nu) \), \( B(K_L \rightarrow \pi\mu\nu) \), \( B(K_L \rightarrow 3\pi^0) \), \( B(K_L \rightarrow \pi^+\pi^-\pi^0) \), and \( \tau_{K_L} \) measured in AMBROSINO 06. See the footnote for the \( \tau_{K_L} \) measurement for the correlation matrix.

2 For correlations with other ALEXOPOULOS 04 measurements, see the footnote with their \( B(K_L \rightarrow \pi e\nu) \) measurement.

\( \Gamma(\pi^+\pi^-\pi^0)/\Gamma(\pi^\pm e^\mp \nu_e) \) / \( \Gamma_{7}/\Gamma_1 \)

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3092 ± 0.0016 OUR FIT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 This measurement enters the fit via their separate measurements for the two modes.

\( \Gamma(\pi^+\pi^-\pi^0)/[\Gamma(\pi^\pm e^\mp \nu_e) + \Gamma(\pi^\pm \mu^\mp \nu_\mu) + \Gamma(\pi^+\pi^-\pi^0)] \) / \( \Gamma_7/(\Gamma_1+\Gamma_2+\Gamma_7) \)

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1565 ± 0.0006 OUR FIT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 For correlations with other ALEXOPOULOS 04 measurements, see the footnote with their \( B(K_L \rightarrow \pi e\nu) \) measurement.

\( \Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}} \) / \( \Gamma_8/\Gamma \)

<table>
<thead>
<tr>
<th>VALUE (units 10^{-3})</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.967 ± 0.010 OUR FIT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 For correlations with other ALEXOPOULOS 04 measurements, see the footnote with their \( B(K_L \rightarrow \pi e\nu) \) measurement.
\[
\frac{\Gamma(\pi^+\pi^-)/\Gamma(\pi^\pm e^\mp\nu_e)}{\Gamma_8/\Gamma_1}
\]

\[
\text{VALUE (units 10}^{-3}\text{)} \quad \text{EVTS} \quad \text{DOCUMENT ID} \quad \text{TECN} \quad \text{COMMENT}
\]

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.849 ± 0.020</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.840 ± 0.020</td>
<td>OUR AVERAGE</td>
<td>47k LAI 07 NA48</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\*\*\* We use the following data for averages but not for fits. \*\*\*

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.856 ± 0.017</td>
<td>84k ALEXOPO... 04 KTEV</td>
<td>Not in fit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 The LAI 07 central value of 4.835 × 10\(^{-3}\) has been reduced by 0.19% to 4.826 × 10\(^{-3}\) to subtract the contribution from the direct emission mode \(K_L^0 \rightarrow \pi^+\pi^-\gamma\)(DE).

2 This measurement enters the fit via their separate measurements for the two modes.

\[
\left[\frac{\Gamma(\pi^+\pi^-) + \Gamma(\pi^+\pi^-\gamma(\text{DE}))}{\Gamma(\pi^\pm \mu^\mp\nu_{\mu})}\right] / \Gamma_2 \quad \Gamma_8/\Gamma_1
\]

\[
\text{VALUE (units 10}^{-3}\text{)} \quad \text{EVTS} \quad \text{DOCUMENT ID} \quad \text{TECN} \quad \text{COMMENT}
\]

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<tr>
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<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.38 ± 0.04</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.275 ± 0.042</td>
<td>OUR FIT</td>
<td>45k AMBROSINO 06f KLOE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Fully inclusive. Taking B(\(K_L^0 \rightarrow \pi\mu\nu\)) from KLOE, AMBROSINO 06, B(\(K_L^0 \rightarrow \pi^+\pi^- + \pi^+\pi^-\gamma(\text{DE})\)) = (1.963 ± 0.012 ± 0.017) × 10\(^{-3}\) is obtained.

\[
\frac{\Gamma(\pi^+\pi^-)/\left[\Gamma(\pi^\pm e^\mp\nu_e) + \Gamma(\pi^\pm \mu^\mp\nu_{\mu})\right]}{\Gamma_8/\Gamma_1+\Gamma_2}
\]

Violates \(CP\) conservation.

\[
\text{VALUE (units 10}^{-3}\text{)} \quad \text{EVTS} \quad \text{DOCUMENT ID} \quad \text{TECN} \quad \text{COMMENT}
\]

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<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.13 ± 0.14</td>
<td>1687 COUPAL 85 SPEC</td>
<td>(\eta_{+-} = 2.28 ± 0.06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.04 ± 0.14</td>
<td>2703 DEVOE 77 SPEC</td>
<td>(\eta_{+-} = 2.25 ± 0.05)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.51 ± 0.23</td>
<td>309 DEBOURD 67 OSPK</td>
<td>(\eta_{+-} = 2.00 ± 0.09)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.35 ± 0.19</td>
<td>525 FITCH 67 OSPK</td>
<td>(\eta_{+-} = 1.94 ± 0.08)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Old experiments excluded from fit. See subsection on \(\eta_{+-}\) in section on “PARAMETERS FOR \(K_L^0 \rightarrow 2\pi\) DECAY” below for average \(\eta_{+-}\) of these experiments and for note on discrepancy.

\[
\frac{\Gamma(\pi^\pm e^\mp\nu_e)/\Gamma(2 \text{ tracks})}{\Gamma_1/(\Gamma_1+\Gamma_2+0.03508\Gamma_6+\Gamma_7+\Gamma_8)}
\]

\[
\Gamma(2 \text{ tracks}) = \Gamma(\pi^\pm e^\mp\nu_e) + \Gamma(\pi^\pm \mu^\mp\nu_{\mu}) + 0.03508 \Gamma(3\pi^0) + \Gamma(\pi^+\pi^-\pi^0) + \Gamma(\pi^+\pi^-) \text{ where 0.03508 is the fraction of 3\pi^0 events with one Dalitz decay (}\pi^0 \rightarrow \gamma e^+e^-\).}

\[
\text{VALUE (units 10}^{-3}\text{)} \quad \text{EVTS} \quad \text{DOCUMENT ID} \quad \text{TECN} \quad \text{COMMENT}
\]

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<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5006 ± 0.0009</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4978 ± 0.0035</td>
<td>6.8M LAI 048 NA48</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\frac{\Gamma(\pi^+\pi^-)/\left[\Gamma(\pi^\pm e^\mp\nu_e) + \Gamma(\pi^\pm \mu^\mp\nu_{\mu}) + \Gamma(\pi^+\pi^-\pi^0)\right]}{\Gamma_8/(\Gamma_1+\Gamma_2+\Gamma_7)}
\]

Violates \(CP\) conservation.

\[
\text{VALUE (units 10}^{-3}\text{)} \quad \text{EVTS} \quad \text{DOCUMENT ID} \quad \text{TECN} \quad \text{COMMENT}
\]

<table>
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<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.454 ± 0.011</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>VALUE</th>
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<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.60 ± 0.07</td>
<td>4200 MESSNER 73 ASPK</td>
<td>(\eta_{+-} = 2.23 ± 0.05)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

\[
\begin{array}{llll}
\text{VALUE (units } 10^{-2}) & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\
1.568 \pm 0.010 \text{ OUR FIT} & \text{Error includes scale factor of 1.3.} \\
1.64 \pm 0.04 & 4200 & \text{MESSNER 73 AS PK } & \eta_{+-} = 2.23
\end{array}
\]

\[ \Gamma(\pi^0\pi^0)/\Gamma_{\text{total}} \]
Violates $CP$ conservation.

\[
\begin{array}{llll}
\text{VALUE (units } 10^{-3}) & \text{DOCUMENT ID} & \text{TECN} \\
0.864 \pm 0.006 \text{ OUR FIT} & \text{Error includes scale factor of 1.8.} \\
0.865 \pm 0.012 & 1 \text{ ALEXOPOUL... 04 KTEV} \\
\end{array}
\]

\[ \Gamma(\pi^0\pi^0)/\Gamma(\pi^+\pi^-) \]
Violates $CP$ conservation.

\[
\begin{array}{llll}
\text{VALUE (units } 10^{-2}) & \text{DOCUMENT ID} & \text{TECN} \\
0.4395 \pm 0.0023 \text{ OUR FIT} & \text{Error includes scale factor of 2.0.} \\
0.4390 \pm 0.0012 & 1 \text{ ETAFIT 16} \\
\end{array}
\]

\[ \Gamma(\pi^0\pi^0)/\Gamma(3\pi^0) \]
Violates $CP$ conservation.

\[
\begin{array}{llll}
\text{VALUE (units } 10^{-2}) & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\
0.443 \pm 0.004 \text{ OUR FIT} & \text{Error includes scale factor of 2.1.} \\
0.4446 \pm 0.0016 \pm 0.0019 & 100K & 1 \text{ ALEXOPOUL... 04 KTEV Not in fit} \\
\end{array}
\]

\[ \Gamma(\pi^\pm e^\mp \nu_e \gamma)/\Gamma(\pi^\pm e^\mp \nu_e) \]
Semileptonic modes with photons

\[
\begin{array}{llll}
\text{VALUE (units } 10^{-2}) & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\
0.935 \pm 0.015 \text{ OUR AVERAGE} & \text{Error includes scale factor of 1.9. See the ideogram below.} \\
0.924 \pm 0.023 \pm 0.016 & 9k & 1 \text{ AMBROSINO 08F KLOE } & E_\gamma^* > 30 \text{ MeV, } \theta_{e\gamma}^* > 20^\circ \\
0.916 \pm 0.017 & 4309 & 2 \text{ ALEXOPO... 05 KTEV } & E_\gamma^* > 30 \text{ MeV, } \theta_{e\gamma}^* > 20^\circ \\
0.964 \pm 0.008 \pm 0.011 & 19K & \text{ LAI } & 05 \text{ NA48 } & E_\gamma^* > 30 \text{ MeV, } \theta_{e\gamma}^* > 20^\circ \\
0.908 \pm 0.008 \pm 0.013 & 15k & \text{ ALAVI-HARAT101 } & \text{ KTEV } & E_\gamma^* \geq 30 \text{ MeV, } \theta_{e\gamma}^* \geq 20^\circ \\
0.934 \pm 0.036 \pm 0.055 & 1384 & \text{ LEBER } & 96 \text{ NA31 } & E_\gamma^* \geq 30 \text{ MeV, } \theta_{e\gamma}^* \geq 20^\circ \\
\end{array}
\]
Direct emission contribution measured $\langle X \rangle = -2.3 \pm 1.3 \pm 1.4$.

2 Also measured cut $E_\gamma^* > 10$ MeV, $\theta_{e\gamma} > 0^\circ$: $\Gamma(\pi^\pm e^\mp \nu_e \gamma) / \Gamma(\pi^\pm e^\mp \nu_e) = (4.942 \pm 0.062)\%$.

**Hadronic modes with photons or $\ell\ell$ pairs**

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

<table>
<thead>
<tr>
<th>VALUE (units $10^{-5}$)</th>
<th>CL%</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt; 0.243$</td>
<td>90</td>
<td>ABOUZAI</td>
<td>08b</td>
<td>KTEV $K^0_L \rightarrow \pi^0 \pi^0_D \gamma$, $\pi^0_D \rightarrow e e\gamma$</td>
</tr>
<tr>
<td>$&lt; 5.6$</td>
<td>90</td>
<td>BARR</td>
<td>94</td>
<td>NA31</td>
</tr>
<tr>
<td>$&lt; 230$</td>
<td>90</td>
<td>ROBERTS</td>
<td>94</td>
<td>E799</td>
</tr>
</tbody>
</table>

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\[ \frac{\Gamma(\pi^+\pi^-\gamma)}{\Gamma(\pi^+\pi^-\pi^0)} \]

\[ \Gamma_{13}/\Gamma_7 \]

\[ \frac{\Gamma(\pi^+\pi^-\pi^0)}{\Gamma(\pi^+\pi^-)} \]

\[ \Gamma_{13}/\Gamma_8 \]

\[ \frac{\Gamma(\pi^+\pi^-\gamma(\text{DE}))}{\Gamma(\pi^+\pi^-)} \]

\[ \Gamma_{14}/\Gamma_{13} \]

\[ \frac{\Gamma(\pi^0 2\gamma)}{\Gamma_{\text{total}}} \]

\[ \Gamma_{15}/\Gamma \]
\[ \Gamma(\pi^0 \gamma e^+ e^-)/\Gamma_{\text{total}} \]

<table>
<thead>
<tr>
<th>VALUE (units 10^{-5})</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
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<tbody>
<tr>
<td>1.62 ± 0.14 ± 0.09</td>
<td></td>
<td>125</td>
<td>1 ABOUZAID 07D</td>
<td>KTEV</td>
</tr>
</tbody>
</table>

- We do not use the following data for averages, fits, limits, etc.
  - 2.34 ± 0.35 ± 0.13
  - <71
  - 0.90

1 ABOUZAID 07D includes 1997 (ALA VI-HARA TI 01) and 1999 data. It measures the ratio of \( B(K_L^0 \rightarrow \pi^0 \gamma e^+ e^-) / B(K_L^0 \rightarrow \pi^0 \pi^0_D) \), where \( \pi^0_D \) is the Dalitz decaying \( \pi^0 \), and uses PDG 06 values \( B(K_L^0 \rightarrow \pi^0 \pi^0_D) = (8.64 ± 0.06) \times 10^{-4} \), and \( B(\pi^0_D \rightarrow e^+ e^-) = (1.198 ± 0.032) \times 10^{-2} \). Supersedes ALA VI-HARA TI 01E result.

\[ \Gamma(2\gamma)/\Gamma_{\text{total}} \]

<table>
<thead>
<tr>
<th>VALUE (units 10^{-4})</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.47 ± 0.04 OUR FIT</td>
<td></td>
<td>1 BANNER 72D</td>
<td>OSPK</td>
<td>Error includes scale factor of 1.1.</td>
</tr>
</tbody>
</table>

- We do not use the following data for averages, fits, limits, etc.
  - 4.54 ± 0.84
  - 4.5 ± 1.0
  - 5.0 ± 1.0
  - 5.5 ± 1.1

1 This value uses \( (\eta_{00}/\eta_{+-})^2 = 1.05 ± 0.14 \). In general, \( \Gamma(2\gamma)/\Gamma_{\text{total}} = [(4.32 ± 0.55) \times 10^{-4}] [(\eta_{00}/\eta_{+-})^2] \).

2 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.

\[ \Gamma(3\pi^0)/\Gamma_6 \]

<table>
<thead>
<tr>
<th>VALUE (units 10^{-3})</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.802 ± 0.017 OUR FIT</td>
<td></td>
<td>1 ADINOLFI 03</td>
<td>KLOE</td>
<td></td>
</tr>
<tr>
<td>2.802 ± 0.018 OUR AVERAGE</td>
<td></td>
<td>2 LAI 02</td>
<td>NA48</td>
<td></td>
</tr>
</tbody>
</table>
\( \Gamma(2\gamma) / \Gamma(\pi^0 \pi^0) \)  \( \Gamma_1 / \Gamma_9 \)

\[
\begin{array}{cccc}
\text{VALUE} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
0.633 \pm 0.006 & \text{OUR FIT} & \text{Error includes scale factor of 1.4.} & \\
0.632 \pm 0.004 \pm 0.008 & & & \\
\end{array}
\]

\( \Gamma(3\gamma) / \Gamma_{\text{total}} \)  \( \Gamma_{18} / \Gamma \)

\[
\begin{array}{cccc}
\text{VALUE} & \text{CL\%} & \text{DOCUMENT ID} & \text{TECN} \\
<7.4 \times 10^{-8} & 90 & 1 \text{TUNG} & 11 \text{K391} \\
<2.4 \times 10^{-7} & 90 & 2 \text{BARR} & 95 \text{NA31} \\
\end{array}
\]

1 TUNG 11 reports the result assuming parity violating interaction and using 2005 data (Run-II and III). Assuming parity conserving or phase space interaction, the 90% upper limits obtained are \( 7.5 \times 10^{-8} \) and \( 8.6 \times 10^{-8} \), respectively.

2 Assumes a phase-space decay distribution.

\( \Gamma(e^+ e^- \gamma) / \Gamma_{\text{total}} \)  \( \Gamma_{19} / \Gamma \)

\[
\begin{array}{cccc}
\text{VALUE (units 10^{-6})} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
9.4 \pm 0.4 & \text{OUR FIT} & \text{Error includes scale factor of 2.0.} & \\
10.0 \pm 0.5 & \text{OUR AVERAGE} & \text{Error includes scale factor of 1.5. See the ideogram below.} & \\
10.6 \pm 0.2 \pm 0.4 & 6864 & 1 \text{FANTI} & 99 \text{B NA48} \\
9.2 \pm 0.5 \pm 0.5 & 1053 & \text{BARR} & 90 \text{B NA31} \\
9.1 \pm 0.4 \pm 0.6 & 919 & \text{OHL} & 90 \text{B B845} \\
\end{array}
\]

The ideogram shows the distribution of the values above the weighted average, with error and scale factor based upon the data in this ideogram only. They are not necessarily the same as our 'best' values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

\( \chi^2 \)  (Confidence Level = 0.099)

\[
\begin{array}{cccc}
\text{FANTI} & 99 \text{B NA48} & 2.0 \\
\text{BARR} & 90 \text{B NA31} & 1.2 \\
\text{OHL} & 90 \text{B B845} & 1.4 \\
\end{array}
\]

HTTP://PDG.LBL.GOV  Page 15  Created: 5/30/2017 17:22
For FANTI 99b, the ±0.4 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.

$\Gamma(e^+e^-\gamma)/\Gamma(3\pi^0)$

<table>
<thead>
<tr>
<th>Value (units $10^{-5}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.82 ± 0.21 OUR FIT</td>
<td>83k</td>
<td>1 ABOUZAID 07B</td>
<td>KTEV</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Value (units $10^{-7}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.59 ± 0.11 OUR AVERAGE</td>
<td>617</td>
<td>ALAVI-HARATI01G</td>
<td>KTEV</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Value (units $10^{-5}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.95 ± 0.33 OUR AVERAGE</td>
<td>1543</td>
<td>ALAVI-HARATI01F</td>
<td>KTEV</td>
<td>$E^*_{\gamma} &gt; 5$ MeV</td>
</tr>
<tr>
<td>8.0 ± 1.5 ±1.4 −1.2</td>
<td>40</td>
<td>SETZU       98</td>
<td>NA31</td>
<td>$E^*_{\gamma} &gt; 5$ MeV</td>
</tr>
<tr>
<td>6.5 ± 1.2 ±0.6</td>
<td>58</td>
<td>NAKAYA      94</td>
<td>E799</td>
<td>$E^*_{\gamma} &gt; 5$ MeV</td>
</tr>
<tr>
<td>6.6 ± 3.2</td>
<td>92</td>
<td>MORSE       82</td>
<td>B845</td>
<td>$E^*_{\gamma} &gt; 5$ MeV</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Value (units $10^{-6}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.48 ± 0.05 OUR AVERAGE</td>
<td>6210</td>
<td>AMBROSE     00</td>
<td>B871</td>
<td></td>
</tr>
</tbody>
</table>

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

$\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$

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

<table>
<thead>
<tr>
<th>Value (units $10^{-6}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.47 ± 0.057</td>
<td>6210</td>
<td>AMBROSE     00</td>
<td>B871</td>
<td></td>
</tr>
<tr>
<td>3.87 ± 0.30</td>
<td>179</td>
<td>1 AKAGI     95</td>
<td>SPEC</td>
<td></td>
</tr>
<tr>
<td>3.38 ± 0.17</td>
<td>707</td>
<td>HEINSON     95</td>
<td>B791</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Value (units $10^{-6}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.9 ± 0.3 ±0.1</td>
<td>178</td>
<td>2 AKAGI 91B</td>
<td>SPEC</td>
<td>In AKAGI 95</td>
</tr>
<tr>
<td>3.45 ± 0.18 ±0.13</td>
<td>368</td>
<td>3 HEINSON 91</td>
<td>SPEC</td>
<td>In HEINSON 95</td>
</tr>
<tr>
<td>4.1 ± 0.5</td>
<td>54</td>
<td>INAGAKI     89</td>
<td>SPEC</td>
<td>In AKAGI 91B</td>
</tr>
<tr>
<td>2.8 ± 0.3 ±0.2</td>
<td>87</td>
<td>MATHIAZHA...89B</td>
<td>SPEC</td>
<td>In HEINSON 91</td>
</tr>
</tbody>
</table>
AKAGI 95 gives this number multiplied by the PDG 1992 average for $\Gamma(K_L^0 \to \pi^+\pi^-)/\Gamma(\text{total})$.

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

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

\begin{align*}
\Gamma(e^+e^-)/\Gamma(\text{total}) & \Gamma_{24}/\Gamma \\
\text{Test for } \Delta S = 1 \text{ weak neutral current. Allowed by higher-order electroweak interaction.}
\end{align*}

\begin{table}[h]
\begin{tabular}{cccc}
\text{VALUE (units $10^{-10}$)} & \text{CL\%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
0.087 & $\pm$ 0.057 & 4 & AMBROSE & 98 B871 \\
\end{tabular}
\end{table}

\begin{itemize}
\item We do not use the following data for averages, fits, limits, etc.
\item ARISAKA 93B includes all events with $<6$ MeV radiated energy.
\end{itemize}

\begin{align*}
\Gamma(\pi^+\pi^-e^+e^-)/\Gamma(\text{total}) & \Gamma_{25}/\Gamma \\
\text{Test for } \Delta S = 1 \text{ weak neutral current. Allowed by higher-order electroweak interaction.}
\end{align*}

\begin{table}[h]
\begin{tabular}{cccc}
\text{VALUE (units $10^{-7}$)} & \text{CL\%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\
3.11 & $\pm$ 0.19 & 1125 & 1 LAI & 03C NA48 \\
3.08 & $\pm$ 0.09 & 37 & ADAMS & 98 KTEV \\
3.2 & $\pm$ 0.6 & 13 & TAKEUCHI & 98 SPEC \\
\end{tabular}
\end{table}

\begin{itemize}
\item We do not use the following data for averages, fits, limits, etc.
\item NOMURA 97 SPEC $m_{ee} > 4$ MeV
\end{itemize}

\begin{align*}
\Gamma(\pi^0\pi^0e^+e^-)/\Gamma(\text{total}) & \Gamma_{26}/\Gamma \\
\text{Test for } \Delta S = 1 \text{ weak neutral current. Allowed by higher-order electroweak interaction.}
\end{align*}

\begin{table}[h]
\begin{tabular}{cccc}
\text{VALUE (units $10^{-9}$)} & \text{CL\%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
<6.6 & 90 & 1 & ALAVI-HARATI102 & E799 \\
\end{tabular}
\end{table}

\begin{align*}
\Gamma(\pi^0\pi^0\mu^+\mu^-)/\Gamma(\text{total}) & \Gamma_{27}/\Gamma \\
\text{Test for } \Delta S = 1 \text{ weak neutral current. Allowed by higher-order electroweak interaction.}
\end{align*}

\begin{table}[h]
\begin{tabular}{cccc}
\text{VALUE (units $10^{-11}$)} & \text{CL\%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
<9.2 \times 10^{-11} & 90 & 1 & ABOUZAI\,D & 11A E799 \\
\end{tabular}
\end{table}

\begin{itemize}
\item ABOUZAI\,D 11A also reports $B(K_L^0 \to \pi^0\pi^0X^0 \to \pi^0\pi^0\mu^+\mu^-) < 1.0 \times 10^{-10}$ at 90\% C.L., where the $X^0$ is a possible new neutral boson that was reported by PARK 05 with a mass of $214.3 \pm 0.5$ MeV/$c^2$.
\end{itemize}
\( \Gamma(\mu^+\mu^- e^+ e^-)/\Gamma_{\text{total}} \) \( \Gamma_{28}/\Gamma \)

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

<table>
<thead>
<tr>
<th>VALUE (units ( 10^{-9} ))</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.69 ± 0.27 OUR AVERAGE</td>
<td>2.69 ± 0.24 ± 0.12</td>
<td>131</td>
<td>ALAVI-HARATI03B</td>
<td>KTEV</td>
<td></td>
</tr>
<tr>
<td>2.9 ± 6.7</td>
<td>2.9 ± 6.7 ± 2.24</td>
<td>1</td>
<td>GU</td>
<td>96</td>
<td>E799</td>
</tr>
</tbody>
</table>

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

\( \Gamma_{29}/\Gamma \)

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

<table>
<thead>
<tr>
<th>VALUE (units ( 10^{-8} ))</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.56 ± 0.21 OUR AVERAGE</td>
<td>3.30 ± 0.24 ± 0.25</td>
<td>200</td>
<td>LAI</td>
<td>05B</td>
</tr>
<tr>
<td>3.72 ± 0.18 ± 0.23</td>
<td>441</td>
<td>ALAVI-HARATI01D</td>
<td>KTEV</td>
<td></td>
</tr>
<tr>
<td>3.96 ± 0.78 ± 0.32</td>
<td>27</td>
<td>GU</td>
<td>94</td>
<td>E799</td>
</tr>
<tr>
<td>3.07 ± 1.25 ± 0.26</td>
<td>6</td>
<td>VAGINS</td>
<td>93</td>
<td>B845</td>
</tr>
</tbody>
</table>

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

1 LAI 05B uses 1998 and 1999 data. Data are normalized to the observed events of \( K_L^0 \rightarrow \pi^+ \pi^- \pi^0 \) (\( \pi^0 \) into Dalitz pair) and PDG 04 values are used for \( B(K_L^0 \rightarrow \pi^+ \pi^- \pi^0) \) and \( B(\pi^0 \rightarrow e^+ e^- \gamma) \). The systematic error includes a normalization error of ±0.10.

2 Values are for the total branching fraction, acceptance-corrected for the \( m_{ee} \) cuts shown.

3 Distribution of angles between two \( e^+ e^- \) pair planes favors \( CP=1 \) for \( K_L^0 \).

\( \Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}} \) \( \Gamma_{30}/\Gamma \)

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

<table>
<thead>
<tr>
<th>VALUE (units ( 10^{-9} ))</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.38</td>
<td>90</td>
<td>ALAVI-HARATI00D</td>
<td>KTEV</td>
<td></td>
</tr>
</tbody>
</table>

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

\( \Gamma_{31}/\Gamma \)

Violates \( CP \) in leading order. Direct and indirect \( CP \)-violating contributions are expected to be comparable and to dominate the \( CP \)-conserving part. LAI 02B result suggests that \( CP \)-violation effects dominate. Test for \( \Delta S = 1 \) weak neutral current. Allowed by higher-order electroweak interaction.

<table>
<thead>
<tr>
<th>VALUE (units ( 10^{-10} ))</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2.8</td>
<td>90</td>
<td>ALAVI-HARATI04A</td>
<td>KTEV</td>
<td>combined result</td>
<td></td>
</tr>
</tbody>
</table>
We do not use the following data for averages, fits, limits, etc.: 

\[ \frac{\Gamma(p^0\nu\bar{\nu})}{\Gamma_{total}} \]

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.

\[ \frac{\Gamma_{32}}{\Gamma} \]

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.

\[ \frac{\Gamma_{33}}{\Gamma} \]

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.

<table>
<thead>
<tr>
<th>Value (units ( 10^{-7} ))</th>
<th>CL%</th>
<th>Document ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.26</td>
<td>90</td>
<td>1 AHN</td>
<td>10 K931</td>
</tr>
<tr>
<td>&lt; 0.67</td>
<td>90</td>
<td>2 AHN</td>
<td>08 K931</td>
</tr>
<tr>
<td>&lt; 2.1</td>
<td>90</td>
<td>3 AHN</td>
<td>06 K931</td>
</tr>
<tr>
<td>&lt; 5.9</td>
<td>90</td>
<td>ALAVI-HARATI00 KTEV</td>
<td></td>
</tr>
<tr>
<td>&lt; 16</td>
<td>90</td>
<td>ADAMS</td>
<td>99 KTEV</td>
</tr>
<tr>
<td>&lt; 2.1</td>
<td>90</td>
<td>WEAVER</td>
<td>94 E799</td>
</tr>
<tr>
<td>&lt; 2200</td>
<td>90</td>
<td>GRAHAM</td>
<td>92 CNTR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Value (units ( 10^{-5} ))</th>
<th>CL%</th>
<th>Document ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 8.1 \times 10^{-7}</td>
<td>90</td>
<td>1 OGA T A</td>
<td>11 K931</td>
</tr>
<tr>
<td>&lt; 4.7 \times 10^{-5}</td>
<td>90</td>
<td>2 NIX</td>
<td>07 K931</td>
</tr>
</tbody>
</table>

1 Obtained combining Run-2 (AHN 08) and Run-3 data.
2 Value obtained using data from February to April 2005.
3 Value obtained analyzing 10% of data of RUN 1 (performed in 2004).

1 Using 2005 Run-I data. OGATA 11 also sets a limit on the \( K_L^0 \rightarrow \pi^0\pi^0 X \rightarrow \) invisible particles process: the limit on the branching fraction varied from \( 7.0 \times 10^{-7} \) to \( 4.0 \times 10^{-5} \) for the mass of \( X \) ranging from 50 to 200 MeV/c^2.
2 Observed 1 event with expected background of 0.43 \( \pm 0.35 \) events. NIX 07 also measured \( B(K_L^0 \rightarrow \pi^0\pi^0 P) < 1.2 \times 10^{-6} \) at 90% CL, where \( P \) is the pseudoscalar particle and \( m_P < 100 \) MeV.
\[ \Gamma(e^\pm \mu^\mp)/\Gamma_{\text{total}} \]

Test of lepton family number conservation.

\[
\begin{array}{ccccc}
\text{VALUE (units } 10^{-11}) & \text{CL\%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
<0.47 & 90 & \text{AMBROSE 98B} & \text{B871} & \\
9.4 & 90 & \text{AKAGI 95} & \text{SPEC} & \\
<3.9 & 90 & \text{ARISAKA 93} & \text{B791} & \\
<3.3 & 90 & 1 & \text{ARISAKA 93} & \text{B791} \\
\end{array}
\]

\[ \Gamma(e^\pm e^\pm \mu^\mp)/\Gamma_{\text{total}} \]

Test of lepton family number conservation.

\[
\begin{array}{ccccc}
\text{VALUE (units } 10^{-11}) & \text{CL\%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\
< 4.12 & 90 & \text{ALAVI-HARATI03B} & \text{KTEV} & \\
< 12.3 & 90 & 1 & \text{ALAVI-HARATI01H} & \text{KTEV} & \text{Sup. by ALAVI-HARATI03B} \\
<610 & 90 & 1 & \text{GU 96} & \text{E799} & \\
\end{array}
\]

\[ \Gamma(\pi^0 \mu^\pm)/\Gamma_{\text{total}} \]

Test of lepton family number conservation.

\[
\begin{array}{ccccc}
\text{VALUE (units } 10^{-10}) & \text{CL\%} & \text{DOCUMENT ID} & \text{TECN} \\
< 0.76 & 90 & \text{ABOUZAID 08C} & \text{KTEV} & \\
<62 & 90 & \text{ARISAKA 98} & \text{E799} & \\
\end{array}
\]

\[ \Gamma(\pi^0 \pi^0 \mu^\pm)/\Gamma_{\text{total}} \]

Test of lepton family number conservation.

\[
\begin{array}{ccccc}
\text{VALUE (units } 10^{-10}) & \text{CL\%} & \text{DOCUMENT ID} & \text{TECN} \\
< 1.7 & 90 & \text{ABOUZAID 08C} & \text{KTEV} & \\
\end{array}
\]

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\section*{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 \(a_u\), \(a_t\), \(a_L\), and \(f_u\), see the earlier version of the same note in the 1982 edition of this Review published in Physics Letters \textbf{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 \(v = (s_2 - s_1) / m_{\pi}^2\)

\section*{LINEAR COEFFICIENT \(g\) FOR K^0_L \(\rightarrow \pi^+ \pi^- \pi^0\)}

\[
\begin{array}{cccc}
\text{VALUE} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
0.678 \pm 0.008 & \text{OUR AVERAGE} & & \\
0.6823 \pm 0.0044 & 500k & \text{ANGELOPO... 98C} & \text{CPLR} \\
0.681 \pm 0.024 & 6499 & \text{CHO} & \text{HBC} \\
0.620 \pm 0.023 & 4709 & \text{PEACH} & \text{HBC} \\
0.677 \pm 0.010 & 509k & \text{MESSNER} & \text{ASPK} \\
\end{array}
\]

Error includes scale factor of 1.5. See the ideogram below.

\[ a_y = -0.917 \pm 0.013 \]

\url{HTTP://PDG.LBL.GOV}
We do not use the following data for averages, fits, limits, etc.

<table>
<thead>
<tr>
<th>Value</th>
<th>Experiment</th>
<th>Value</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.69 ± 0.07</td>
<td>192 BALDO... 75 HLBC</td>
<td>0.619 ± 0.027</td>
<td>20k 1,2 BISI 74 ASPK</td>
</tr>
<tr>
<td>0.590 ± 0.022</td>
<td>56k 1 BUCHANAN 75 SPEC</td>
<td>0.612 ± 0.032</td>
<td>1 ALEXANDER 73B HBC</td>
</tr>
<tr>
<td>0.73 ± 0.04</td>
<td>3200 1 BRANDENB... 73 HBC</td>
<td>0.608 ± 0.043</td>
<td>1486 1 KRENZ 72 HLBC</td>
</tr>
<tr>
<td>0.650 ± 0.012</td>
<td>29k 1 ALBROW 70 ASPK</td>
<td>0.593 ± 0.022</td>
<td>36k 1,3 BUCHANAN 70 SPEC</td>
</tr>
<tr>
<td>0.664 ± 0.056</td>
<td>4400 1 SMITH 70 OSPK</td>
<td>0.400 ± 0.045</td>
<td>2446 1 BASILE 68B OSPK</td>
</tr>
<tr>
<td>0.649 ± 0.044</td>
<td>1350 1 HOPKINS 67 HBC</td>
<td>0.428 ± 0.055</td>
<td>1198 1 NEFKENS 67 OSPK</td>
</tr>
</tbody>
</table>

1 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.

2 BISI 74 value comes from quadratic fit with quad. term consistent with zero. $g$ error is thus larger than if linear fit were used.

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

![Graph](HTTP://PDG.LBL.GOV)
QUADRATIC COEFFICIENT $h$ FOR $K_L^0 \rightarrow \pi^+\pi^-\pi^0$

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.076±0.006</td>
<td>500k</td>
<td>ANGELOPO... 98C</td>
<td>CPLR</td>
</tr>
<tr>
<td>0.061±0.004±0.015</td>
<td>6499</td>
<td>CHO         77</td>
<td>HBC</td>
</tr>
<tr>
<td>0.048±0.036</td>
<td>4709</td>
<td>PEACH       77</td>
<td>HBC</td>
</tr>
<tr>
<td>0.079±0.007</td>
<td>509k</td>
<td>MESSNER     74</td>
<td>ASPK</td>
</tr>
</tbody>
</table>

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

\[ -0.011±0.018 \]
\[ 0.043±0.052 \]

See notes in section “LINEAR COEFFICIENT $g$ FOR $K_L^0 \rightarrow \pi^+\pi^-\pi^0$ | MATRIX ELEMENT|^2 above.

1 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 $K_L^0 \rightarrow \pi^+\pi^-\pi^0$

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0099±0.0015</td>
<td>500k</td>
<td>ANGELOPO... 98C</td>
<td>CPLR</td>
</tr>
<tr>
<td>0.0104±0.0017±0.0024</td>
<td>6499</td>
<td>CHO         77</td>
<td>HBC</td>
</tr>
<tr>
<td>0.024±0.010</td>
<td>4709</td>
<td>PEACH       77</td>
<td>HBC</td>
</tr>
<tr>
<td>−0.008±0.012</td>
<td>509k</td>
<td>MESSNER     74</td>
<td>ASPK</td>
</tr>
</tbody>
</table>

LINEAR COEFFICIENT $j$ FOR $K_L^0 \rightarrow \pi^+\pi^-\pi^0$ (CP-VIOLATING TERM)

Listed in CP-violation section below.

QUADRATIC COEFFICIENT $f$ FOR $K_L^0 \rightarrow \pi^+\pi^-\pi^0$ (CP-VIOLATING TERM)

Listed in CP-violation section below.

QUADRATIC COEFFICIENT $h$ FOR $K_L^0 \rightarrow \pi^0\pi^-\pi^0$

We do not average measurements that do not account for the effect of final state rescattering.

<table>
<thead>
<tr>
<th>VALUE (units $10^{-3}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.59±0.20±1.16</td>
<td>68M</td>
<td>1 ABOUZAI... 08A</td>
<td>KTEV</td>
</tr>
</tbody>
</table>

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

\[ -6.1 \pm 0.9 \pm 0.5 \]
\[ -3.3 \pm 1.1 \pm 0.7 \]

1 Result obtained using CI3pl model of CABIBBO 05 to include $\pi\pi$ rescattering effects.

The systematic error includes an external error of $1.06 \times 10^{-3}$ from the parametrization input of $(a_0-a_2) \frac{m_{\pi^+}}{m_{\pi^-}} = 0.268 \pm 0.017$ from BATLEY 06B.

2 LAI 01B and SOMALWAR 92 results do not include $\pi\pi$ final state rescattering effects.

3 SOMALWAR 92 chose $m_{\pi^-}$ as normalization to make it compatible with the Particle Data Group $K_L^0 \rightarrow \pi^+\pi^-\pi^0$ definitions.
**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.
- $f_0(t) = f_+(t) + f_-(t) \ t/(m^2_{K^0} - m^2_{\pi^+})$.
- $t = $ momentum transfer to the $\pi$.
- $\lambda_+$ and $\lambda_0$ are the linear expansion coefficients of $f_+$ and $f_0$.
- $f_+(t) = f_+(0) (1 + \lambda_+ t / m^2_{\pi^+})$

For quadratic expansion

$$f_+(t) = f_+(0) \left(1 + \lambda'_+ t / m^2_{\pi^+} + \frac{\lambda''_+}{2} t^2 / m^4_{\pi^+}\right)$$

as used by KTeV. If there is a non-vanishing quadratic term, then $\lambda_+$ represents an average slope, which is then different from $\lambda'_+$.

- NA48 ($K_{e3}$) and ISTRA quadratic expansion coefficients are converted with $\lambda'_{+}^{PDG} = \lambda'_{N A 4 8}$ and $\lambda''_{+}^{PDG} = 2 \lambda'_{N A 4 8}$
- $\lambda'_{+}^{PDG} = (\frac{m_{\pi^0}}{m_{\pi^+}})^2 \lambda'_{+}^{ISTRA}$ and $\lambda''_{+}^{PDG} = 2 (\frac{m_{\pi^0}}{m_{\pi^+}})^4 \lambda'_{+}^{ISTRA}$

ISTRA linear expansion coefficients are converted with $\lambda'_{+}^{PDG} = (\frac{m_{\pi^0}}{m_{\pi^+}})^2 \lambda'_{+}^{ISTRA}$ and $\lambda_0^{PDG} = (\frac{m_{\pi^0}}{m_{\pi^+}})^2 \lambda_0^{ISTRA}$

The pole parametrization is

$$f_+(t) = f_+(0) \left(\frac{M^2_V}{M^2_V - t}\right)$$

$$f_0(t) = f_0(0) \left(\frac{M^2_S}{M^2_S - t}\right)$$

where $M_V$ and $M_S$ are the vector and scalar pole masses.

The dispersive parametrization is

$$f_+(t) = f_+(0) \exp \left(\frac{t}{m^2_{\pi}} \left(A_+ + H(t)\right)\right);$$

$$f_0(t) = f_+(0) \exp \left(\frac{t}{m^2_{K} - m^2_{\pi}} \left(\ln[C] - G(t)\right)\right);$$

where $A_+$ is the slope parameter and $\ln[C] = \ln \left[ f_0 \left(m^2_{K} - m^2_{\pi}\right)\right]$ is the logarithm of the scalar form factor at the Callan-Treiman point. $H(t)$ and $G(t)$ are dispersive integrals.

The following abbreviations are used:

- 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 \( K_3^0 \) DECAY)**

For radiative correction of \( K_3^0 \) DP, see GINSBERG 67, BECHERRAWY 70, CIRIGLIANO 02, CIRIGLIANO 04, and ANDRE 07. Results labeled OUR FIT are discussed in the review “\( K_{33}^{\pm} \) and \( K_3^0 \) Form Factors” in the \( K^{\pm} \) Listings. For earlier, lower statistics results, see the 2004 edition of this review, Physics Letters B592 1 (2004).

<table>
<thead>
<tr>
<th>VALUE (units 10^{-2})</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.82 ±0.04 OUR FIT</td>
<td>Error includes scale factor of 1.1. Assuming ( \mu-e ) universality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.82 ±0.04 OUR AVERAGE</td>
<td>2M</td>
<td>AMBROSINO   06D</td>
<td>KLOE</td>
<td></td>
</tr>
<tr>
<td>2.82 ±0.04 · · ·</td>
<td>2M</td>
<td>ALEXOPOULOS 04A</td>
<td>KTEV PI, no ( \mu = e )</td>
<td></td>
</tr>
<tr>
<td>2.88 ±0.04 ±0.11</td>
<td>5.6M</td>
<td>1 LAI        04C</td>
<td>NA48 DP</td>
<td></td>
</tr>
</tbody>
</table>

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

\( \lambda_+ \) **(LINEAR ENERGY DEPENDENCE OF \( f_+ \) IN \( K_3^0 \) DECAY)**

Results labeled OUR FIT are discussed in the review “\( K_{33}^{\pm} \) and \( K_3^0 \) Form Factors” in the \( K^{\pm} \) Listings. For earlier, lower statistics results, see the 2004 edition of this review, Physics Letters B592 1 (2004).

<table>
<thead>
<tr>
<th>VALUE (units 10^{-2})</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.82 ±0.04 OUR FIT</td>
<td>Error includes scale factor of 1.1. Assuming ( \mu-e ) universality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.71 ±0.10 OUR FIT</td>
<td>Error includes scale factor of 1.4. Not assuming ( \mu-e ) universality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.67 ±0.06 ±0.08</td>
<td>2.3M</td>
<td>1 LAI        07A</td>
<td>NA48 DP</td>
<td></td>
</tr>
<tr>
<td>2.745 ±0.088 ±0.063</td>
<td>1.5M</td>
<td>ALEXOPOULOS 04A</td>
<td>KTEV DP, no ( \mu = e )</td>
<td></td>
</tr>
<tr>
<td>2.813 ±0.051</td>
<td>3.4M</td>
<td>ALEXOPOULOS 04A</td>
<td>KTEV PI, DP, ( \mu = e )</td>
<td></td>
</tr>
<tr>
<td>3.0 ±0.3</td>
<td>1.6M</td>
<td>DONALDSON    74B</td>
<td>SPEC DP</td>
<td></td>
</tr>
</tbody>
</table>

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

\( \lambda_0 \) **(LINEAR ENERGY DEPENDENCE OF \( f_0 \) IN \( K_3^0 \) DECAY)**

Wherever possible, we have converted the above values of \( \xi(0) \) into values of \( \lambda_0 \) using the associated \( \lambda_0^\pm \) and \( \xi(0)/d\lambda_0 \). Results labeled OUR FIT are discussed in the review “\( K_{33}^{\pm} \) and \( K_3^0 \) Form Factors” in the \( K^{\pm} \) Listings. For earlier, lower statistics results, see the 2004 edition of this review, Physics Letters B592 1 (2004).

<table>
<thead>
<tr>
<th>VALUE (units 10^{-2})</th>
<th>( d\lambda_0/d\lambda_+ )</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.38 ±0.18 OUR FIT</td>
<td>Error includes scale factor of 2.2. Assuming ( \mu-e ) universality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.42 ±0.23 OUR FIT</td>
<td>Error includes scale factor of 2.8. Not assuming ( \mu-e ) universality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.17 ±0.07 ±0.10</td>
<td>2.3M</td>
<td>1 LAI        07A</td>
<td>NA48 DP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.657 ±0.125</td>
<td>−0.44</td>
<td>1.5M</td>
<td>2 ALEXOPOULOS 04A</td>
<td>KTEV DP, no ( \mu = e )</td>
<td></td>
</tr>
</tbody>
</table>

HTTP://PDG.LBL.GOV Page 24 Created: 5/30/2017 17:22
1.635 ± 0.121  
3.4M  
+1.9 ± 0.4  
−0.47  
1.6M  

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

3.41 ± 0.67  
unknown  
150k  

1. We use AMBROSINO 06D result in the fit not assuming $\mu - e$ universality. This result enters the fit assuming $\mu - e$ universality via AMBROSINO 07C measurement of $\lambda'_{+}$ in $K_{\mu 3}$ decays. AMBROSINO 06D gives a correlation $-0.95$ between their $\lambda'_{+}$ and $\lambda''_{+}$.

2. ALEXOPOULOS 04A gives a correlation $-0.97$ between their $\lambda'_{+}$ and $\lambda''_{+}$.

3. For LAI 04C we calculate a correlation $-0.88$ between their $\lambda'_{+}$ and $\lambda''_{+}$.

\[
\chi^2 = \frac{X^2}{N - M}
\]

(Confidence Level = 0.111)
$\lambda''_e$ (QUADRATIC $K^{0}_{e3}$ FORM FACTOR)

<table>
<thead>
<tr>
<th>VALUE (units $10^{-2}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20 ±0.05 OUR FIT</td>
<td></td>
<td>AMBROSINO 06D KLOE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.16 ±0.05 OUR FIT</td>
<td></td>
<td>AMBROSINO 07C KLOE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.17 ±0.07 OUR AVERAGE</td>
<td></td>
<td>LAI 04C NA48 DP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We use AMBROSINO 06D result in the fit not assuming $\mu - e$ universality. This result enters the fit assuming $\mu - e$ universality via AMBROSINO 07C measurement of $\lambda''_e$ in $K_{\mu 3}$ decays. AMBROSINO 06D gives a correlation $-0.95$ between their $\lambda'_e$ and $\lambda''_e$.

ALEXOPOULOS 04A gives a correlation $-0.97$ between their $\lambda'_e$ and $\lambda''_e$.

Values doubled to agree with PDG conventions described above.

LAI 04C gives a correlation $-0.88$ between their $\lambda'_e$ and $\lambda''_e$.

WEIGHTED AVERAGE
0.17±0.07 (Error scaled by 1.5)

Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our 'best' values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

$\chi^2$

<table>
<thead>
<tr>
<th>VALUE (units $10^{-2}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.40 ±0.12 OUR FIT</td>
<td></td>
<td>AMBROSINO 07C KLOE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.89 ±0.24 OUR FIT</td>
<td></td>
<td>AMBROSINO 07C KLOE</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We use AMBROSINO 07C result in the fit not assuming $\mu - e$ universality. This result enters the fit assuming $\mu - e$ universality via AMBROSINO 07C measurement of $\lambda'_e$ in $K^{0}_{e3}$ form factor. AMBROSINO 07C gives a correlation $-0.7$ between their $\lambda'_e$ and $\lambda'_e$.

ALEXOPOULOS 04A gives a correlation $-0.7$ between their $\lambda'_e$ and $\lambda''_e$.

Values doubled to agree with PDG conventions described above.

LAI 07A NA48 DP gives a correlation $-0.7$ between their $\lambda'_e$ and $\lambda''_e$.

1 See section $\lambda_0$ below for correlations.
\( \lambda''_+ (\text{QUADRATIC } K^0_{\mu_3} \text{ FORM FACTOR}) \)

<table>
<thead>
<tr>
<th>VALUE (units (10^{-2}))</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20 ± 0.05 OUR FIT</td>
<td>Error includes scale factor of 1.2. Assuming (\mu)-(e) universality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.37 ± 0.12 OUR FIT</td>
<td>Error includes scale factor of 1.3. Not assuming (\mu)-(e) universality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.48 ± 0.49 ± 0.16</td>
<td>1.8M</td>
<td>AMBROSINO 07c KLOE</td>
<td>no (\mu = e)</td>
<td></td>
</tr>
<tr>
<td>0.15 ± 0.07 ± 0.04</td>
<td>3.8M</td>
<td>AMBROSINO 07c KLOE</td>
<td>(\mu = e)</td>
<td></td>
</tr>
<tr>
<td>0.26 ± 0.09 ± 0.10</td>
<td>2.3M</td>
<td>LAI 07A NA48</td>
<td>DP</td>
<td></td>
</tr>
<tr>
<td>0.443 ± 0.131 ± 0.072</td>
<td>1.5M</td>
<td>ALEXOPOULOS 04A KTEV</td>
<td>DP, no (\mu = e)</td>
<td></td>
</tr>
<tr>
<td>0.320 ± 0.069</td>
<td>3.4M</td>
<td>ALEXOPOULOS 04A KTEV</td>
<td>PI, DP, (\mu = e)</td>
<td></td>
</tr>
</tbody>
</table>

1. See section \(\lambda_0\) below for correlations.

\( \lambda_0 (\text{LINEAR } f_0 K^0_{\mu_3} \text{ FORM FACTOR FROM QUADRATIC FIT}) \)

<table>
<thead>
<tr>
<th>VALUE (units (10^{-2}))</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.16 ± 0.09 OUR FIT</td>
<td>Error includes scale factor of 1.2. Assuming (\mu)-(e) universality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.07 ± 0.14 OUR FIT</td>
<td>Error includes scale factor of 1.3. Not assuming (\mu)-(e) universality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.91 ± 0.59 ± 0.26</td>
<td>1.8M</td>
<td>AMBROSINO 07c KLOE</td>
<td>no (\mu = e)</td>
<td></td>
</tr>
<tr>
<td>1.54 ± 0.18 ± 0.13</td>
<td>3.8M</td>
<td>AMBROSINO 07c KLOE</td>
<td>(\mu = e)</td>
<td></td>
</tr>
<tr>
<td>0.95 ± 0.11 ± 0.08</td>
<td>2.3M</td>
<td>LAI 07A NA48</td>
<td>DP</td>
<td></td>
</tr>
<tr>
<td>1.281 ± 0.136 ± 0.122</td>
<td>1.5M</td>
<td>ALEXOPOULOS 04A KTEV</td>
<td>DP, no (\mu = e)</td>
<td></td>
</tr>
<tr>
<td>1.372 ± 0.131</td>
<td>3.4M</td>
<td>ALEXOPOULOS 04A KTEV</td>
<td>PI, DP, (\mu = e)</td>
<td></td>
</tr>
</tbody>
</table>

1. AMBROSINO 07c, not assuming \(\mu\)-\(e\) universality, gives a correlation matrix

\[
\begin{pmatrix}
\lambda'_+ & \lambda''_+ \\
\lambda''_+ & 1
\end{pmatrix}
\]

2. AMBROSINO 07c, assuming \(\mu\)-\(e\) universality, gives a correlation matrix

\[
\begin{pmatrix}
\lambda'_+ & \lambda''_+ \\
\lambda''_+ & 1
\end{pmatrix}
\]

3. LAI 07A gives a correlation matrix

\[
\begin{pmatrix}
\lambda'_+ & \lambda''_+ \\
\lambda''_+ & 1
\end{pmatrix}
\]

4. ALEXOPOULOS 04A, not assuming \(\mu\)-\(e\) universality, gives a correlation matrix

\[
\begin{pmatrix}
\lambda'_+ & \lambda''_+ & \lambda_0 \\
\lambda'_+ & 1 \\
\lambda''_+ & -0.96 & 1 \\
\lambda_0 & 0.65 & -0.75 & 1
\end{pmatrix}
\]

5. ALEXOPOULOS 04A, assuming \(\mu\)-\(e\) universality, gives a correlation matrix

\[
\begin{pmatrix}
\lambda'_+ & \lambda''_+ & \lambda_0 \\
\lambda'_+ & 1 \\
\lambda''_+ & -0.97 & 1 \\
\lambda_0 & 0.34 & -0.44 & 1
\end{pmatrix}
\]
### $M^\ast_V$ (Pole Mass for $K^0_{e3}$ Decay)

<table>
<thead>
<tr>
<th>Value (MeV)</th>
<th>EVTS</th>
<th>Document ID</th>
<th>TECN</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>878 ± 6</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.1. Assuming $\mu$-e universality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>875 ± 5</td>
<td>OUR AVERAGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>870 ± 6 ± 7</td>
<td>2M</td>
<td>AMBROSINO 06d KLOE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>881.03 ± 5.12 ± 4.94</td>
<td>1.9M</td>
<td>ALEXOPOULOS 04a KTEV PI, no $\mu = e$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>859 ± 18</td>
<td>5.6M</td>
<td>LAI 04c NA48</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### $M^\mu_V$ (Pole Mass for $K^0_{\mu3}$ Decay)

<table>
<thead>
<tr>
<th>Value (MeV)</th>
<th>EVTS</th>
<th>Document ID</th>
<th>TECN</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>878 ± 6</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.1. Assuming $\mu$-e universality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>900 ± 21</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.7. Not assuming $\mu$-e universality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>905 ± 9 ± 17</td>
<td>2.3M</td>
<td>1 LAI 07a NA48 DP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>889.19 ± 12.81 ± 9.92</td>
<td>1.5M</td>
<td>1 ALEXOPOULOS 04a KTEV DP, no $\mu = e$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>882.32 ± 6.54</td>
<td>3.4M</td>
<td>1 ALEXOPOULOS 04a KTEV PI, DP, $\mu = e$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 See section $M^\mu_S$ below for correlations.

### $M^\mu_S$ (Pole Mass for $K^0_{\mu3}$ Decay)

<table>
<thead>
<tr>
<th>Value (MeV)</th>
<th>EVTS</th>
<th>Document ID</th>
<th>TECN</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1252 ± 90</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 2.6. Assuming $\mu$-e universality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1222 ± 80</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 2.3. Not assuming $\mu$-e universality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1400 ± 46 ± 53</td>
<td>2.3M</td>
<td>1 LAI 07a NA48 DP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1167.14 ± 28.30 ± 31.04</td>
<td>1.5M</td>
<td>2 ALEXOPOULOS 04a KTEV PI, no $\mu = e$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1173.80 ± 39.47</td>
<td>3.4M</td>
<td>3 ALEXOPOULOS 04a KTEV PI, DP, $\mu = e$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 LAI 07a gives a correlation $-0.47$ between their $M^\mu_S$ and $M^\mu_V$ measurements, not assuming $\mu$-e universality.

2 ALEXOPOULOS 04a gives a correlation $-0.46$ between their $M^\mu_S$ and $M^\mu_V$ measurements, not assuming $\mu$-e universality.

3 ALEXOPOULOS 04a gives a correlation $-0.40$ between their $M^\mu_S$ and $M^\mu_V$ measurements, assuming $\mu$-e universality.

### $\Lambda_+$ (Dispersive Vector Form Factor for $K^0_{\mu3}$ Decay)

See the review on $K^\pm_{\ell 3}$ and $K^0_{\ell 3}$ Form Factors for details of the dispersive parametrization.

<table>
<thead>
<tr>
<th>Value (units 10^{-1})</th>
<th>EVTS</th>
<th>Document ID</th>
<th>TECN</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.251 ± 0.006 OUR AVERAGE</td>
<td>Error includes scale factor of 1.5. See the ideogram below.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.2509 ± 0.0035 ± 0.0043</td>
<td>3.4M</td>
<td>1 ABOUZAID 10 KTEV $\mu = e$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.257 ± 0.004 ± 0.004</td>
<td>3.8M</td>
<td>2 AMBROSINO 07c KLOE $\mu = e$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.233 ± 0.005 ± 0.008</td>
<td>2.3M</td>
<td>3 LAI 07a NA48 DP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Obtained from a sample of 1.9 M $K_{e3}$ and 1.5 M $K_{\mu3}$. The correlation between $\Lambda_+$ and $\ln(C)$ is $-0.269$.

2 AMBROSINO 07c results include 2M $K_{e3}$ events from AMBROSINO 06d. The correlation between $\Lambda_+$ and $\ln(C)$ is $-0.26$.

3 LAI 07a gives a correlation $-0.44$ between their $\Lambda_+$ and $\ln(C)$ measurements.
\( \Lambda_+ \) (DISPERSSIVE VECTOR FORM FACTOR FOR \( K^0_{\mu 3} \) DECAY) (units \( 10^{-1} \))

\( \ln(C) \) (DISPERSSIVE SCALAR FORM FACTOR FOR \( K^0_{\mu 3} \) DECAY)

See the review on “\( K^\pm_{\ell 3} \) and \( K^0_{\ell 3} \) Form Factors” for details of the dispersive parametrization.

<table>
<thead>
<tr>
<th>VALUE (units ( 10^{-1} ))</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.75 ±0.18 OUR AVERAGE</td>
<td>Error includes scale factor of 2.0. See the ideogram below.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.915±0.078±0.094</td>
<td>3.4M</td>
<td>1 ABOUZAID 10 KTEV ( \mu = e )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.04±0.19±0.15</td>
<td>3.8M</td>
<td>2 AMBROSINO 07C KLOE ( \mu = e )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.438±0.080±0.112</td>
<td>2.3M</td>
<td>3 LAI 07A NA48 DP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Obtained from a sample of 1.9 M \( K_{\ell 3} \) and 1.5 M \( K_{\mu 3} \). The correlation between \( \Lambda_+ \) and \( \ln(C) \) is \( -0.269 \).

2 AMBROSINO 07C results include 2M \( K_{\ell 3} \) events from AMBROSINO 06D. We convert (\( \Lambda_+ \), \( \Lambda_0 \)) to (\( \Lambda_+ \), \( \ln(C) \)) parametrization using \( \ln(C) = (\Lambda_0 \cdot 11.713 \pm 0.0398) \pm 0.0041 \), where the error is due to theory parametrization of the form factor. The correlation between \( \Lambda_+ \) and \( \ln(C) \) is \( -0.26 \).

3 LAI 07A gives a correlation \( -0.44 \) between their \( \Lambda_+ \) and \( \ln(C) \) measurements.
WEIGHTED AVERAGE
1.75±0.18 (Error scaled by 2.0)

\[ \ln(C) \] (DISPERSCAL FORM FACTOR FOR \( K_0^{03} \) DECAY) (units \( 10^{-1} \))

\( a_1(t_0, Q^2) \) FORM FACTOR PARAMETER
See HILL 06 for a definition of this parameter.

\[
\begin{array}{cccc}
\text{VALUE} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
1.023\pm0.028\pm0.029 & 2M & 1 \text{ ABOUZAI}D 06c & \text{KTEV} \\
\end{array}
\]

\( Q^2 = 2 \text{ GeV}^2, t_0 = 0.49 (m_K - m_\pi)^2. \) Correlation between \( a_1 \) and \( a_2: \rho_{12} = -0.064. \)

\( a_2(t_0, Q^2) \) FORM FACTOR PARAMETER
See HILL 06 for a definition of this parameter.

\[
\begin{array}{cccc}
\text{VALUE} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
0.75\pm1.58\pm1.47 & 2M & 1 \text{ ABOUZAI}D 06c & \text{KTEV} \\
\end{array}
\]

\( Q^2 = 2 \text{ GeV}^2, t_0 = 0.49 (m_K - m_\pi)^2. \) Correlation between \( a_1 \) and \( a_2: \rho_{12} = -0.064. \)

\( |f_S/f_+| \) FOR \( K_0^{03} \) DECAY
Ratio of scalar to \( f_+ \) couplings.

\[
\begin{array}{cccc}
\text{VALUE (units 10^{-2})} & \text{CL\%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\
1.5\pm0.7 & 5.6M & 1 \text{ LAI 04} & \text{NA48} \\
\end{array}
\]

\( \bullet \bullet \bullet \) We do not use the following data for averages, fits, limits, etc. \( \bullet \bullet \bullet \)

\[
\begin{array}{cccc}
\text{VALUE} & \text{CL\%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \ \\
<9.5 & 95 & 18k & \text{HILL} & 78 & \text{STRC} \\
<7. & 68 & 48k & \text{BIRULEV} & 76 & \text{SPEC} & \text{See also BIRULEV 81} \\
<4. & 68 & 25k & \text{BLUMENTHAL75} & \text{SPEC} \\
\end{array}
\]

\( ^1 \) Results from linear fit with \( |f_S/f_+| \) and \( |f_T/f_+| \) free.
\[ |f_T/f_+| \text{ FOR } K_{0\mu3} \text{ DECAY} \]

Ratio of tensor to \( f_+ \) couplings.

<table>
<thead>
<tr>
<th>VALUE (units ( 10^{-2} ))</th>
<th>CL%</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 5^{+3}_{-4} \pm 3 )</td>
<td>5.6M</td>
<td>1 LAI</td>
<td>047 NA48</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

\(<40. \quad 95 \quad 18k \quad \text{HILL} \quad 78 \quad \text{STRC} \)
\(<34. \quad 68 \quad 48k \quad \text{BIRULEV} \quad 76 \quad \text{SPEC} \) See also BIRULEV 81
\(<23. \quad 68 \quad 25k \quad \text{BLUMENTHAL75 SPEC} \)

Results from linear fit with \(|f_S/f_+|\) and \(|f_T/f_+|\) free.

\[ |f_T/f_+| \text{ FOR } K_{0\ell3} \text{ DECAY} \]

Ratio of tensor to \( f_+ \) couplings.

\[ 12. \pm 12. \]

\( \alpha_{K^*} \) DECAY FORM FACTOR FOR \( K_L \rightarrow \ell^+ \ell^- \gamma, K_{0\ell3} \rightarrow \ell^+ \ell^- \ell^+ \ell^- \)

Average of all \( \alpha_{K^*} \) measurements (from each of three datablocks following this one) assuming lepton universality.

\[ \text{VALUE} \quad \text{DOCUMENT ID} \]
\[ -0.205 \pm 0.022 \quad \text{OUR AVERAGE} \quad \text{Includes data from the 3 datablocks that follow this one. Error includes scale factor of 1.8. See the ideogram below.} \]

**WEIGHTED AVERAGE**

\(-0.205 \pm 0.022 \) (Error scaled by 1.8)

\( \chi^2 \)

\( \chi^2 = 9.2 \)

(Confidence Level = 0.027)

\( \alpha_{K^*} \) DECAY FORM FACTOR FOR \( K_L \rightarrow \ell^+ \ell^- \gamma, K_{0\ell3} \rightarrow \ell^+ \ell^- \ell^+ \ell^- \)
$\alpha_{K^*}$ 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 $K_L \to \pi, \eta, \eta' \to \gamma \gamma^*$.

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.217 \pm 0.034$ OUR AVERAGE</td>
<td>83k</td>
<td>1 ABOUZAI D 07B</td>
<td>KTEV</td>
</tr>
<tr>
<td>$-0.207 \pm 0.012 \pm 0.009$</td>
<td>9684</td>
<td>FANTI 99B</td>
<td>NA48</td>
</tr>
<tr>
<td>$-0.36 \pm 0.06 \pm 0.02$</td>
<td>6864</td>
<td>BARR 90B</td>
<td>NA31</td>
</tr>
<tr>
<td>$-0.28 \pm 0.13$</td>
<td></td>
<td>OHL 90B</td>
<td>B845</td>
</tr>
</tbody>
</table>

$\alpha_{K^*}$ measures $C \cdot \alpha_{K^*} = -0.517 \pm 0.030 \pm 0.022$. We assume $C = 2.5$, as in all other measurements.

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

$\alpha_{K^*}$ is the constant in the model of BERGSTROM 83 described in the previous section.

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.158 \pm 0.027$ OUR AVERAGE</td>
<td>9100</td>
<td>ALAVI-HARATI01G</td>
<td>KTEV</td>
</tr>
<tr>
<td>$-0.160 \pm 0.026 \pm 0.028$</td>
<td></td>
<td>FANTI 97</td>
<td>NA48</td>
</tr>
<tr>
<td>$-0.04 \pm 0.24 \pm 0.21$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

$\alpha_{K^*}^{\text{eff}}$ is the parameter describing the relative strength of an intermediate pseudoscalar decay amplitude and a vector meson decay amplitude in the model of BERGSTROM 83. It takes into account both the radiative effects and the form factor. Since there are two $e^+ e^-$ pairs here compared with one in $e^+ e^- \gamma$ decays, a factorized expression is used for the $e^+ e^- e^+ e^-$ decay form factor.

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.14 \pm 0.16 \pm 0.15$</td>
<td>441</td>
<td>ALAVI-HARATI01D</td>
<td>KTEV</td>
</tr>
</tbody>
</table>

$\alpha_{DIP}$ DECAY FORM FACTOR FOR $K_L^0 \to \ell^+ \ell^- \gamma$,

Average of all $\alpha_{DIP}$ measurements (from each of three datablocks following this one) assuming lepton universality.

<table>
<thead>
<tr>
<th>VALUE</th>
<th>DOCUMENT ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-1.69 \pm 0.08$ OUR AVERAGE</td>
<td>Includes data from the 3 datablocks that follow this one. Error includes scale factor of 1.7.</td>
</tr>
</tbody>
</table>

$\alpha_{DIP}$ DECAY FORM FACTOR FOR $K_L^0 \to e^+ e^- \gamma$

$\alpha_{DIP}$ parameter in $K_L^0 \to \gamma^* \gamma^*$ form factor by DAMBROSIO 98, motivated by vector meson dominance and a proper short distance behavior.

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-1.729 \pm 0.043 \pm 0.028$</td>
<td>83k</td>
<td>1 ABOUZAI D 07B</td>
<td>KTEV</td>
</tr>
</tbody>
</table>
\( \alpha_{\text{DIP}} \) DECAY FORM FACTOR FOR \( K^0_L \rightarrow \mu^+ \mu^- \gamma \\
\alpha_{\text{DIP}} \) is a constant in the model of DAMBROSIO 98 described in the previous section.

The data in this block is included in the average printed for a previous datablock.

\[ -1.54 \pm 0.10 \]

\( \alpha_{\text{DIP}} \) DECAY FORM FACTOR FOR \( K^0_L \rightarrow e^+ e^- \mu^+ \mu^- \\
\alpha_{\text{DIP}} \) is a constant in the model of DAMBROSIO 98 described in the previous section.

The data in this block is included in the average printed for a previous datablock.

\[ -1.59 \pm 0.37 \]

\( a_1/a_2 \) FORM FACTOR FOR M1 DIRECT EMISSION AMPLITUDE

\[
\text{Form factor } = \tilde{g}_{M1} \left[ 1 + \frac{a_1/a_2}{(M^2 - M^2_K) + 2M_K E_\gamma} \right] \]

as described in ALAVI-HARATI 00B.

\[ \begin{array}{|c|c|c|c|}
\hline
\text{VALUE (GeV}^2\text{)} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\\n\hline
-0.737 \pm 0.014 & \text{OUR AVERAGE} & 5241 & \\
-0.744 \pm 0.027 & 111k & 06 & KTEV \\
0.738 \pm 0.007 & 111k & 06 & KTEV \\
-0.81 & 111k & 03C & NA48 \\
-0.737 & 111k & 03C & NA48 \\
-0.720 & 1766 & 00B & KTEV \\
\hline
\end{array} \]

1. ABOUZAI 06 also measured \( |\tilde{g}_{M1}| = 1.11 \pm 0.14 \).
2. ABOUZAI 06 also measured \( |\tilde{g}_{M1}| = 1.198 \pm 0.035 \pm 0.086 \).
3. LAI 03C also measured \( |\tilde{g}_{M1}| = 0.99^{+0.28}_{-0.27} \pm 0.07 \).
4. ALAVI-HARATI 01B fit gives \( \chi^2/\text{DOF} = 38.8/27 \). Linear and quadratic fits give \( \chi^2/\text{DOF} = 43.2/27 \) and 37.6/26 respectively.
5. ALAVI-HARATI 00B also measured \( |\tilde{g}_{M1}| = 1.35^{+0.20}_{-0.17} \pm 0.04 \).

\( \tilde{T}_S \) DECAY FORM FACTOR FOR \( K^0_L \rightarrow \pi^+ \pi^- e^+ \nu_e \)

\[ \text{VALUE \hspace{1cm} DOCUMENT ID \hspace{1cm} TECN} \]
\[ \text{0.049 \pm 0.011 OUR AVERAGE} \hspace{1cm} \text{Error includes scale factor of 1.7}. \]
\[ 0.052 \pm 0.006 \pm 0.002 \hspace{1cm} \text{BATLEY \hspace{1cm} 04 \hspace{1cm} NA48} \]
\[ 0.010 \pm 0.016 \pm 0.017 \hspace{1cm} \text{MAKOFF \hspace{1cm} 93 \hspace{1cm} E731} \]

\( \tilde{T}_P \) DECAY FORM FACTOR FOR \( K^0_L \rightarrow \pi^+ \pi^- e^+ \nu_e \)

\[ \text{VALUE \hspace{1cm} DOCUMENT ID \hspace{1cm} TECN} \]
\[ \text{0.052 \pm 0.012 OUR AVERAGE} \]
\[ 0.051 \pm 0.011 \pm 0.005 \hspace{1cm} \text{BATLEY \hspace{1cm} 04 \hspace{1cm} NA48} \]
\[ 0.079 \pm 0.049 \pm 0.022 \hspace{1cm} \text{MAKOFF \hspace{1cm} 93 \hspace{1cm} E731} \]

\( \lambda_5 \) DECAY FORM FACTOR FOR \( K^0_L \rightarrow \pi^+ \pi^- e^+ \nu_e \)

\[ \text{VALUE \hspace{1cm} DOCUMENT ID \hspace{1cm} TECN} \]
\[ \text{0.085 \pm 0.020 OUR AVERAGE} \]
\[ 0.087 \pm 0.019 \pm 0.006 \hspace{1cm} \text{BATLEY \hspace{1cm} 04 \hspace{1cm} NA48} \]
\[ 0.014 \pm 0.007 \pm 0.070 \hspace{1cm} \text{MAKOFF \hspace{1cm} 93 \hspace{1cm} E731} \]
$\bar{\eta}$ DECAY FORM FACTOR FOR $K_L^0 \rightarrow \pi^\pm \pi^0 e^{\mp} \nu_e$

<table>
<thead>
<tr>
<th>VALUE</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.30 \pm 0.13$</td>
<td>OUR AVERAGE</td>
<td></td>
</tr>
<tr>
<td>$-0.32 \pm 0.12 \pm 0.07$</td>
<td>BATLEY 04</td>
<td>NA48</td>
</tr>
<tr>
<td>$-0.07 \pm 0.31 \pm 0.31$</td>
<td>MAKOFF 93</td>
<td>E731</td>
</tr>
</tbody>
</table>

$L_3$ CHIRAL PERT. THEO. PARAM. FOR $K_L^0 \rightarrow \pi^\pm \pi^0 e^{\mp} \nu_e$

<table>
<thead>
<tr>
<th>VALUE (units $10^{-3}$)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-3.96 \pm 0.28$ OUR AVERAGE</td>
<td>Error includes scale factor of 1.6.</td>
<td></td>
</tr>
<tr>
<td>$-4.1 \pm 0.2$</td>
<td>BATLEY 04</td>
<td>NA48</td>
</tr>
<tr>
<td>$-3.4 \pm 0.4$</td>
<td>1 MAKOFF 93</td>
<td>E731</td>
</tr>
</tbody>
</table>

1 MAKOFF 93 sign has been changed to negative to agree with the sign convention used in BATLEY 04.

$\alpha_V$, VECTOR MESON EXCHANGE CONTRIBUTION

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.43 \pm 0.06$ OUR AVERAGE</td>
<td>Error includes scale factor of 1.5.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$-0.31 \pm 0.05 \pm 0.07$</td>
<td>1.4k</td>
<td>1 ABOUZAID 08</td>
<td>KTEV</td>
</tr>
<tr>
<td>$-0.16 \pm 0.03 \pm 0.04$</td>
<td>LAI 02B</td>
<td>NA48</td>
<td></td>
</tr>
<tr>
<td>$-0.67 \pm 0.21 \pm 0.12$</td>
<td>ALAVI-HARATI 101E</td>
<td>KTEV</td>
<td></td>
</tr>
</tbody>
</table>

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

$-0.72 \pm 0.05 \pm 0.06$ 2 ALAVI-HARATI 199B | KTEV |

2 Superseded by ABOUZAID 08.

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CP-VIOLATION PARAMETERS IN $K_L^0$ DECAYS

CHARGE ASYMMETRY IN $K_L^3$ DECAYS

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

$A_L = \text{weighted average of } A_L(\mu) \text{ and } A_L(e)$

In previous editions and in the literature the symbol used for this asymmetry was $\delta_L$ or $\delta$. We use $A_L$ for consistency with $B^0$ asymmetry notation and with recent $K_S^0$ notation.

<table>
<thead>
<tr>
<th>VALUE (%)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.332±0.006 OUR AVERAGE</td>
<td>EVTS</td>
<td>DOCUMENT ID</td>
<td>TECN</td>
<td>COMMENT</td>
</tr>
<tr>
<td>0.333±0.050</td>
<td>33M</td>
<td>WILLIAMS 73</td>
<td>ASPK</td>
<td>$K_{\mu 3} + K_{e 3}$</td>
</tr>
</tbody>
</table>

$A_L(\mu) = \frac{[\Gamma(\pi^- \mu^+ \nu_\mu) - \Gamma(\pi^+ \mu^- \bar{\nu}_\mu)]}{\text{SUM}}$

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

<table>
<thead>
<tr>
<th>VALUE (%)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.304±0.025 OUR AVERAGE</td>
<td>0.313±0.029</td>
<td>15M</td>
<td>GEWENIGER 74</td>
</tr>
<tr>
<td>0.278±0.051</td>
<td>7.7M</td>
<td>PICCIONI 72</td>
<td>ASPK</td>
</tr>
</tbody>
</table>

HTTP://PDG.LBL.GOV
We do not use the following data for averages, fits, limits, etc.

\begin{itemize}
\item 0.60 ± 0.14 \hspace{1cm} 4.1M \hspace{1cm} MCCARTHY \hspace{1cm} 73 \hspace{1cm} CNTR
\item 0.57 ± 0.17 \hspace{1cm} 1M \hspace{1cm} 1 PACIOTTI \hspace{1cm} 69 \hspace{1cm} OSPK
\item 0.403 ± 0.134 \hspace{1cm} 1M \hspace{1cm} 1 DORFAN \hspace{1cm} 67 \hspace{1cm} OSPK
\end{itemize}

\[ A_L(e) = \left[ \frac{\Gamma(\pi^- e^+ \nu_e) - \Gamma(\pi^+ e^- \bar{\nu}_e)}{\Sigma} \right] \]

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

\begin{tabular}{lrr}
\textbf{VALUE} & \textbf{EVTS} & \textbf{DOCUMENT ID} & \textbf{TECN} \\
\hline
0.334 ± 0.007 & 0.3322 ± 0.0058 ± 0.0047 & 298M & ALAVI-HARATI \text{102} \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
0.341 ± 0.018 & 34M & GEWENIGER \text{74} & ASPK \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
0.318 ± 0.038 & 40M & FITCH \text{73} & ASPK \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
0.346 ± 0.033 & 10M & MARX \text{70} & CNTR \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
\end{tabular}

\textbf{PARAMETERS FOR} \( K_L^0 \rightarrow 2\pi \) \textbf{DECAY} \textbf{---}

\[ \eta_{+-} = \frac{A(K_L^0 \rightarrow \pi^+ \pi^-)}{A(K_S^0 \rightarrow \pi^+ \pi^-)} \]
\[ \eta_{00} = \frac{A(K_L^0 \rightarrow \pi^0 \pi^0)}{A(K_S^0 \rightarrow \pi^0 \pi^0)} \]

The fitted values of \( |\eta_{+-}| \) and \( |\eta_{00}| \) given below are the results of a fit to \( |\eta_{+-}| \), \( |\eta_{00}| \), \( |\eta_{+-}|/|\eta_{00}| \), and Re\((\epsilon'/\epsilon)\). Independent information on \( |\eta_{+-}| \) and \( |\eta_{00}| \) can be obtained from the fitted values of the \( K_L^0 \rightarrow \pi \pi \) and \( K_S^0 \rightarrow \pi \pi \) branching ratios and the \( K_L^0 \) and \( K_S^0 \) lifetimes. This information is included as data in the \( |\eta_{+-}| \) and \( |\eta_{00}| \) sections with a Document ID “BRFIT.” See the note “CP violation in \( K_L^0 \) decays” above for details.

\[ |\eta_{00}| = \left| \frac{A(K_L^0 \rightarrow 2\pi^0)}{A(K_S^0 \rightarrow 2\pi^0)} \right| \]

\begin{tabular}{lrr}
\textbf{VALUE} (units \( 10^{-3} \)) & \textbf{DOCUMENT ID} \hspace{1cm} \textbf{TECN} \hspace{1cm} \textbf{COMMENT} \\
\hline
2.220 ± 0.011 & \text{OUR FIT} & Error includes scale factor of 1.8. \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
2.243 ± 0.014 & BRFIT \hspace{1cm} 16 & \text{---} \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
\end{tabular}

\textbf{--- We do not use the following data for averages, fits, limits, etc. ---}

\begin{itemize}
\item 2.47 ± 0.31 \hspace{1cm} 0.24 \hspace{1cm} ANGELOPOLO... \text{98} \hspace{1cm} CPLR \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
\item 2.49 ± 0.40 \hspace{1cm} 1 \hspace{1cm} ADLER \text{96}\text{B} \hspace{1cm} CPLR \hspace{1cm} Sup. by ANGELOPOLOUS \text{98} \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
\item 2.33 ± 0.18 \hspace{1cm} \text{CHRISTENS...} \text{79} \hspace{1cm} ASPK \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
\item 2.71 ± 0.37 \hspace{1cm} \text{WOLFF} \text{71} \hspace{1cm} OSPK \hspace{1cm} Cu reg., 4γ's \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
\item 2.95 ± 0.63 \hspace{1cm} \text{CHOLLET} \text{70} \hspace{1cm} OSPK \hspace{1cm} Cu reg., 4γ's \\[ \text{SAAL 69 is a reanalysis of BENNETT 67.} \]
\end{itemize}
1 Error is statistical only.

2 CHOLLET 70 gives $|\eta_{00}| = (1.23 \pm 0.24) \times (\text{regeneration amplitude}, 2 \text{ GeV/c Cu})/10000 \text{mb}$. WOLFF 71 gives $|\eta_{00}| = (1.13 \pm 0.12) \times (\text{regeneration amplitude}, 2 \text{ GeV/c Cu})/10000 \text{mb}$. We compute both $|\eta_{00}|$ values for (regeneration amplitude, 2 GeV/c Cu) = 24 ± 2 mb. 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).

$$|\eta_{+-}| = \frac{|A(K_L^{0} \rightarrow \pi^{+} \pi^{-})|}{|A(K_S^{0} \rightarrow \pi^{+} \pi^{-})|}$$

<table>
<thead>
<tr>
<th>VALUE (units $10^{-3}$)</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.232 ± 0.011 OUR FIT</td>
<td>Error includes scale factor of 1.8.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.226 ± 0.007</td>
<td>BRFIT 16</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

2.232 ± 0.012
2.219 ± 0.013
2.228 ± 0.010
2.266 ± 0.023 ± 0.026 70M
2.310 ± 0.043 ± 0.031
2.32 ± 0.14 ± 0.03 105
2.30 ± 0.035

1 Value obtained from the NA48 measurements of $\Gamma(K_L^{0} \rightarrow \pi^{+} \pi^{-})/\Gamma(K_L^{0} \rightarrow \pi^{+} \pi^{-})$ and $\tau_{K_S^{0}}$ and KLOE measurements of $B(K_S^{0} \rightarrow \pi^{+} \pi^{-})$ and $\tau_{K_S^{0}}$. $\Gamma(K_L^{0} \rightarrow \pi^{+} \pi^{-})$ is defined to include the inner bremsstrahlung component $\Gamma(K_L^{0} \rightarrow \pi^{+} \pi^{-} \gamma (IB))$ but exclude the direct emission component $B(K_S^{0} \rightarrow \pi^{+} \pi^{-} (DE))$. Their $|\eta_{+-}|$ value is not directly used in our fit, but enters the fit via their branching ratio and lifetime measurements.

2 AMBROSINO 06F uses KLOE branching ratios and $\tau_{K_L}$ together with $\tau_{S}$ from PDG 04. Their $|\eta_{+-}|$ value is not directly used in our fit, but enters the fit via their branching ratio and lifetime measurements.

3 ALEXOPOULOS 04 $|\eta_{+-}|$ uses their $K^0_L \rightarrow \pi^{+} \pi$ branching fractions, $\tau_{S} = (0.8963 \pm 0.0005) \times 10^{-10}$ s from the average of KTeV and NA48 $\tau_{S}$ measurements, and assumes that $\Gamma(K_S^{0} \rightarrow \pi^0 \nu \bar{\nu}) = \Gamma(K_L^{0} \rightarrow \pi^0 \nu \bar{\nu})$ giving $B(K_S^{0} \rightarrow \pi^0 \nu \bar{\nu}) = 0.118\%$. Their $|\eta_{+-}|$ is not directly used in our fit, but enters our fit via their branching ratio measurements.

4 APOSTOLAKIS 99C report (2.264 ± 0.023 ± 0.026 + 9.1[\tau_{S} = 0.8934])] \times 10^{-3}$. We evaluate for our 2006 best value $\tau_{S} = (0.8958 \pm 0.0005) \times 10^{-10}$ s.

5 ADLER 95B report (2.312 ± 0.043 ± 0.030 – 1[\Delta m = 0.5274] + 9.1[\tau_{S} = 0.8926])] \times 10^{-3}$. We evaluate for our 1996 best values $\Delta m = (0.5304 \pm 0.0014) \times 10^{-10}$ $\text{hs}^{-1}$ and $\tau_{S} = (0.8927 \pm 0.0009) \times 10^{-10}$ s. Superseded by APOSTOLAKIS 99C.

$$|\epsilon| = \frac{|2|\eta_{+-}| + |\eta_{00}|}{3}$$

This expression is a very good approximation, good to about one part in $10^{-4}$ because of the small measured value of $\phi_{00} - \phi_{+-}$ and small theoretical ambiguities.
\[
\left| \eta_{00}/\eta_{+-} \right|
\]

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9950 ± 0.0007 OUR FIT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.9930 ± 0.0020 OUR AVERAGE</td>
<td>1.2 BARR</td>
<td>93D NA31</td>
<td></td>
</tr>
<tr>
<td>1.0000 ± 0.0036</td>
<td>3 WOODS</td>
<td>88 E731</td>
<td></td>
</tr>
</tbody>
</table>

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

We use the following data for averages but not for fits. • • •

1.92 ± 0.21
1.47 ± 0.22
0.74 ± 0.52 ± 0.29
2.3 ± 0.65

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

2.110 ± 0.343
2.07 ± 0.28
1.53 ± 0.26
2.80 ± 0.30 ± 0.28
1.85 ± 0.45 ± 0.58
2.0 ± 0.7
-0.4 ± 1.4 ± 0.6
3.3 ± 1.1
3.2 ± 2.8 ± 1.2

1 This is the square root of the ratio \( R \) given by BURKHARDT 88 and BARR 93D.
2 This is the combined results from BARR 93D and BURKHARDT 88, taking into account a common systematic uncertainty of 0.0014.
3 We calculate \( |\eta_{00}/\eta_{+-}| = 1 - 3(\epsilon'/\epsilon) \) from WOODS 88 (\( \epsilon'/\epsilon \)) value.

We have neglected terms of order \( \omega \cdot \Re(\epsilon'/\epsilon) \), where \( \omega = \Re(A_2)/\Re(A_0) \approx 1/22 \). If included, this correction would lower \( \Re(\epsilon'/\epsilon) \) by about \( 0.04 \times 10^{-3} \). See SOZZI 04.

We use the following data for averages but not for fits. • • •

1.92 ± 0.21
1.47 ± 0.22
0.74 ± 0.52 ± 0.29
2.3 ± 0.65

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

2.110 ± 0.343
2.07 ± 0.28
1.53 ± 0.26
2.80 ± 0.30 ± 0.28
1.85 ± 0.45 ± 0.58
2.0 ± 0.7
-0.4 ± 1.4 ± 0.6
3.3 ± 1.1
3.2 ± 2.8 ± 1.2

1 The two ABOUZAID 11 values use the same data. The fits are performed with and without \( CPT \) invariance requirement.
2 These values are derived from \( |\eta_{00}/\eta_{+-}| \) measurements. They enter the average in this section but enter the fit via the \( |\eta_{00}/\eta_{+-}| \) only.
3 This is the combined results from BARR 93D and BURKHARDT 88, taking into account their common systematic uncertainty.
4 We use ABOUZAID 11 \( \Re(\epsilon'/\epsilon) \) value with \( CPT \) assumption in our fits for \( |\eta_{+-}|, |\eta_{00}|, \) and \( \Re(\epsilon'/\epsilon) \).
5 These values are derived from \( |\eta_{00}/\eta_{+-}| \) measurements.
WEIGHTED AVERAGE
1.68±0.20 (Error scaled by 1.4)

Values above of weighted average, error, and scale factor are based upon the data in this ideogram only. They are not necessarily the same as our 'best' values, obtained from a least-squares constrained fit utilizing measurements of other (related) quantities as additional information.

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 $10^{10}$ $\text{fs}^{-1}$ and $\tau_S$ is the $K_S^0$ mean life in units $10^{-10}$ $\text{s}$. We also give the regeneration phase $\phi_F$ in the comments below.

OUR FIT is described in the note on "CP violation in $K_L$ decays" in the $K_L^0$ Particle Listings. Most experiments in this section are included in both the "Not Assuming CPT" and "Assuming CPT" fits. In the latter fit, they have little direct influence on $\phi_{+-}$ because their errors are large compared to that assuming CPT, but they influence $\Delta m$ and $\tau_S$ through their dependencies on these parameters, which are given in the footnotes.

\[
\text{Re}(\epsilon'/\epsilon) = \left(1 - \left|\eta_{00}/\eta_{+-}\right|\right)/3
\]
1 ADLER 95c measures $\phi_{+m} = (43.19 \pm 0.53 \pm 0.28) + 300 \cdot [\Delta m - 0.5301] (^\circ)$. We have adjusted the measurement to use our best values of $[\Delta m = 0.5293 \pm 0.0009]$ ($10^{10}$ $\bar{n}$ s$^{-1}$). Our first error is their experiment’s error and our second error is the systematic error from using our best values.

2 SCHWINGENHEUER 95 measures $\phi_{+m} = (43.53 \pm 0.76) + 173 \cdot [\Delta m - 0.5282] - 275 \cdot [\tau_S - 0.8926] (^\circ)$. We have adjusted the measurement to use our best values of $[\Delta m = 0.5293 \pm 0.0009]$ ($10^{10}$ $\bar{n}$ s$^{-1}$), $(\tau_S = 0.8954 \pm 0.0004) (10^{-10}$ s). Our first error is their experiment’s error and our second error is the systematic error from using our best values.

These experiments measure $\phi_{+m} - \phi_f$ 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$^\circ$ [0.5$^\circ$] for uncertainties in their modeling of the regeneration amplitude.

3 GIBBONS 93 measures $\phi_{+m} = (42.21 \pm 0.9) + 189 \cdot [\Delta m - 0.5257] - 460 \cdot [\tau_S - 0.8922] (^\circ)$. We have adjusted the measurement to use our best values of $[\Delta m = 0.5293 \pm 0.0009]$ ($10^{10}$ $\bar{n}$ s$^{-1}$), $(\tau_S = 0.8954 \pm 0.0004) (10^{-10}$ s). Our first error is their experiment’s error and our second error is the systematic error from using our best values. They measure $\phi_{+m} - \phi_f$ and calculate the regeneration phase $\phi_f$ from the power law momentum dependence of the regeneration amplitude using analyticity. Any error of 0.6$^\circ$ is included for possible uncertainties in the regeneration phase.

4 CAROSI 90 measures $\phi_{+m} = (46.9 \pm 1.4 \pm 0.7) + 579 \cdot [\Delta m - 0.5351] + 303 \cdot [\tau_S - 0.8922] (^\circ)$. We have adjusted the measurement to use our best values of $[\Delta m = 0.5293 \pm 0.0009]$ ($10^{10}$ $\bar{n}$ s$^{-1}$), $(\tau_S = 0.8954 \pm 0.0004) (10^{-10}$ s). Our first error is their experiment’s error and our second error is the systematic error from using our best values.

6 GEWENIGER 74$^c$ measures $\phi_{+m} = (49.4 \pm 1.0) + 565 \cdot [\Delta m - 0.540] (^\circ)$. We have adjusted the measurement to use our best values of $[\Delta m = 0.5293 \pm 0.0009]$ ($10^{10}$ $\bar{n}$ s$^{-1}$). Our first error is their experiment’s error and our second error is the systematic error from using our best values.

7 Not independent of other phase parameters reported in ABOUZAI'D 11.

8 ALAVI-HARATI 03 $\phi_{+m}$ is correlated with their $\Delta m = m_{K_L} - m_{K_S}$ and $\tau_{K_S}$ measurements in the $K_L$ and $K_S$ sections respectively. The correlation coefficients are $\rho(\phi_{+m}, \Delta m) = +0.955$, $\rho(\phi_{+m}, \tau_S) = -0.871$, and $\rho(\tau_S, \Delta m) = -0.840$. CPT is not assumed. Uses scintillator Pb regenerator. Superseded by ABOUZAI'D 11.

9 ADLER 96c measures $\phi_{+m} = (43.82 \pm 0.41) + 339 \cdot [\Delta m - 0.5307] - 252 \cdot [\tau_S - 0.8922] (^\circ)$. We have adjusted the measurement to use our best values of $[\Delta m = 0.5293 \pm 0.0009]$ ($10^{10}$ $\bar{n}$ s$^{-1}$), $(\tau_S = 0.8954 \pm 0.0004) (10^{-10}$ s). Our first error is their experiment’s error and our second error is the systematic error from using our best values.

10 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)).

11 ADLER 95b measures $\phi_{+m} = (42.7 \pm 0.9 \pm 0.6) + 316 \cdot [\Delta m - 0.5274] + 30 \cdot [\tau_S - 0.8926] (^\circ)$. We have adjusted the measurement to use our best values of $[\Delta m = 0.5293 \pm 0.0009]$ ($10^{10}$ $\bar{n}$ s$^{-1}$), $(\tau_S = 0.8954 \pm 0.0004) (10^{-10}$ s). Our first error is their experiment’s error and our second error is the systematic error from using our best values.

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

13 KARLSSON 90 systematic error does not include regeneration phase uncertainty.
\[ \phi_{00} = (2\phi_{+-} + \phi_{00})/3 \]

This expression is a very good approximation, good to about \(10^{-3}\) degrees because of the small measured values of \(\phi_{00}, \phi_{+-}\) and Re \(\epsilon'/\epsilon\), and small theoretical ambiguities.

\[ \phi_{\epsilon} = (2\phi_{+-} + \phi_{00})/3 \]

This expression is a very good approximation, good to about \(10^{-3}\) degrees because of the small measured values of \(\phi_{00}, \phi_{+-}\) and Re \(\epsilon'/\epsilon\), and small theoretical ambiguities.

\[ \phi_{\epsilon} = (2\phi_{+-} + \phi_{00})/3 \]

This expression is a very good approximation, good to about \(10^{-3}\) degrees because of the small measured values of \(\phi_{00}, \phi_{+-}\) and Re \(\epsilon'/\epsilon\), and small theoretical ambiguities.

\[ \phi_{\epsilon} = (2\phi_{+-} + \phi_{00})/3 \]

This expression is a very good approximation, good to about \(10^{-3}\) degrees because of the small measured values of \(\phi_{00}, \phi_{+-}\) and Re \(\epsilon'/\epsilon\), and small theoretical ambiguities.
$\text{Im}(\epsilon'/\epsilon) = -(\phi_{00} - \phi_{+-})/3$

For small $|\epsilon'/\epsilon|$, $\text{Im}(\epsilon'/\epsilon)$ is related to the phases of $\eta_{00}$ and $\eta_{+-}$ by the above expression.

<table>
<thead>
<tr>
<th>VALUE ($^{\circ}$)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.002 \pm 0.005$</td>
<td>OUR FIT</td>
<td>Error includes scale factor of 1.7. Assuming CPT</td>
<td></td>
</tr>
<tr>
<td>$-0.11 \pm 0.11$</td>
<td>OUR FIT</td>
<td>Not assuming CPT</td>
<td></td>
</tr>
<tr>
<td>$-0.0985 \pm 0.1157$</td>
<td>1 ABOUZAID</td>
<td>KTEV</td>
<td>Not assuming CPT</td>
</tr>
</tbody>
</table>

1 ABOUZAID 11 uses the full KTeV dataset collected in 1996, 1997, and 1999. The fit has $\Delta m, \tau_s, \phi_e, \text{Re}(\epsilon'/\epsilon)$, and $\text{Im}(\epsilon'/\epsilon)$ as free parameters. The reported value of $\text{Im}(\epsilon'/\epsilon)$

$$\text{Im}(\epsilon'/\epsilon) = (17.20 \pm 20.20) \times 10^{-4} \text{ rad.}$$

The correlation coefficients are $\rho(\phi_e, \Delta m) = 0.828$, $\rho(\phi_e, \tau_s) = -0.765$, $\rho(\Delta m, \tau_s) = -0.858$, $\rho(\text{Im}(\epsilon'/\epsilon), \phi_e) = -0.041$, $\rho(\text{Im}(\epsilon'/\epsilon), \Delta m) = 0.026$, $\rho(\text{Im}(\epsilon'/\epsilon), \tau_s) = -0.010$.

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

This is the CP-violating asymmetry

$$A = \frac{N_{\sin \phi > 0} - N_{\sin \phi < 0}}{N_{\sin \phi > 0} + N_{\sin \phi < 0}}$$

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

<table>
<thead>
<tr>
<th>VALUE (%)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$13.7 \pm 1.5$ OUR AVERAGE</td>
<td>ABOUZAID</td>
<td>06 KTEV</td>
</tr>
<tr>
<td>$13.6 \pm 1.4 \pm 1.5$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$14.2 \pm 3.0 \pm 1.9$</td>
<td>LAI</td>
<td>03C NA48</td>
</tr>
<tr>
<td>$13.6 \pm 2.5 \pm 1.2$</td>
<td>ALAVI-HARATI100b</td>
<td>KTEV</td>
</tr>
</tbody>
</table>

### PARAMETERS FOR $e^+e^- e^+e^-$ DECAYS

These are the CP-violating parameters in the $\phi$ distribution, where $\phi$ is the angle between the planes of the two $e^+e^-$ pairs in the kaon rest frame:

$$f' / f \propto 1 + \beta CP \cos(2\phi) + \gamma CP \sin(2\phi)$$

<table>
<thead>
<tr>
<th>$\beta_{CP}$ from $K_L^0 \rightarrow e^+e^- e^+e^-$</th>
<th>VALUE</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.19 \pm 0.07$ OUR AVERAGE</td>
<td>$-0.13 \pm 0.10 \pm 0.03$</td>
<td>200</td>
<td>1 LAI 05B NA48</td>
</tr>
<tr>
<td>$-0.23 \pm 0.09 \pm 0.02$</td>
<td>441</td>
<td>ALAVI-HARATI101D</td>
<td>KTEV $M_{ee} &gt; 8 \text{ MeV}/c^2$</td>
</tr>
</tbody>
</table>

1 LAI 05B obtains $\beta_{CP} = -0.13 \pm 0.10 \text{ (stat)}$ if $\gamma_{CP} = 0$ is assumed.

<table>
<thead>
<tr>
<th>$\gamma_{CP}$ from $K_L^0 \rightarrow e^+e^- e^+e^-$</th>
<th>VALUE</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.01 \pm 0.11$ OUR AVERAGE</td>
<td>$0.13 \pm 0.10 \pm 0.03$</td>
<td>200</td>
<td>LAI 05B NA48</td>
</tr>
<tr>
<td>$-0.09 \pm 0.09 \pm 0.02$</td>
<td>441</td>
<td>ALAVI-HARATI101D</td>
<td>KTEV $M_{ee} &gt; 8 \text{ MeV}/c^2$</td>
</tr>
</tbody>
</table>

Error includes scale factor of 1.6.
CHARGE ASYMMETRY IN $\pi^+\pi^-\pi^0$ DECAYS

These are CP-violating charge-asymmetry parameters, defined at beginning of section “LINEAR COEFFICIENT $j$ FOR $K_L^0 \rightarrow \pi^+\pi^-\pi^0$ above.

See also note on Dalitz plot parameters in $K^\pm$ section and note on “CP violation in $K_L$ decays” above.

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

\[
\begin{array}{cccc}
\text{VALUE} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
0.0012 \pm 0.0008 & \text{OUR AVERAGE} & 500k & \text{ANGELOPOLO... 98c CPLR} \\
0.0010 \pm 0.0024 \pm 0.0030 & 6499 & \text{CHO 77} \\
-0.001 \pm 0.011 & 4709 & \text{PEACH 77} \\
0.0013 \pm 0.0009 & 3M & \text{SCRIBANO 70} \\
0.0 \pm 0.017 & 4400 & \text{SMITH 70 OSPK} \\
0.001 \pm 0.004 & 238k & \text{BLANPIED 68}
\end{array}
\]

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

\[
\begin{array}{cccc}
\text{VALUE} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
0.0045 \pm 0.0024 \pm 0.0059 & 500k & \text{ANGELOPOLO... 98c CPLR} \\
\end{array}
\]

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

\[
|\eta_{+-}\gamma| = |A(K_L^0 \rightarrow \pi^+\pi^-\gamma, \text{CP violating})/A(K_S^0 \rightarrow \pi^+\pi^-\gamma)|
\]

\[
\begin{array}{cccc}
\text{VALUE (units 10^{-3})} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
2.35 & \pm 0.07 & \text{OUR AVERAGE} & 9045 \text{ MATTHEWS 95 E773} \\
2.359 \pm 0.062 \pm 0.40 & 3671 & \text{RAMBERG 93b E731} \\
2.15 \pm 0.26 \pm 0.20 & \text{OUR AVERAGE} & 9045 \text{ MATTHEWS 95 E773} \\
72 \pm 23 & 3671 & \text{RAMBERG 93b E731} \\
\end{array}
\]

\[
\phi_{+-}\gamma = \text{phase of } \eta_{+-}\gamma
\]

\[
\begin{array}{cccc}
\text{VALUE (degree)} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
44 \pm 4 & \text{OUR AVERAGE} & 9045 \text{ MATTHEWS 95 E773} \\
43.8 \pm 3.5 \pm 1.9 & 3671 & \text{RAMBERG 93b E731} \\
72 \pm 23 & 3671 & \text{RAMBERG 93b E731} \\
\end{array}
\]

\[
|\epsilon_{+-}\gamma|/\epsilon \text{ for } K_L^0 \rightarrow \pi^+\pi^-\gamma
\]

\[
\begin{array}{cccc}
\text{VALUE} & \text{CL%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} \\
<0.3 & & 90 \text{ 3671} \text{ 1 RAMBERG 93b E731} \\
\end{array}
\]

\[
^1 \text{RAMBERG 93b limit on } |\epsilon_{+-}\gamma|/\epsilon \text{ assumes than any difference between } \eta_{+-} \text{ and } \eta_{+-}\gamma
\]

is due to direct CP violation.

\[
|g(E_1)| \text{ for } K_L^0 \rightarrow \pi^+\pi^-\gamma
\]

This parameter is the amplitude of the direct emission of a CP violating E1 electric dipole photon.

\[
\begin{array}{cccc}
\text{VALUE} & \text{CL%} & \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\
<0.21 & & 90 \text{ 111k} \text{ ABOUZAID 06a KTEV } E_1^* > 20 \text{ MeV} \\
\end{array}
\]
**T Violation Tests in $K^0_L$ Decays**

**Im($\xi$) in $K^0_{\mu 3}$ Decay (from Transverse $\mu$ Pol.)**

Test of $T$ reversal invariance.

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.007\pm 0.026$ OUR AVERAGE</td>
<td></td>
<td>MORSE 80</td>
<td>CNTR</td>
<td>Polarization</td>
</tr>
<tr>
<td>0.009±0.030</td>
<td>12M</td>
<td>CLARK 77</td>
<td>SPEC</td>
<td>POL, $t=0$</td>
</tr>
<tr>
<td>0.35±0.30</td>
<td>207k</td>
<td>SANDWEISS 73</td>
<td>CNTR</td>
<td>POL, $t=0$</td>
</tr>
<tr>
<td>−0.085±0.064</td>
<td>2.2M</td>
<td>LONGO 69</td>
<td>CNTR</td>
<td>POL, $t=3.3$</td>
</tr>
<tr>
<td>−0.2±0.6</td>
<td></td>
<td>ABRAMS 68B</td>
<td>OSPK</td>
<td>Polarization</td>
</tr>
</tbody>
</table>

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

0.012±0.026 SCHMIDT 79 CNTR Repl. by MORSE 80

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

2 SANDWEISS 73 value corrected from value quoted in their paper due to new value of $\text{Re}(\xi)$. See footnote 4 of SCHMIDT 79.

**CPT-Invariance Tests in $K^0_L$ Decays**

**Phase Difference $\phi_{00} - \phi_{+-}$**

Test of CPT.

Our fit is described in the note on “CP violation in $K_L$ decays” in the $K_L$ Particle Listings.

<table>
<thead>
<tr>
<th>VALUE ($^\circ$)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.006\pm 0.014$ OUR FIT</td>
<td>Error includes scale factor of 1.7. Assuming CPT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0.34\pm 0.32$ OUR FIT</td>
<td>Not assuming CPT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.006±0.008</td>
<td>1 SUPERWEAK 16</td>
<td>Assumed CPT</td>
<td></td>
</tr>
<tr>
<td>−0.3±0.38</td>
<td>2 SCHWINGENHEUER 95</td>
<td>Combined E731, E773</td>
<td></td>
</tr>
</tbody>
</table>

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

0.30±0.35 ABOUZAID 11 KTEV Not assuming CPT

0.39±0.22±0.45 ALAVI-HARATI 03 KTEV

0.62±0.71±0.75 SCHWINGENHEUER 95 E773

−1.6±1.2 GIBBONS 93 E731

0.2±2.6±1.2 CAROL 90 NA31

−0.3±2.4±1.2 KARLSSON 90 E731

1 SUPERWEAK 16 is a fake experiment to constrain $\phi_{00} - \phi_{+-}$ to a small value as described in the note “CP violation in $K_L$ decays.”

2 This SCHWINGENHEUER 95 values is the combined result of SCHWINGENHEUER 95 and GIBBONS 93, accounting for correlated systematic errors.

3 Not independent of other phase parameters reported in ABOUZAID 11.

4 ALAVI-HARATI 03 fit Re($\epsilon'$/$\epsilon$), $\text{Im}(\epsilon'/\epsilon)$, $\Delta m$, $\tau_S$, and $\phi_{+-}$ simultaneously, not assuming CPT. Phase difference is obtained from $\phi_{00} - \phi_{+-} \approx \text{Re}(\epsilon'/\epsilon)$ for small $|\epsilon'/\epsilon|$. Supersedes by ABOUZAID 11.

5 GIBBONS 93 give detailed dependence of systematic error on lifetime (see the section on the $K^0_S$ mean life) and mass difference (see the section on $m_{K^0_L} - m_{K^0_S}$).

6 CAROL 90 is excluded from the fit because it is not independent of $\phi_{+-}$ and $\phi_{00}$ values.
PHASE DIFFERENCE $\phi_+ - \phi_{SW}$

Test of CPT. The Superweak phase $\phi_{SW} \equiv \tan^{-1} (2\Delta m/\Delta \Gamma)$ where $\Delta m = m_{K_S^0} - m_{K_L^0}$ and $\Delta \Gamma = \tau_L(\tau_L - \tau_S)/(\tau_L \tau_S)$.

<table>
<thead>
<tr>
<th>Value ($^\circ$)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.61 $\pm$ 0.62 $\pm$ 1.01</td>
<td>ALAVI-HARATI03</td>
<td>KTEV</td>
</tr>
</tbody>
</table>

$1$ ALAVI-HARATI 03 fit is the same as their $\phi_{+-} = \tau_{K_S^0}^\Delta m$ fit, except that the parameter $\phi_{+-} - \phi_{SW}$ is used in place of $\phi$.

Re\left(\frac{2}{3} \eta_{+-} + \frac{1}{3} \eta_{00}\right) - \frac{A_L}{2}$

Test of CPT

<table>
<thead>
<tr>
<th>Value (units $10^{-6}$)</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-3$ $\pm$ 35</td>
<td>ALAVI-HARATI02</td>
<td>E799</td>
<td>Uses $A_L$ from $K_{e3}$ decays</td>
</tr>
</tbody>
</table>

$1$ ALAVI-HARATI 02 uses PDG 00 values of $\eta_{+-}$ and $\eta_{00}$.

$\Delta S = \Delta Q$ IN $K^0$ DECAYS

The relative amount of $\Delta S \neq \Delta Q$ component present is measured by the parameter $x$, defined as

$$x = A(\bar{K}^0 \rightarrow \pi^- \ell^+ \nu)/A(K^0 \rightarrow \pi^- \ell^+ \nu)$$

We list Re$\{x\}$ and Im$\{x\}$ for $K_{e3}$ and $K_{\mu3}$ combined.

<table>
<thead>
<tr>
<th>Real Part of $x$</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.0018 \pm 0.0041 \pm 0.0045$</td>
<td>ANGELOPO... 98D</td>
<td>CPLR</td>
<td>$K_{e3}$ from $K^0$</td>
<td></td>
</tr>
</tbody>
</table>

$\bullet$ $\bullet$ $\bullet$ We do not use the following data for averages, fits, limits, etc. $\bullet$ $\bullet$ $\bullet$

- $0.10$ $+0.18$ $-0.19$ 79 SMITH 75B WIRE $\pi^- p \rightarrow K^0 \Lambda$
- $0.04$ $+0.03$ $-0.03$ 4724 NIEBERGALL 74 ASPK $K^+ p \rightarrow K^0 p \pi^+$
- $-0.008$ $+0.044$ $-0.007$ 1757 FACKLER 73 OSPK $K_{e3}$ from $K^0$
- $-0.03$ $+0.07$ $-0.07$ 1367 HART 73 OSPK $K_{e3}$ from $K^0$
- $-0.070$ $+0.036$ $-0.070$ 1079 MALLARY 73 OSPK $K_{e3}$ from $K^0 \Lambda X$
- $0.03$ $+0.06$ $-0.03$ 410 1 BURGUN 72 HBC $K^+_p \rightarrow K^0 p \pi^+$
- $0.04$ $+0.10$ $-0.13$ 100 2 GRAHAM 72 OSPK $K_{\mu3}$ from $K^0 \Lambda$
- $-0.05$ $+0.09$ $-0.05$ 442 2 GRAHAM 72 OSPK $\pi^- p \rightarrow K^0 \Lambda$
- $0.26$ $+0.10$ $-0.14$ 126 MANN 72 HBC $K^- p \rightarrow n \bar{K}^0$
- $-0.13$ $+0.11$ $-0.13$ 342 2 MANTSCH 72 OSPK $K_{e3}$ from $K^0 \Lambda$
- $0.04$ $+0.07$ $-0.08$ 222 1 BURGUN 71 HBC $K^+_p \rightarrow K^0 p \pi^+$
0.25  $$\pm 0.07$$  -0.09  252  WEBBER  71  HBC  $$K^- p \rightarrow n\pi^0$$  
0.12  $$\pm 0.09$$  3  CHO  70  DBC  $$K^+ d \rightarrow K^0 p p$$  
-0.020  $$\pm 0.025$$  4  BENNETT  69  CNTR  Charge asym+ Cu regen.  
0.09  $$\pm 0.14$$  -0.16  686  LITTENBERG  69  OSPK  $$K^+ n \rightarrow K^0 p$$  
0.03  $$\pm 0.03$$  4  BENNETT  68  CNTR  
0.09  $$\pm 0.07$$  -0.09  121  JAMES  68  HBC  $$\bar{\pi}p$$  
0.17  $$\pm 0.16$$  -0.35  116  FELDMAN  67B  OSPK  $$\pi^- p \rightarrow K^0 \Lambda$$  
0.17  $$\pm 0.10$$  3  HILL  67  DBC  $$K^+ d \rightarrow K^0 p p$$  
0.035  $$\pm 0.11$$  -0.13  196  AUBERT  65  HLBC  $$K^+$$ charge exch.  
0.06  $$\pm 0.18$$  -0.44  152  5  BALDO-CEOLIN  65  HLBC  $$K^+$$ charge exch.  
-0.08  $$\pm 0.16$$  -0.28  109  6  FRANZINI  65  HBC  $$\bar{\pi}p$$  

1 BURGUN 72 is a final result which includes BURGUN 71.  
2 First GRAHAM 72 value is second GRAHAM 72 value combined with MANTSCH 72.  
3 CHO 70 is analysis of unambiguous events in new data and HILL 67.  
4 BENNETT 69 is a reanalysis of BENNETT 68.  
5 BALDO-CEOLIN 65 gives $$\pi$$ and $$\theta$$ converted by us to Re($$x$$) and Im($$x$$).  
6 FRANZINI 65 gives $$\pi$$ 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.

<table>
<thead>
<tr>
<th>VALUE</th>
<th>EVTS</th>
<th>DOCUMENT ID</th>
<th>TECN</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0012 $$\pm 0.0019$$</td>
<td>640k</td>
<td>ANGELOPO...</td>
<td>01B</td>
<td>CPLR</td>
</tr>
<tr>
<td>-0.10</td>
<td>79</td>
<td>SMITH</td>
<td>75B</td>
<td>WIRE</td>
</tr>
<tr>
<td>-0.06</td>
<td>$$\pm 0.05$$</td>
<td>4724</td>
<td>NIEBERGALL</td>
<td>74</td>
</tr>
<tr>
<td>-0.017</td>
<td>$$\pm 0.060$$</td>
<td>1757</td>
<td>FACKLER</td>
<td>73</td>
</tr>
<tr>
<td>0.09</td>
<td>$$\pm 0.07$$</td>
<td>1367</td>
<td>HART</td>
<td>73</td>
</tr>
<tr>
<td>0.107</td>
<td>$$\pm 0.092$$</td>
<td>1079</td>
<td>MALLARY</td>
<td>73</td>
</tr>
<tr>
<td>0.07</td>
<td>$$\pm 0.06$$</td>
<td>410</td>
<td>2</td>
<td>BURGUN</td>
</tr>
<tr>
<td>0.12</td>
<td>$$\pm 0.17$$</td>
<td>100</td>
<td>3</td>
<td>GRAHAM</td>
</tr>
<tr>
<td>0.05</td>
<td>$$\pm 0.13$$</td>
<td>442</td>
<td>3</td>
<td>GRAHAM</td>
</tr>
<tr>
<td>0.21</td>
<td>$$\pm 0.15$$</td>
<td>126</td>
<td>MANN</td>
<td>72</td>
</tr>
<tr>
<td>-0.04</td>
<td>$$\pm 0.16$$</td>
<td>342</td>
<td>3</td>
<td>MANTSCH</td>
</tr>
<tr>
<td>0.12</td>
<td>$$\pm 0.08$$</td>
<td>222</td>
<td>2</td>
<td>BURGUN</td>
</tr>
<tr>
<td>0.0</td>
<td>$$\pm 0.08$$</td>
<td>252</td>
<td>WEBBER</td>
<td>71</td>
</tr>
<tr>
<td>-0.08</td>
<td>$$\pm 0.07$$</td>
<td>215</td>
<td>4</td>
<td>CHO</td>
</tr>
<tr>
<td>-0.11</td>
<td>$$\pm 0.10$$</td>
<td>686</td>
<td>LITTENBERG</td>
<td>69</td>
</tr>
</tbody>
</table>
\( K^0_L \) references

1 Superseded by ANGELOPOULOS 01B.
2 BURGUN 72 is a final result which includes BURGUN 71.
3 First GRAHAM 72 value is second GRAHAM 72 value combined with MANTSCH 72.
4 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.
5 BALDO-CEolin 65 gives x and θ converted by us to Re(x) and Im(x).
6 FRANZINI 65 gives x and θ for Re(x) and Im(x). See SCHMIDT 67.
<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
<th>Journal</th>
<th>Authors</th>
<th>Affiliations</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARMIN</td>
<td>71</td>
<td>PL 35B 604</td>
<td>V.V. Barmin et al.</td>
<td>ITEP</td>
</tr>
<tr>
<td>BURGUN</td>
<td>71</td>
<td>LNC 2 1169</td>
<td>G. Burgun et al.</td>
<td>(SACL, CERN, OSLO)</td>
</tr>
<tr>
<td>CARNEGIE</td>
<td>71</td>
<td>PR D4 1</td>
<td>R.K. Carnegie et al.</td>
<td>(PRIN)</td>
</tr>
<tr>
<td>CHAN</td>
<td></td>
<td>Thesis LBL-350</td>
<td>J.H.S. Chan</td>
<td>(LBL)</td>
</tr>
<tr>
<td>CHOE</td>
<td>71</td>
<td>PR D3 1557</td>
<td>Y. Cho et al.</td>
<td>(CMU, BNL, CASE)</td>
</tr>
<tr>
<td>ENSTROM</td>
<td>71</td>
<td>PR D4 2629</td>
<td>J. Enstrom et al.</td>
<td>(SLAC, STAN)</td>
</tr>
<tr>
<td>JAMES</td>
<td>71</td>
<td>PL 35B 265</td>
<td>F. James et al.</td>
<td>(CERN, SACL, OSLO)</td>
</tr>
<tr>
<td>MEISNER</td>
<td>71</td>
<td>PR D3 59</td>
<td>G.W. Meisner et al.</td>
<td>(MASA, BNL, YALE)</td>
</tr>
<tr>
<td>REPELLIN</td>
<td>71</td>
<td>PL 36B 603</td>
<td>J.P. Repellin et al.</td>
<td>(ORSAY, CERN)</td>
</tr>
<tr>
<td>WEBBER</td>
<td>71</td>
<td>PR D3 64</td>
<td>B.R. Webber et al.</td>
<td>(LRL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PRL 21 498</td>
<td>B.R. Webber et al.</td>
<td>(LRL)</td>
</tr>
<tr>
<td>WOLFF</td>
<td>71</td>
<td>PL 36B 517</td>
<td>B. Wolff et al.</td>
<td>(ORSAY, CERN)</td>
</tr>
<tr>
<td>ALBROW</td>
<td>70</td>
<td>PL 33B 516</td>
<td>M.G. Albrow et al.</td>
<td>(MCHS, DARE)</td>
</tr>
<tr>
<td>ARONSON</td>
<td>70</td>
<td>PRL 25 1057</td>
<td>S.H. Aronson et al.</td>
<td>(EF1, ILLC, SLAC)</td>
</tr>
<tr>
<td>BARMIN</td>
<td>70</td>
<td>PL 33B 377</td>
<td>V.V. Barmin et al.</td>
<td>(ITEP, JINR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PRL 2 78</td>
<td>P. Basile et al.</td>
<td>(SACL)</td>
</tr>
<tr>
<td>BECHERRAY</td>
<td>70</td>
<td>PR D1 1452</td>
<td>T. Becherrawy</td>
<td>(ROCH)</td>
</tr>
<tr>
<td>BUCHANAN</td>
<td>70</td>
<td>PL 33B 623</td>
<td>C.D. Buchanan et al.</td>
<td>(SLAC, JHU, UCLA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thesis UCRL 19226</td>
<td>B.R. Webber et al.</td>
<td>(LRL)</td>
</tr>
<tr>
<td>BUDAGOV</td>
<td>70</td>
<td>PR D2 815</td>
<td>I.A. Budagov et al.</td>
<td>(CERN, ORSA, EPOL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PL 28B 215</td>
<td>I.A. Budagov et al.</td>
<td>(CERN, ORSA, EPOL)</td>
</tr>
<tr>
<td>CHOE</td>
<td>70</td>
<td>PRL 1 3031</td>
<td>Y. Cho et al.</td>
<td>(CMU, BNL, CASE)</td>
</tr>
<tr>
<td>CHOLLET</td>
<td>70</td>
<td>PL 31B 658</td>
<td>J.C. Chollet et al.</td>
<td>(CERN)</td>
</tr>
<tr>
<td>CULLEN</td>
<td>70</td>
<td>PL 32B 523</td>
<td>M. Cullen et al.</td>
<td>(AACH, CERN, TORI)</td>
</tr>
<tr>
<td>MARX</td>
<td>70</td>
<td>PL 32B 219</td>
<td>J. Marx et al.</td>
<td>(COLU, HARV, CERN)</td>
</tr>
<tr>
<td>SCHRIBANO</td>
<td>70</td>
<td>PL 32B 224</td>
<td>A. Scribano et al.</td>
<td>(PIA, COLU, HARV)</td>
</tr>
<tr>
<td>SMITH</td>
<td>70</td>
<td>PL 32B 133</td>
<td>R.C. Smith et al.</td>
<td>(UMD, BNL)</td>
</tr>
<tr>
<td>WEBBER</td>
<td>70</td>
<td>PR D1 1967</td>
<td>B.R. Webber et al.</td>
<td>(LRL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thesis UCRL 19226</td>
<td>B.R. Webber et al.</td>
<td>(LRL)</td>
</tr>
<tr>
<td>BANNER</td>
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